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Research**
Traditional and Creative Approaches

Edited by Maria Bartekova



International Business Research - Traditional and Creative Approaches

Edited by Mária Barteková

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IntechOpen Book Series

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Aims and Scope of the Series

This series will provide a comprehensive overview of recent research trends in business and management, economics, and marketing. Topics will include asset liability management, financial consequences of the financial crisis and covid-19, financial accounting, mergers and acquisitions, management accounting, SMEs, financial markets, corporate finance and governance, managerial technology and innovation, resource management and sustainable development, social entrepreneurship, corporate responsibility, ethics and accountability, microeconomics, labour economics, macroeconomics, public economics, financial economics, econometrics, direct marketing, creative marketing, internet marketing, market planning and forecasting, brand management, market segmentation and targeting and other topics under business and management. This book series will focus on various aspects of business and management whose in-depth understanding is critical for business and company management to function effectively during this uncertain time of financial crisis, Covid-19 pandemic, and military activity in Europe.

Meet the Series Editor



Prof. Choudhry holds a BSc degree in Economics from the University of Iowa, as well as a Masters and Ph.D. in Applied Economics from Clemson University, USA. In January 2006, he became a Professor of Finance at the University of Southampton Business School. He was previously a Professor of Finance at the University of Bradford Management School. He has over 80 articles published in international finance and economics journals. His research interests and specialties include financial econometrics, financial economics, international economics and finance, housing markets, financial markets, among others.

Meet the Volume Editor



Dr. Mária Barteková, Ph.D., attained her doctoral degree in Management from Comenius University in Bratislava. As an Assistant Professor, she primarily focuses on research in the creative industries and sustainable production and consumption. She leads the OpenmusE project within the Horizon Europe program at the Bratislava University of Economics and Business. She has chaired sections at conferences in Italy, Spain, Croatia, and Thailand. She has published over 110 works, including monographs, scientific articles, and book chapters. She works as a reviewer for prestigious journals and an evaluator of scientific projects. In 2025, she received the Rector's Award for the Development of Science and Research at the Bratislava University of Economics and Business.

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Frontline Employees' Emotional Displays in Service Encounters: A Framework
Enabling Design and Further Research

by Florian Urmetzer and Peter Wunderlich

Preface

The publication before the reader focuses on three important areas of contemporary research and practice in business: internationalization, sustainability, and innovative approaches. These topics represent key pillars not only of academic research but also of business practice in the 21st-century global environment. The selection of contributions reflects an effort to provide the reader with a comprehensive view of current trends, challenges, and perspectives in business. Individual chapters are based on empirical experiences, case studies, and theoretical approaches from different geographical regions and cultural contexts.

The first section of the book, entitled “Internationalization in the Current Business Environment”, is devoted to the issue of internationalization and its impact on businesses in a dynamic and constantly changing global environment. The chapter *Internationalization and Firm Performance of Firms in India: The Role of Top Management* (Do Thuy Huong and Phan Anh Tu) analyzes the role of top management in the internationalization of Indian companies and shows the importance of the quality of leadership and decision-making processes for long-term competitiveness. The next chapter, *Global Labor Mobility: Patterns, Drivers, and Implications for Trade, Investment, and Business Dynamics* (Chujian Shao), examines the patterns and drivers of global labor mobility. The author highlights its implications for trade relations, direct investment flows, and broader business dynamics. Together, these chapters create a framework that allows the reader to understand how internationalization is translated into different businesses and markets, and what factors determine the success or failure of this process.

The second section of the book, entitled “Sustainable Business Practices”, focuses on the issue of sustainability, which has become a key motif in business and public policy. The chapter, *Interrelation of Sustainability Indicators and Sustainable Solutions in Road Freight Transportation: A Review of Innovative Practices and Implementation Challenges* (Elena Kaledinova and Ngoc Bao Tran), takes a comprehensive look at the connection between sustainability indicators and practical solutions in road freight transportation. The authors offer an overview of innovative practices and, at the same time, draw attention to the implementation challenges that prevent their widespread use. The chapter *Sustainable Entrepreneurship in European Petrochemical Industry* (Mária Barteková) analyzes the possibilities of sustainable entrepreneurship in a specific and at the same time environmentally demanding sector of the European petrochemical industry. The author emphasizes the need for a balance between economic goals and ecological constraints and offers concrete suggestions for linking innovation with environmental responsibility. The third chapter of this part is *Critical Dialogs of 3D Printing Waste Recycling in Circular Fashion* (Shahbaj Kabir, Yu Li, and Young-A Lee), which brings a perspective on circular fashion and the possibilities of recycling waste from 3D printing. The authors point out that technological innovations must be accompanied by sustainable strategies in order to contribute to long-term development.

The third part of the publication, “Innovative Approaches to Business”, is dedicated to creative and unconventional perspectives on entrepreneurship and research. The chapter *The Creative Approach in International Business Research (Islamic Context)* (Naseem Akhter, Shumaila Rafiq, Farida Begum, Arshad Munir, Syed Hamid Farooq Bukhari, and Shakir Hussain) brings a new framework for studying international business with an emphasis on the Islamic cultural and value context. This approach enriches traditional models with a perspective that reflects specific social and religious factors. The final chapter, *Frontline Employees’ Emotional Displays in Service Encounters: A Framework Enabling Design and Further Research* (Peter Wunderlich and Florian Urmetzer), explores the manifestations of human emotions during musical performances. The authors present a framework that can serve as a basis for further research in the field of design and interaction between art and audience.

The presented collection thus combines the topics of internationalization, sustainable development, and innovation into a single whole. Each part of the book presents a distinct perspective, yet all chapters complement one another, creating a coherent picture of how the business environment is evolving and changing today. The reader will find inspiration, suggestions for further research, and practical recommendations in the book that can be used in academic and business practice.

We believe that this publication will enrich the discussion on key business issues in a globalized world and provide a stimulating perspective on the current challenges and opportunities facing businesses, researchers, and policymakers.

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Section 1

**Internationalization in
the Current Business
Environment**

Chapter 1

Internationalization and Firm Performance of Firms in India: The Role of Top Management

Do Thuy Huong and Phan Anh Tu

Abstract

This study analyzes the relationship between the degree of internationalization and firm performance of 380 firms in the manufacturing and service sectors in India, considering the moderating effects of top manager characteristics—specifically gender and managerial experience. Using Feasible Generalized Least Squares (FGLS) regression on panel data from the World Bank Enterprise Surveys, results reveal: (1) internationalization negatively impacts firm performance initially due to high entry costs, including market unfamiliarity, cultural barriers, and resource constraints; (2) top managers' experience and gender diversity (female leadership) positively moderate this relationship, enhancing performance by fostering innovation, adaptability, and strategic responsiveness. The research contributes to internationalization theory by extending the Uppsala model and Upper Echelons Theory through the integration of managerial characteristics, providing valuable insights for managerial practice and policy in developing countries.

Keywords: internationalization, firm performance, top management, gender diversity, managerial experience, Uppsala model, Upper Echelons Theory, India

1. Introduction

In the field of International Business, “Internationalization” is the strategy that businesses implement to expand their operations overseas to increase revenue. Many studies have focused on the relationship between internationalization and firm performance; however, the empirical results are inconsistent, showing contradictions and even conflicts [1–4]. The relationship between internationalization and firm performance has yielded mixed empirical findings [3, 4]. Recent research highlights the significance of moderating variables such as top management characteristics in clarifying this relationship [5, 6]. Employing the Uppsala model [7, 8] and Upper Echelons Theory [9], this study investigates how managerial gender and experience moderate the internationalization-performance link in Indian firms.

Since 2007, studies have integrated moderating factors into the model and found that these factors can positively or negatively impact the relationship between internationalization and business performance [5, 6]. Ignoring these factors can

lead to biased predictions, especially when top management characteristics, such as age, tenure, international experience, and education [10], strongly influence the internationalization process. Top managers with experience and flexibility in decision-making help businesses adapt better to the global environment. Moreover, the internationalization process is considered an important strategy to help businesses expand their markets and increase revenue [11], but the empirical results on the relationship between internationalization and firm performance remain inconsistent. Anderson and McKenzie [12] emphasized that the local economic context and top management characteristics are important factors affecting the effectiveness of internationalization, especially in developing economies. Recent studies have also pointed out the role of moderating factors, such as top management characteristics, in clarifying this relationship [6]. Therefore, more research is needed on the role of top management characteristics in the context of developing economies to better understand how they influence internationalization strategy and firm performance. This study aims to answer the question: “Do top management characteristics directly influence firm performance through decision-making ability?”

This study will make three main contributions to the theoretical basis of internationalization: (1) examining the relationship between the degree of internationalization and firm performance in Indian firms; (2) using the Uppsala model and Upper Echelons Theory to analyze the moderating role of top management characteristics; and (3) providing empirical evidence on the impact of internationalization on firm performance in the context of developing economies.

2. Literature review

2.1 Theoretical background

In internationalization research, various theories explain the benefits and costs of internationalization and its impact on firm performance. These include Transaction Cost Theory, the resource-based view, agency theory, the Uppsala model, behavioral theory of the firm, and the eclectic paradigm. This study applies Johanson and Vahlne’s Uppsala model, both the original (1977) [7] and revised versions (2017, 2020) [13, 14], incorporating Hambrick and Mason’s [9] Upper Echelons Theory for support. This approach explains the moderating role of top management team (TMT) individual characteristics in the relationship between internationalization and firm performance.

2.2 Uppsala model

In this study, the research model is built upon the 1977 Uppsala model [7] to explain the involvement of businesses in the international market. According to this model, internationalization is a crucial growth strategy, progressing through four stages: (1) no regular export, (2) export through independent representatives, (3) establishment of sales branches abroad, and (4) production in foreign markets [7]. This stage-wise progression allows firms to gradually build experiential knowledge and reduce uncertainty when entering foreign markets. The model emphasizes that the knowledge, understanding, and international experience of managers play a central role in shaping the pace and scope of internationalization [7].

The 2017 and 2020 revised versions of the model [13, 14] further elaborate on the dynamic nature of internationalization by introducing four key elements: capabilities,

commitment processes, knowledge development, and relational networks. These additions reflect the shift toward a network-based view of international expansion in uncertain global environments. In such settings, top managers must demonstrate strategic judgment, adapt value chains, and manage cross-border relationships to secure long-term growth [13].

Furthermore, both the original and revised versions of the Uppsala model underscore the importance of managerial experience in reducing liability of foreignness, especially in culturally or institutionally distant markets. However, some scholars caution that internationalization may incur high costs and risk for firms lacking sufficient managerial resources or international embeddedness [15].

2.3 Upper echelons

Upper Echelons Theory refers to individuals with high social standing in a business, such as the CEO, top managers, or the top management team [16]. These individuals have their own cognitive backgrounds and values, and they evaluate business situations based on their personal perspectives [17]. This personal perspective influences the perception and strategic business decisions of the enterprise [16].

This theory, initiated by Hambrick and Mason [9], emphasizes that a company's strategic decisions reflect the personal characteristics of its managers. Characteristics such as gender, experience, and psychological traits of the manager play a crucial role in shaping the company's internationalization strategy. Empirical studies [18] have confirmed the significant role of gender and experience in creating substantial differences in how businesses respond to internationalization challenges. Additionally, Hambrick and Mason's [9] theory adds that psychological characteristics and the top manager's experience not only influence internationalization strategy but also shape how businesses seize opportunities and cope with risks in the global business environment.

This study draws from Upper Echelons Theory to emphasize that top managers' gender and experience serve as cognitive frames that shape how they interpret internationalization risks and opportunities. Female executives often bring relational skills and cultural sensitivity, supporting adaptability in diverse global markets [19]. Experienced managers, by contrast, leverage accumulated knowledge to mitigate uncertainty and reduce liability of foreignness [20].

2.4 Hypothesis development

2.4.1 The relationship between the degree of internationalization (DOI) and firm performance (P) of firms in India

The relationship between internationalization and firm performance is central to international business research. Most empirical studies suggest a positive linear relationship between internationalization and firm performance; as firms expand internationally, their performance tends to improve. However, some studies have also found nonlinear patterns, such as U-shaped, inverted U-shaped, S-shaped, W-shaped, or mixed relationships. These findings suggest that the benefits of internationalization may not be consistent and can vary depending on the stage or extent of a firm's internationalization.

When examining the linear relationship between internationalization and firm performance, there's a perspective suggesting that expanding business operations into

international markets will enhance a company's performance if it possesses sufficient conditions and competitive advantages to overcome the "cost of foreignness." Firstly, businesses can learn and accumulate experience from international markets, helping them gain market knowledge and identify risks in subsequent stages [7]. Secondly, international expansion also strengthens the company's position and relationships with suppliers and customers [15]. Furthermore, internationalization helps reduce operating costs and opens up opportunities to access new markets. Finally, businesses can diversify risks by operating in multiple markets, thereby avoiding institutional, political, and economic cycle risks [15].

Conversely, the internationalization process also comes with significant costs. For example, the legal responsibilities of being a "foreigner" can increase operating costs if the business is not part of a business network in that market [21]. Additionally, transportation costs and the cost of understanding foreign markets also increase, especially when the business lacks market knowledge [13]. At the same time, according to Contractor et al. [15], international operating costs and cultural distances can reduce the operational efficiency of businesses in the early stages of internationalization.

H1: Internationalization has a negative impact on the firm's performance.

2.5 Top manager's experience

The Uppsala model indicates that the managerial capacity of the leader plays a crucial role in promoting business growth in the international market [13, 14]. Upper Echelons Theory also suggests that a company's business results are influenced by the personal characteristics of the top manager [9]; internationalization strategy depends on the leader's personal perspective and strategic decisions. Accordingly, numerous empirical studies have affirmed the important role of the top manager's experience and gender [22] in shaping a company's internationalization behavior, further reinforcing the foundation of Upper Echelons Theory.

The top manager's accumulated knowledge over the years, developed from practical experience, becomes an essential factor in responding to the complexity and uncertainty of the international market. Specifically, this experience helps minimize "psychic distance"—the difference in culture, education, and perspectives between the company's country of origin and the international market [7]. Factors such as language differences, cultural disparities, and levels of economic development contribute to this distance, hindering information flow and increasing risks when businesses enter new markets. From internationalization experiences, managers will have more motivation and confidence to expand business operations into new markets [23].

Besides the expansion motivation as mentioned, the top manager's experience also has a direct impact on business results in the international market [24]. Hambrick and Mason [9] demonstrated that the psychological characteristics of the managers not only affect growth but also improve the company's business results. The manager's experience is considered a strategic resource that businesses can leverage to optimize benefits from international activities [25]. According to Sambharya [26], the benefits of a manager include the ability to reduce information costs, decrease anxiety, and enhance adaptability when a business enters foreign markets.

Furthermore, a manager's deep understanding of other countries' cultures and business practices enables the company to overcome cultural barriers by adapting products and branding strategies to each specific culture. This not only instills confidence in the manager's management but also contributes to risk reduction and profit

optimization, thereby enhancing the effectiveness of the company’s international business operations. According to Crossland et al. [18], the top manager’s extensive experience helps businesses build more effective strategies to navigate challenges in international markets.

H2: The relationship between internationalization and firm performance will be strengthened when the top manager has many years of experience.

2.6 Top manager’s gender

Some Asian cultures tend to value masculine traits such as strength, power, independence, and competitiveness. Therefore, many studies have shown that businesses led by men tend to achieve more benefits than those led by women [27]. Typically, businesses founded or run by men have more stable financial resources, which is a crucial factor in internationalization, as this process requires high costs to build and maintain relationships and consolidate positions in foreign markets [28]. Moreover, male managers often face fewer barriers when entering international markets compared to women, creating favorable conditions for businesses in internationalization activities [29].

On the other hand, studies also indicate that gender diversity, especially in management roles, enhances firm performance by bringing diverse perspectives, improving decision-making processes, and fostering innovation. Concurrently, female managers possess the capacity to formulate creative strategic decisions, enhancing adaptability within the international environment [9]. In India, where the proportion of women in top management roles is higher than the global average, female managers can bring unique perspectives to optimize business strategies in the international environment, such as better cultural adaptability and relationship-building skills, supporting global expansion. Furthermore, the presence of women in top

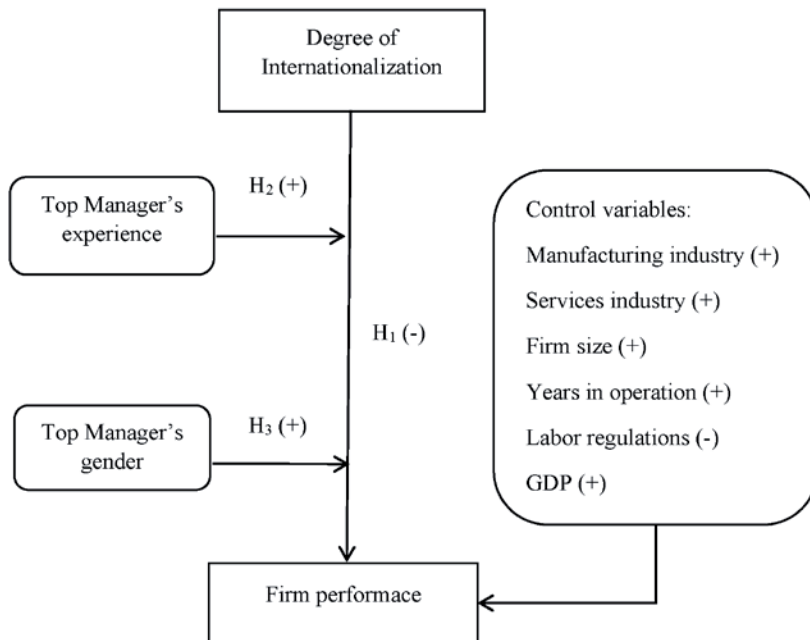


Figure 1. Conceptual model. Source: Authors’ compilation (2025).

management roles can also signal a progressive corporate culture that is more open to international collaborations and cross-border partnerships, further enhancing the benefits of internationalization for firm performance.

H3: The relationship between internationalization and firm performance will be strengthened when the top manager is a female.

From the literature review and theoretical basis, the author proposes the research model shown in **Figure 1**.

3. Methodology

3.1 Data

The analysis uses panel data from the World Bank Enterprise Surveys [30] covering 380 firms in India, representing both the manufacturing and service sectors. This dataset is widely used in international business research due to its standardized methodology, firm-level detail, and comparability across countries [31]. It allows for robust analysis of management characteristics and performance, particularly in emerging markets, and enhances the external validity of findings [5, 10].

3.2 Estimation method

This study employs Feasible Generalized Least Squares (FGLS) regression to examine the moderating effects of top management characteristics on the relationship between internationalization and firm performance. FGLS is chosen for its efficiency in correcting panel-level heteroscedasticity and autocorrelation, particularly under the Random Effects Model. The Hausman test indicated REM was appropriate (Prob > chi2 = 0.3019), while the Lagrange Multiplier test showed no significant heteroscedasticity (Prob > chibar2 = 1.0000). Multicollinearity was also not a concern as all VIF values remained below the 10.0 threshold [32]. The model specification is as follows:

$$\begin{aligned}
 ROS_{it} = & \beta_0 + \beta_1 doi_{it} + \beta_2 expertm_{it} + \beta_3 gendertm_{it} + \beta_4 industry_se_{it} \\
 & + \beta_5 industry_ma_{it} + \beta_6 firmsize_{it} + \beta_7 openyear_{it} + \beta_8 laborregulation_{it} \\
 & + \beta_9 lngdp_{it} + \beta_{10} (doiex)_{it} + \beta_{11} (doige)_{it} + \beta_{it}
 \end{aligned}$$

Where: ROS: dependent variable (firm performance); β_0 : intercept; β_1 - β_{11} : estimated coefficients of independent, moderating, and control variables; i : firm number; t : study period; ϵ_{it} : error term. The full regression results are reported in **Table 1**.

3.3 Variables and summary statistics

3.3.1 Dependent variable (firm performance) and independent variables

Several methods exist for measuring firm performance. Financial metrics like ROE [39], ROA [1], and ROS [40] are commonly used. This study used ROS due to its lower susceptibility to inflation and accounting principles, offering a more accurate performance reflection [41].

Construct	Measurement	Expectation
Dependent variable		
Firm performance (ros)	Returns on sales [33]	
Independent variable		
Degree of Internationalization (doi)	Overseas revenue over total revenue [33]	(+)
Moderating variable		
Top manager's experience (expertm)	Measured by the number of years of top manager's experience [34]	(+)
Top manager's gender (gendertm)	Top manager's gender is a dummy variable, getting value equal to 1 if the Top manager is Female and 0 if Male [35]	(+)
Control variables		
Services industry (industry_se)	Dummy variable (1: Services, 0: Others) [15]	(+)
Manufacturing industry (industry_ma)	Dummy variable (1: Manufacturing, 0: Others) [15]	(+)
Firm size (firmsize)	The number of employees can be measured by a dummy variable with 0 is SMEs (> = 5 to <=99 employees), 1 is large (> = 100 employees) [36]	(+)
Years in operation (openyear)	Year in operation as the number of years since the business has been in operation (year) [37]	(+)
Labor regulation (laborregulation)	Likert-5 levels: "To what extent, labor regulations are an obstacle to business operation." 0: no obstacles, 4: extreme obstacles [38]	(-)
GDP (lngdp)	GDP at purchaser's prices (World Bank)	(+)

Source: Authors' compilation (2025).

Table 1.
 Explanation of variables in the research model.

Numerous studies employ various methods to measure internationalization. FSTS (Overseas revenue/Total revenue) is most common [1]. Ruigrok and Wagner [42] highlighted this as measuring the core financial aspect of internationalization. The FSTS calculation is:

$$FSTS = (\text{Overseas sales} / \text{Total sales}) \times 100(\%)$$

3.3.2 Moderating variable

Top manager's experience: is measured by the number of years of the top manager's experience [34].

Top manager's gender (gendertm): is a dummy variable, getting a value equal to 1 if the manager is Female and 0 if Male [35].

3.3.3 Control variable

Manufacturing industry: is represented as a dummy variable (1: Manufacturing, 0: Others) [15].

Other services industry: is represented as a dummy variable (1: Manufacturing, 0: Others) [15].

Firm size: this variable is measured by the number of employees and can be measured by a dummy variable with 0 is SMEs ($> = 5$ to ≤ 99 employees), 1 is large ($> = 100$ employees) [36].

Years in operation: measured in years since operation began [37].

Labor regulations: 5-point Likert scale (“To what extent are labor regulations an obstacle?” 0: No obstacle, 4: Extreme obstacle) [38].

GDP: measured at purchaser’s prices (World Bank).

4. Result

Table 2 presents descriptive statistics. The average ROS is 30.34%, ranging from –660% to 98,166%. The average degree of internationalization is 0.056%, ranging from 0–100%. **Table 3** presents the correlation matrix between variable pairs. **Table 4** presents the summary of regression results of the REM and FEM models. The moderated regression results with FGLS estimation are shown in **Table 5**.

The FGLS regression analysis supports all three hypotheses. Internationalization negatively affects firm performance ($\beta = -36.66$, $p < 0.001$), confirming H1. Managerial experience positively moderates this relationship ($\beta = 1.55$, $p < 0.001$), supporting H2. Female leadership also strengthens the internationalization-performance link ($\beta = 77.03$, $p < 0.001$), confirming H3.

5. Discussion

Model 3 in **Table 5** includes all variables in the research model. The value of Prob $>$ $\chi^2 = 0.0000$ indicates the model’s fit with the actual data at a 99% confidence level.

According to Model 3, the relationship between the degree of internationalization and firm performance is a negative linear relationship, with the coefficient of the

Variables	Obs.	Mean	S.D	Min	Max
Firm performance (ROS) (%)	760	30.340	47.603	–660	98.166
Degree of internationalization (DOI) (%)	760	0.056	0.186	0	100
Top Manager’s experience (expertm)	760	20.369	12.647	1	70
Top Manager’s gender (gendertm)	760	0.049	0.215	0	1
Service industry (industry_se)	760	0.756	0.429	0	1
Manufacturing industry (industry_ma)	760	0.289	0.168	0	1
Firm size (firm size)	760	0.249	0.432	0	1
Years in operation (openyear)	760	30.819	15.432	4	92
Labor regulation (laborregulation)	760	1.005	1.078	0	4
GDP (lngdp)	760	28.6	0.260	28.34	28.86

Source: Authors’ compilation (2025).

Table 2.
Descriptive statistics of variables in the research model.

Variables	S.D	VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. ROS (%)	47.603		1									
2. DOI (%)	0.186	4.43	-0.0449 ^{ns}	1								
3. Expertm	12.647	1.40	0.0098 ^{ns}	-0.0257 ^{ns}	1							
4. Gendertm	0.215	1.13	-0.0667 ^{ns}	-0.0096 ^{ns}	0.0519 ^{ns}	1						
5. Industry_se	0.429	1.40	0.0896 [*]	-0.0380 ^{ns}	0.0741 [*]	0.0143 ^{ns}	1					
6. Industry_ma	0.168	1.24	0.0237 ^{ns}	-0.0185 ^{ns}	0.0955 ^{**}	-0.0026 ^{ns}	-0.3044 ^{***}	1				
7. Firmsize	0.432	1.13	-0.0624 ^{ns}	0.1996 ^{***}	0.0764 [*]	0.0820 [*]	-0.1347 ^{***}	-0.0812 [*]	1			
8. Openyear	15.432	1.27	-0.0033 ^{ns}	-0.0123 ^{ns}	0.3434 ^{***}	0.0387 ^{ns}	0.0005 ^{ns}	-0.0402 ^{ns}	0.1390 ^{***}	1		
9. Laborregulation	1.078	1.06	-0.0300 ^{ns}	-0.0731 [*]	-0.1281 ^{***}	0.0102 ^{ns}	-0.0428 ^{ns}	-0.0300 ^{ns}	-0.0198 ^{ns}	0.1172 ^{**}	1	
10. Lngdp	0.260	1.50	0.1670 ^{***}	-0.1331 ^{***}	0.2448 ^{***}	-0.0183 ^{ns}	0.3649 ^{***}	0.1727 ^{***}	-0.2040 ^{***}	-0.1549 ^{***}	-0.1295 ^{***}	1

Note: (***) $p < 0.001$; (**) $p < 0.01$; (*) $p < 0.05$; (ns) $p > 0.10$ (ns = non significance); values in parentheses are standard errors. Source: Authors' compilation (2025).

Table 3.
Descriptive statistics and correlation matrix of variables in the model ($n = 760$).

Variables	Firm performance: ROS	
	REM	FEM
Constant	-861.567*** (226.741)	-517.616 ^{ns} (274.851)
<i>Control variables</i>		
Industry_se	3.741 ^{ns} (4.674)	13.407 ^{ns} (6.967)
Industry_ma	3.464 ^{ns} (11.269)	9.259 ^{ns} (16.280)
Firmsize	-2.631 ^{ns} (4.167)	-10.161 ^{ns} (7901)
Openyear	0.160 ^{ns} (0.124)	0.187 ^{ns} (0.219)
Laborregulation	-0.689 ^{ns} (1.622)	-4.769 [*] (2.310)
Lngdp	31.204*** (7.970)	19.036 [*] (9.667)
<i>Main effect</i>		
Doi	-51.820** (19.229)	-41.413 ^{ns} (28.051)
Expertm	-0.291 ^{ns} (0.158)	-0.189 ^{ns} (0.226)
Gendertm	18.761 [*] (8.376)	-25.767 [*] (12.007)
<i>Interaction terms</i>		
Doiex	92.077 ^{ns} (57.332)	1.666 ^{ns} (1.257)
Doige	2.298** (0.885)	116.628 ^{ns} (82.082)
Observations	760	760
	Wald chi2 (11) = 39,87	F(11.369) = 3.60
	Prob> chi2 = 0.0000	Prob>F = 0.0001
	R ² within = 0.0801	R ² within = 0.0969

Note: (***) $p < 0.001$, (**) $p < 0.01$, (*) $p < 0.05$, (ns) $p > 0.1$ (non significance), values in parentheses are standard errors. Source: Authors' compilation (2025).

Table 4.
REM and FEM models.

Variables	Firm performance: ROS		
	Model 1	Model 2	Model 3
Constant	-766.656*** (34.297)	-831.818*** (37.976)	-873.023*** (41.502)
<i>Control variables</i>			
Industry_se	2.423** (0.851)	3.140*** (0.865)	3.303*** (0.913)
Industry_ma	-0.912 ^{ns} (1.905)	0.739 ^{ns} (2.145)	1.248 ^{ns} (2.611)
Firmsize	-3.179*** (0.644)	-2.438*** (0.660)	-3.016*** (0.736)
Openyear	0.881*** (0.019)	0.133*** (0.023)	0.166*** (0.022)
Laborregulation	-0.710** (0.245)	-0.927** (0.268)	-0.696 [*] (0.281)
Lngdp	27.760*** (1.208)	30.091*** (1.336)	31.577*** (1.465)
<i>Main effect</i>			
Doi		-5.393*** (1.297)	-36.664*** (5.460)
Expertm		-0.149*** (0.031)	-0.266*** (0.0341)

Variables	Firm performance: ROS		
	Model 1	Model 2	Model 3
Gendertm		-12.193*** (1.338)	-12.434*** (1.911)
<i>Interaction terms</i>			
Doiex			1.546*** (0.238)
Doige			77.032*** (19.876)
Observations	760	760	760
Wald chi2	834.08***	1297.24***	980.23***

*Note: (***) $p < 0.001$, (**) $p < 0.01$, (*) $p < 0.05$, (ns) $p > 0.10$ (non significance), values in parentheses are standard errors. Source: Authors' compilation (2025).*

Table 5.
 Regression model results using the Feasible Generalized Least Squares (FGLS) estimation method.

variable DOI being negative (36.664), thus supporting hypothesis H1. Businesses new to international operations often face substantial initial costs in exploring and penetrating foreign markets. These costs include investments to adapt products to international market requirements, which do not arise if the business operates only domestically [7]. Furthermore, in the early stages of internationalization, as businesses expand into new markets, they face liabilities of foreignness, especially if they lack an established business network in that market [21]. Along with that, businesses also encounter liabilities of newness when entering the international market, including finding human resources, capital, and customers. Additionally, the geographical distance between international and domestic markets increases transportation costs for businesses [15]. Because business managers often lack knowledge and information about foreign markets, they may incur additional costs to learn and adapt to the business environment in new countries [13].

Model 3 in **Table 5** indicates a positive correlation between the interaction of the degree of internationalization and the managerial experience of the leader. With the interaction coefficient doiex being positive (1.55) and statistically significant ($p < 0.001$), this result supports the initial expectation and accepts hypothesis H2. This implies that the relationship between internationalization and firm performance is strengthened when top managers have more managerial experience. Increased years of experience often equate to accumulated knowledge and skills, creating momentum and a foundation for expanding into international markets [7]. The top manager's experience provides support, helping businesses overcome barriers and challenges in the international environment, such as cultural differences, legal regulations, and supply chain management complexities. According to Carpenter and Fredrickson [43], experienced managers tend to make faster and more effective decisions in complex international environments due to their extensive knowledge and ability to adapt to various situations. Particularly in the Indian context, where cultural and regulatory barriers can be more complex due to significant differences between domestic and international markets, managerial experience acts as a "lever" to help businesses achieve higher operating efficiency. The study by Elango and Pattnaik [44] also emphasizes that the international experience of managers enhances the competitiveness of businesses when expanding into new markets (**Figure 2**).

In Model 3 of **Table 5**, the interaction between the level of internationalization and the manager's gender reveals a positive correlation supporting Hypothesis H3

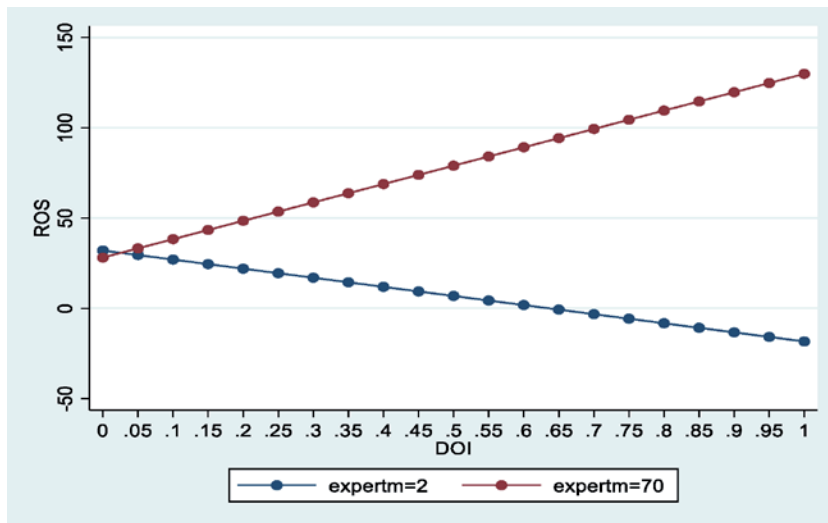


Figure 2. Moderating effect of top manager’s experience on internationalization and firm performance. Source: Authors’ compilation (2025).

(positive interaction coefficient of 77.032 and statistically significant ($p < 0.001$)). This finding suggests that the relationship between the level of internationalization and firm performance is strengthened when the business has a female top manager. Conversely, when the manager is male, the positive impact of internationalization on firm performance tends to decrease. Female managers are often recognized for their flexible management skills, empathy, and multidimensional strategic thinking—qualities that support businesses in navigating the diverse and complex international market. Dezsö and Ross [20] indicate that women in top management positions tend to promote organizational innovation through their ability to diversify perspectives and foster creativity. In the context of internationalization, where businesses face cultural diversity and product adaptation requirements, this becomes particularly important. Specifically, research by Post and Byron [19] also shows that female managers excel in adapting to different cultural factors, building relationships, and managing conflicts. These skills help businesses enhance their adaptability in a rapidly changing international environment, thereby improving firm performance (**Figure 3**).

Additionally, the remaining variables in the model also influence firm performance (ROS), including: services industry ($\beta = 3.303$; $p < 0.000$), years in operation ($\beta = 0.166$; $p < 0.000$), and GDP ($\beta = 31.577$; $p < 0.000$) having a positive impact on ROS; top manager’s experience ($\beta = -0.266$; $p < 0.000$), top manager’s gender ($\beta = -12.434$; $p < 0.000$), firm size ($\beta = -3.016$; $p < 0.000$), and labor regulation ($\beta = -0.696$; $p < 0.013$) having a negative impact on ROS. The remaining variable, manufacturing industry, is not statistically significant.

5.1 Research limitations and future research directions

This study has some limitations: (1) it only considers two personal moderating factors of top manager’s experience and top manager’s gender; influencing the relationship between internationalization and firm performance; (2) the sample is

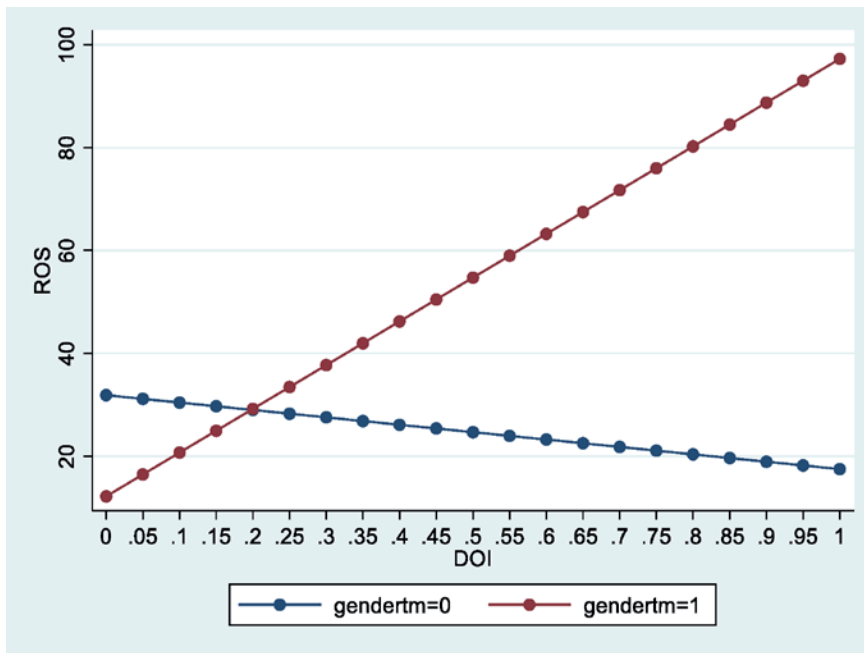


Figure 3. Moderating effect of top manager's gender on internationalization and firm performance. Source: Authors' compilation (2025).

limited to a single country (India); and (3) the degree of internationalization and firm performance are measured using single indicators.

Based on these limitations, suggestions for future research include: (1) expanding the analysis to include other moderating factors such as cultural, geographical, and economic distances and the characteristics of board members; (2) broadening the scope to multiple countries and analyzing different stages of international market entry; and (3) employing multidimensional measurement methods to provide a more comprehensive understanding of the relationship between internationalization and firm performance.

5.2 Implications

5.2.1 Theoretical implications

This research contributes to the Uppsala model and the Upper Echelons Theory by illustrating how top managers' attributes influence the relationship between internationalization and firm performance, especially in developing economies.

The Uppsala model [7, 8] posits that firms internationalize incrementally through experiential knowledge acquisition, mitigating risks tied to foreign market entry. This study expands the model by showing how top managers' experience and gender can affect this process. Managerial experience enhances firms' ability to navigate international markets by expediting learning, bridging information gaps, and facilitating more effective strategic decision-making. This challenges the traditional view of internationalization as an exclusively organizational process and underscores the critical role of individual decision-makers. Furthermore, female top managers can positively influence firm performance during internationalization due to their

cross-cultural management adaptability and relationship-building skills. This suggests that the Uppsala model should integrate individual managerial competencies with firm-level learning to better assess the speed and success of internationalization.

This study supports the Upper Echelons Theory [9] by demonstrating that top managers' characteristics significantly impact strategic decisions and firm performance during internationalization. Experienced managers can mitigate the liabilities of foreignness using their knowledge, networks, and foresight, leading to more effective strategies. This aligns with the Upper Echelons perspective that managerial cognition and experience shape organizational outcomes, especially in uncertain environments. Furthermore, leadership gender diversity improves internationalization outcomes, as female top managers often exhibit greater flexibility, stronger cross-cultural competencies, and superior relationship management—crucial for success in foreign markets. This contributes to the discussion on executive diversity, suggesting that gender-diverse leadership teams may achieve better performance globally.

5.3 Practical implications

For management and policy, this study offers key insights into how firms in developing economies can improve internationalization strategies by leveraging top managers' characteristics. Firms should not rely exclusively on the sequential approach of the traditional Uppsala model but should also account for managerial experience and leadership diversity. Investing in leadership development that enhances international exposure and cross-cultural competencies can significantly improve firms' ability to operate abroad. Prioritizing gender diversity in executive roles is also beneficial, as female managers demonstrate strategic advantages in international business. Policymakers should support firms with targeted training and resources that facilitate knowledge acquisition and leadership development for managers in early internationalization stages. These measures will help firms overcome initial obstacles and optimize global market performance.

5.4 Recommendations

This study presents key managerial implications for boards and policymakers in developing economies. First, boards should prioritize recruiting experienced female managers, as female participation in top management not only improves adaptability but also benefits internationalization, contributing to enhanced performance in the global competitive landscape. Simultaneously, businesses should develop phased internationalization strategies. Initially, firms face high costs and risks, potentially hindering performance, but once established internationally, the benefits of internationalization increase significantly, improving performance in later stages. Finally, managers must recognize the role of personal characteristics, such as management experience, in shaping internationalization strategies. To support these objectives, training programs for female managers and policies supporting small and medium-sized enterprises during initial internationalization should be prioritized, fostering sustainable and effective development in the international environment.

6. Conclusion

This study employs Feasible Generalized Least Squares (FGLS) regression analysis to identify factors influencing the relationship between internationalization and firm

performance in a developing economy, with India as the focus. Results indicate a negative linear relationship, with the top manager's experience and the fact that the top manager is female positively moderating this relationship. Specifically, Hypothesis H1 is supported, consistent with Transaction Cost Theory [15], which emphasizes that high initial internationalization costs can reduce firm performance. Furthermore, Hypothesis H2 is supported, indicating that the top manager's experience possesses a greater understanding of international markets, reducing information costs and risks [18]. This contrasts with Phan Anh Tu et al. [45] but aligns with Tu and Thanh [46], which examined top management characteristics in a transitional economy, and with Hsu et al. [10], which focused on CEO experience. Finally, Hypothesis H3 is supported, suggesting female managers enhance firm performance through innovative thinking and flexible management, particularly during internationalization [9]. This aligns with Tu and Thanh [46]. Therefore, understanding performance differences in internationalizing firms, especially in developing economies, requires considering top management characteristics.

The study also analyzes control variables and factors directly influencing operational effectiveness. The variables services industry, years in operation, and GDP show a positive correlation with firm performance, while the top manager's experience, the top manager's gender, firm size, labor regulation, and degree of internationalization exhibit an inverse relationship. Notably, the manufacturing industry variable lacks statistical significance but is included in the model due to its contextual importance in business.


This study extends internationalization theory by integrating the top management team's individual moderating factors. By combining the Uppsala theory [7, 13, 14] and Upper Echelons Theory [9], the study provides a comprehensive theoretical framework to explain how top manager characteristics influence internationalization strategy.

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References

- [1] Geringer JM, Tallman S, Olsen DM. Product and international diversification among Japanese multinational firms. *Strategic Management Journal*. 2000;**21**(1):51-80. DOI: 10.1002/(SICI)1097-0266(200001)21:1<51::AID-SMJ77>3.0.CO;2-K
- [2] Gomes L, Ramaswamy K. An empirical examination of the form of the relationship between multinationality and performance. *Journal of International Business Studies*. 1999;**30**(1):173-187. DOI: 10.1057/palgrave.jibs.8490065
- [3] Grant RM. Multinationality and performance among British manufacturing companies. *Journal of International Business Studies*. 1987;**18**(3):79-89. DOI: 10.1057/palgrave.jibs.8490413
- [4] Lu JW, Beamish PW. International diversification and firm performance: The S-curve hypothesis. *Academy of Management Journal*. 2004;**47**(4):598-609. DOI: 10.5465/20159604
- [5] Cuervo-Cazurra A, Ciravegna L, Melgarejo M, Lopez L. Home country uncertainty and the internationalization-performance relationship: Building an uncertainty management capability. *Journal of World Business*. 2018;**53**(2):209-221. DOI: 10.1016/j.jwb.2017.11.002
- [6] Pangarkar N. Internationalization and performance of small-and medium-sized enterprises. *Journal of World Business*. 2008;**43**(4):475-485. DOI: 10.1016/j.jwb.2007.11.009
- [7] Johanson J, Vahlne JE. The internationalization process of the firm—a model of knowledge development and increasing foreign market commitments. *Journal of International Business Studies*. 1977;**8**:23-32. DOI: 10.1057/palgrave.jibs.8490676
- [8] Johanson J, Vahlne JE. The internationalization process of the firm—A model of knowledge development and increasing foreign market commitments. In: *International Business*. Routledge; 2017. pp. 145-154
- [9] Hambrick DC, Mason PA. Upper echelons: The organization as a reflection of its top managers. *Academy of Management Review*. 1984;**9**:193-206. DOI: 10.5465/amr.1984.4277628
- [10] Hsu WT, Chen HL, Cheng CY. Internationalization and firm performance of SMEs: The moderating effects of CEO attributes. *Journal of World Business*. 2013;**48**(1):1-12. DOI: 10.1016/j.jwb.2012.06.001
- [11] Kindleberger CP. Measuring equilibrium in the balance of payments. *Journal of Political Economy*. 1969;**77**(6):873-891
- [12] Anderson SJ, McKenzie D. Improving business practices and the boundary of the entrepreneur: A randomized experiment comparing training, consulting, insourcing, and outsourcing. *Journal of Political Economy*. 2022;**130**(1):157-209. DOI: 10.1086/717044
- [13] Vahlne JE, Johanson J. From internationalization to evolution: The Uppsala model at 40 years. *Journal of International Business Studies*. 2017;**48**(9):1087-1102. DOI: 10.1057/s41267-017-0107-7
- [14] Vahlne JE, Johanson J. The Uppsala model: Networks and micro-foundations.

Journal of International Business Studies. 2020;**51**(1):4-10. DOI: 10.1057/s41267-019-00277-x

[15] Contractor FJ, Kumar V, Kundu SK. Nature of the relationship between international expansion and performance: The case of emerging market firms. *Journal of World Business*. 2007;**42**(4):401-417. DOI: 10.1016/j.jwb.2007.06.003

[16] Hambrick DC. Upper echelons theory: An update. *Academy of Management Review*. 2007;**32**(2):334-343. DOI: 10.5465/amr.2007.24345254

[17] Finkelstein S, Hambrick DC, Cannella AA. *Strategic Leadership: Theory and Research on Executives, Top Management Teams, and Boards*. USA: Oxford University Press; 2009

[18] Crossland C, Zyung J, Hiller NJ, Hambrick DC. CEO career variety: Effects on firm-level strategic and social novelty. *Academy of Management Journal*. 2014;**57**(3):652-674. DOI: 10.5465/amj.2012.0469

[19] Post C, Byron K. Women on boards and firm financial performance: A meta-analysis. *Academy of Management Journal*. 2015;**58**(5):1546-1571. DOI: 10.5465/amj.2013.0319

[20] Dezsö CL, Ross DG. Does female representation in top management improve firm performance? A panel data investigation. *Strategic Management Journal*. 2012;**33**(9):1072-1089. DOI: 10.1002/smj.1955

[21] Johanson J, Vahlne JE. The Uppsala internationalization process model revisited: From liability of foreignness to liability of outsidership. *Journal of International Business Studies*. 2009;**40**(9):1411-1431. DOI: 10.1057/jibs.2009.24

[22] Ho SS, Li AY, Tam K, Zhang F. CEO gender, ethical leadership, and accounting conservatism. *Journal of Business Ethics*. 2015;**127**:351-370. DOI: 10.1007/s10551-013-2044-0

[23] Tihanyi L, Ellstrand AE, Daily CM, Dalton DR. Composition of the top management team and firm international diversification. *Journal of Management* (Thousand Oaks, California, USA: Sage Publications). 2000;**26**(6):1157-1177. DOI: 10.1177/014920630002600605

[24] Athanassiou N, Nigh D. Internationalization, tacit knowledge and the top management teams of MNCs. *Journal of International Business Studies*. 2000;**31**:471-487. DOI: 10.1057/palgrave.jibs.8490917

[25] Hofer CW, Schendel D. *Strategy Formulation: Analytical Concepts*. St. Paul: West Publishing Corporation. Minnesota; 1978. p. 219

[26] Sambharya RB. Foreign experience of top management teams and international diversification strategies of US multinational corporations. *Strategic Management Journal*. 1996;**17**(9):739-746. DOI: 10.1002/(SICI)1097-0266(199611)17:9<739::AID-SMJ846>3.0.CO;2-K

[27] Fairlie RW, Robb AM. Gender differences in business performance: Evidence from the characteristics of business owners survey. *Small Business Economics*. 2009;**33**(4):375-395. DOI: 10.1007/s11187-009-9207-5

[28] Williams DA. Gender and the internationalization of smes. *Allied Academies International Conference*. Academy for Studies in International Business. Proceedings. 2012;**12**(2):21-25. Available from: <https://www.proquest.com/scholarly-journals/gender-internationalization-smes/docview/1272323622/se-2>

- [29] Brush CG, Manolova TS. Women, age, and money: International entrepreneurship theory in the work of Candida G. Brush. In: Handbook of Research on International Entrepreneurship. Cheltenham, op. cit: Edward Elgar; 2004. pp. 41-57. DOI: 10.4337/9781845420512
- [30] World Bank. World Bank Enterprise Surveys. Washington, D.C.: World Bank; 2014 & 2022. Available from: <https://www.enterprisesurveys.org/>
- [31] World Bank. Enterprise Surveys: Data and Methodology. Washington, D.C., USA: The World Bank; 2023. Available from: <https://www.enterprisesurveys.org/>
- [32] Hair JF Jr, Black WC, Babin BJ, Anderson RE. Multivariate data analysis. In: Multivariate Data Analysis. 2010. pp. 785-785
- [33] Xiao SS, Jeong I, Moon JJ, Chung CC, Chung J. Internationalization and performance of firms in China: Moderating effects of governance structure and the degree of centralized control. *Journal of International Management*. 2013;**19**(2):118-137. DOI: 10.1016/j.intman.2012.12.003
- [34] Johanson J, Vahlne JE. The mechanism of internationalisation. *International Marketing Review*. 1990;**7**(4):11-24. DOI: 10.1108/02651339010137414
- [35] Bathula H. Board Characteristics and Firm Performance: Evidence from New Zealand [PhD Dissertation]. Auckland, New Zealand: Auckland University of Technology; 2008
- [36] Cerrato D, Piva M. The internationalization of small and medium-sized enterprises: The effect of family management, human capital and foreign ownership. *Journal of Management & Governance*. 2012;**16**:617-644. DOI: 10.1007/s10997-010-9166-x
- [37] Fort TC, Haltiwanger J, Jarmin RS, Miranda J. How firms respond to business cycles: The role of firm age and firm size. *IMF Economic Review*. 2013;**61**(3):520-559. DOI: 10.1057/imfer.2013.15
- [38] Baykal NA, Gunes E. Effectiveness of SMEs in Turkish economy and agricultural industry sector. *International Journal of Management and Enterprise Development*. 2004;**1**(4):359-374. DOI: 10.1504/IJMED.2004.004639
- [39] Thomas DE, Eden L. What is the shape of the multinationality-performance relationship? *Multinational Business Review*. 2004;**12**(1):89-110. DOI: 10.1108/1525383X200400005
- [40] Contractor FJ, Kundu SK, Hsu CC. A three-stage theory of international expansion: The link between multinationality and performance in the service sector. *Journal of International Business Studies*. 2003;**34**(1):5-18. DOI: 10.1057/palgrave.jibs.8400003
- [41] Tu P, Huong D, Triet P. The moderating effects of managers' experience and gender on internationalization and firm performance of manufacturing enterprises in Turkey. *Accounting*. 2020;**6**(7):1209-1216. DOI: 10.5267/j.ac.2020.9.006
- [42] Ruigrok W, Wagner H. Internationalization and performance: An organizational learning perspective. *MIR: Management International Review*. 2003;**43**(1):63-83. Available from: <https://www.jstor.org/stable/40835634>
- [43] Carpenter MA, Fredrickson JW. Top management teams, global strategic posture, and the moderating role of uncertainty. *Academy of Management*

Journal. 2001;**44**(3):533-545.
DOI: 10.5465/3069368

[44] Elango B, Pattnaik C. Building capabilities for international operations through networks: A study of Indian firms. *Journal of International Business Studies*. 2007;**38**:541-555. DOI: 10.1057/palgrave.jibs.8400280

[45] Phan Anh T, Van Song N, Van Tien D, Van Ha T, Tiep NC, Thang DQ, et al. The moderating effects of the manager's characteristics and financial obstacles on internationalization and firm performance in Poland. *PalArch's Journal of Archaeology of Egypt/Egyptology*. 2021;**18**(4):4063-4081. Available from: <https://archives.palarch.nl/index.php/jae/article/view/6975>

[46] Tu P, Thanh T. Business barriers and degree of internationalization of manufacturing companies in Peru. *Accounting*. 2020;**6**(6):931-936.
DOI: 10.5267/j.ac.2020.8.004

Chapter 2

Global Labor Mobility: Patterns, Drivers, and Implications for Trade, Investment, and Business Dynamics

Chujian Shao

Abstract

As the world is becoming more economically and socially integrated, international labor migration plays an increasingly important role in shaping international business. This chapter examines the drivers, patterns, and economic implications of global labor mobility, highlighting how economic globalization, demographic shifts, and education systems jointly shape cross-border labor flows. It also investigates the economic impact of migration through remittances, trade, and foreign direct investment. High-skilled immigration is fueled by the global competition for talent in innovation-intensive industries, whereas low-skilled immigration is primarily driven by shortages in sectors such as construction, agriculture, and caregiving. Both low- and high-skilled immigrants play essential roles in increasing productivity, fostering economic development, and contributing to global trade and international business dynamism. Special attention is given to the United States, one of the world's largest migrant-receiving economies. Immigrant labor in the United States not only addresses labor shortage, but also helps drive multinational enterprise activity, sectoral competitiveness, and innovation. To strengthen the empirical foundation of these insights, the chapter includes a causal analysis of the relationship between immigration and trade with two different Bartik instruments. The main results imply that immigration does indeed help drive trade, highlighting how labor migration plays a key role in supporting international business and deeper economic ties between countries.

Keywords: international migration, demographic trends, remittance, global trade, foreign direct investment, multinational business

1. Introduction

Over the past few decades, there has been a significant increase in global migration, which is a reflection of the intricate relationships between policy frameworks, demographic pressures, economic opportunities, and geopolitical forces. International labor mobility is still primarily driven by economic factors, such as the desire for better jobs and higher salaries, but social, educational, and family-related factors also have a big impact

on how migration flows are shaped. These dynamics have been made even more intense by growing globalization, which connects human mobility to larger flows of capital, goods, and knowledge. Therefore, migration now includes temporary labor mobility, educational exchanges, and skill-based talent flows in addition to permanent relocations. They are essential in addressing the demands of the labor market, promoting innovation, assisting aging populations, and easing international trade and investment. Understanding these diverse drivers is essential for analyzing the evolving patterns of global labor distribution and their implications for both sending and receiving countries.

This chapter is divided into six main sections. Section 2 explores the drivers, patterns, and economic implications of global labor mobility. It begins by documenting long-run trends in international migration, emphasizing how economic globalization, demographic shifts, and education systems jointly influence labor flows. With an emphasis on both high- and low-skilled migrants. Section 3 examines how immigration helps offset labor shortages and sustain productivity in aging high-income countries. In Section 4, the emphasis is shifting to labor market pressures in low-income nations, emphasizing how informality and youth unemployment fuel emigration and increase reliance on remittances. Section 5 reviews how immigration interacts with trade and foreign direct investment (FDI), highlighting the role of migrant networks in lowering transaction costs and enhancing global connectivity. Section 6 examines the intersection of immigrant labor and multinational enterprise (MNE) activity across US industries, showing how both immigration and global business operations shape sectoral dynamics and contribute to economic performance. To strengthen the empirical foundation of these insights, Section 7 tests the causal relationship between immigration and trade using instrumental variable (IV) techniques. By employing alternative Bartik instruments and panel regression models, this section investigates whether immigration causally facilitates trade, thereby providing empirical evidence on how labor migration shapes global economic integration. This exercise complements existing empirical research on trade and immigration by applying Bartik instruments.

Overall, the main objective of this chapter is to illustrate that global labor mobility not only promotes productivity through both low- and high-skilled migration and relieves demographic pressures in aging high-income countries. In addition, it addresses persistent employment gaps in low-income countries, maintains household welfare through remittances, facilitates trade and foreign direct investment through migrant networks, and strengthens sectoral competitiveness through immigrant entrepreneurship and integration into multinational enterprise activity. The addition of causal analysis further reinforces the role of migration as a driver of global economic connectivity and growth.

2. Drivers and trends of cross-border labor mobility

Economic drivers are the most powerful forces shaping global migration patterns. Workers migrate across countries for better employment opportunities, higher wages, and improved living standards. Particularly, economic globalization fosters labor mobility along trade and investment corridors, linking the movement of goods, capital, and people. Social and demographic drivers also play an important role in shaping migration decisions. Family reunification remains one of the primary legal channels for permanent migration in many destination countries. Another significant pull factor is education, as students migrate to pursue professional training and higher education, frequently entering the local labor market after graduation.

Table 1 shows that the number of international migrants increased significantly over the last three decades, with the total number of international migrants increasing from 153.9 million in 1990 to 304 million by mid-2024. This growth reflects deeper global integration, labor market imbalances, conflict-driven displacement, and increased legal migration pathways. The two regions with the biggest absolute increases were Europe and Asia. Europe hosted 94.1 million migrants, closely followed by Asia at 92.2 million. The Americas and Africa also experienced steady growth, though at different scales.

The United States remained the top global destination for international migrants, consistently hosting the largest absolute number of migrants, rising from 23 million in 1990 to over 52 million in 2024, though its share of the world’s migrant population declined slightly from 15.1% to 17.2%, reflecting broader global migration growth (see **Figure 1**). Meanwhile, the absolute number and global share of migrants increased significantly in Germany, Saudi Arabia, the United Kingdom, and Canada; Saudi Arabia and the United Kingdom experienced particularly strong growth as a result of labor migration and asylum flows, respectively. While France and Canada maintained a relatively stable global share, Spain saw the most dramatic increase, with its migrant stock more than tenfold increasing between 1990 and 2024, particularly in the 2000s. These countries exhibit a combination of economic attractiveness, historical ties, and policy openness. Europe’s sharp rise is driven by intra-EU mobility and asylum inflows. Overall, the data shows how economic, demographic, and geopolitical factors have increasingly influenced global migration, increasing its scope and geographic reach.

Within the broader landscape of international migration, student mobility has become an increasingly important channel of global talent flows. With roughly 1.1 million and 621.6 thousand students sent overseas, respectively, China and India were the two biggest countries from which international tertiary students were sent in 2022. Germany, Vietnam, and Uzbekistan are other noteworthy countries of origin. On the destination side, the United States had just over 1 million international students, followed by the United Kingdom (675 k), Germany (403.5 k), and Australia (382 k). Russia and Canada also received substantial numbers of international students, each hosting over 330,000. These findings highlight the English-speaking

Year	Global	Africa	Americas	Asia	Europe
1990	153.9	16.2	34.8	46.7	51.5
1995	163.2	16.7	40.1	44.8	56.5
2000	174.6	15.4	46.9	47.6	59.2
2005	192.8	16.6	52.8	51.6	65.8
2010	221.0	17.8	59.3	64.3	72.5
2015	250.0	22.7	65.1	78.3	75.7
2020	275.3	25.3	73.1	84.7	83.0
2024 (mid-year)	304.0	29.2	78.7	92.2	94.1

Source: United Nations, Department of Economic and Social Affairs, Population Division (2024). International Migration Stock.

Table 1.
 Total number of international migrants at 1990 – mid-year 2024 (millions).

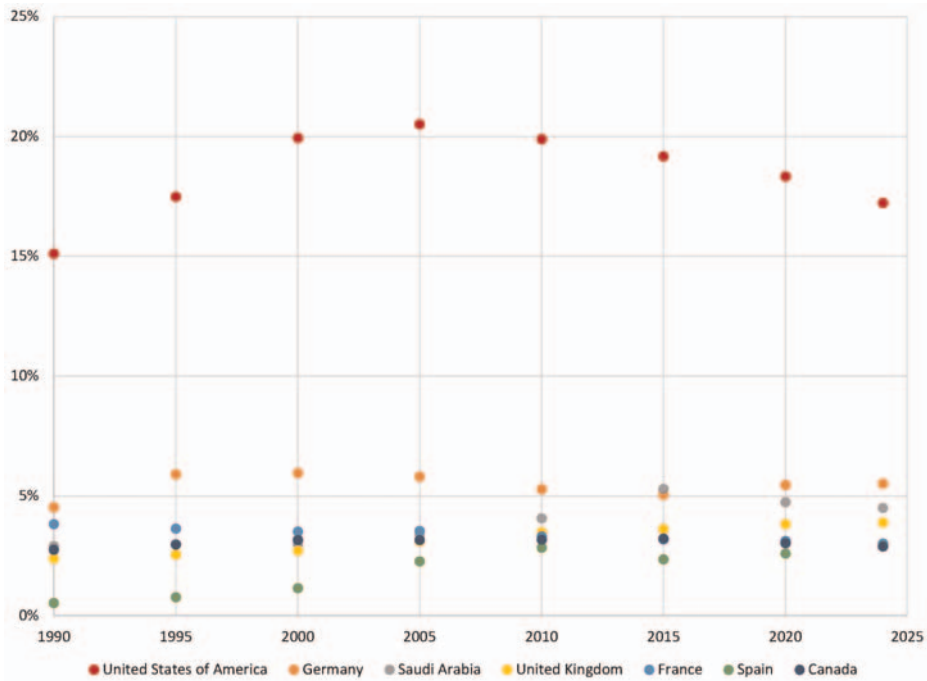


Figure 1. Share of the world's migrant population by selected country. Source: United Nations, Department of Economic and Social Affairs, Population Division (2024). *International Migration Stock*.

nations' continued dominance as educational destinations, but they also show the expansion of educational ties between nations like Germany and Russia. The trends reflect broader patterns in global talent mobility, education policy, and international economic integration.

These migration trends underscore the changing character of global human capital mobility, with implications for workforce development, innovation ecosystems, and global competitiveness, whether through labor flows or educational pathways.

3. Demographic aging, productivity, and the role of immigration in high-income countries

An aging population results in a shrinking workforce and a higher old-age dependency ratio, which slows economic growth by reducing the size of the labor force. Furthermore, a decrease in overall labor productivity may result from older workers retiring or switching to less physically demanding positions. The top five nations in terms of the age dependency ratio are advanced economies, including Monaco, Japan, Finland, Portugal, and Italy. Concerns over the long-term labor supply and economic productivity are becoming more prevalent. Significantly higher age dependency ratios are seen in the Euro area and high-income nations generally (33% and 30%, respectively), indicating that the developed world's population is aging. Since the global average and low- and middle-income countries continue to be relatively low, these nations continue to enjoy the "demographic dividend," which is the advantage of having more working-age people than dependents (Figure 2).

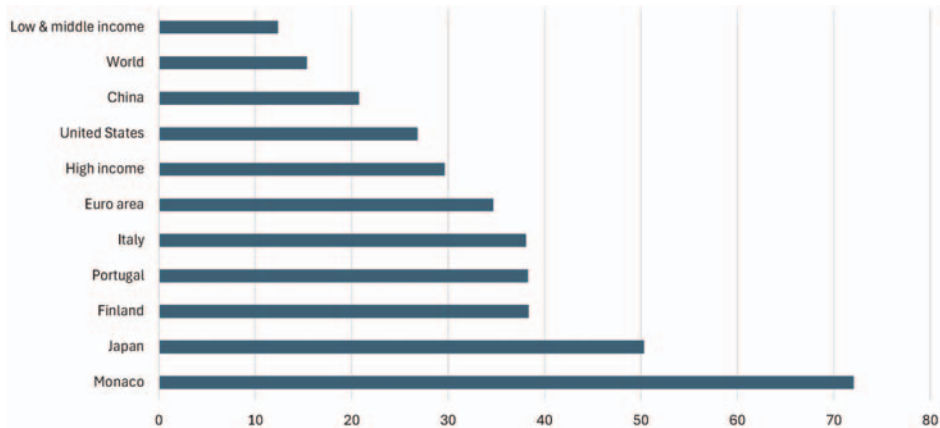


Figure 2.
Age dependency ratio, old (% of working-age population) 2023. Source: World Bank, World Development Indicators.

Recent literature highlights that demographic shifts, particularly population aging, account for a significant share of cross-country differences in productivity growth. Feyrer [1] finds that a larger share of the population in the 40–49 age cohort is positively associated with higher productivity, emphasizing the importance of prime-age workers in driving economic performance. According to Maestas et al. [2], a 10% increase in the proportion of people aged 60 and over lowers per capita GDP in the United States by 5.5%, with slower employment growth accounting for one-third of the decline and lower productivity accounting for the other two-thirds.

Labor migration has become an increasingly vital mechanism for supporting both labor supply and productivity. Since they are usually younger workers, migrants can support economic growth and help restock the labor force. In high-income countries, immigrants play essential roles across a wide range of sectors, including healthcare, construction, agriculture, infrastructure, and technology, which are critical to the functioning of aging economies. High-skilled migrants contribute to cutting-edge fields like engineering and information technology, while low-skilled migrants frequently support labor-intensive jobs in construction and agriculture.

A growing body of literature highlights the significant role of skilled migrants in entrepreneurship, innovation and productivity growth in knowledge-intensive industries. Some studies show that skilled immigrants are more likely than natives to start businesses, particularly in high-tech and knowledge-intensive sectors [3, 4]. They are overrepresented among high-growth and venture-backed startups in innovation hubs, where their impact is particularly noticeable [5]. An increase in the immigrant college graduates' population share results in higher patents per capita in the United States, as shown in Ref. [6]. Hunt [7] also uses US survey data to show that immigrants who entered on high-skill or student visas outperform natives in productivity-enhancing activities, such as wages, patenting, publishing, and entrepreneurship, largely due to differences in education and field of study. These results imply that skilled migration boosts economic dynamism through business creation, innovation, and job growth in addition to meeting labor market demands.

Though low-skilled immigrants may have lower individual productivity levels, their presence enables labor specialization, cost reduction, and sectoral efficiency, which together contribute to higher aggregate productivity and economic output.

For instance, Peri and Sparber [8] demonstrate how immigration can result in task specialization, where migrants perform complementary tasks and natives transition to higher-skilled roles, improving overall efficiency. Hence, low-skilled immigrants support aging societies' infrastructure, agricultural, and service sectors by addressing critical labor shortages and boosting overall macroeconomic productivity.

Research on how low-skilled immigration affects wages in host nations is still crucial. Early work by Borjas [9] finds that an influx of low-skilled immigrants tends to reduce wages for native workers with similar skills, especially those without a high school diploma. However, subsequent research provides a more nuanced view. Ottaviano and Peri [10] argue that immigrants often complement native labor by performing different tasks or working in different sectors, resulting in minimal or even positive wage effects for most natives. Card [11] similarly finds limited evidence that immigration depresses native wages, emphasizing the adaptability of labor markets through capital deepening and job reallocation. In addition, Dustmann et al. [12] show that the wage impacts vary across the distribution, with small negative effects at the lowest 20th percentile and positive effects at the top. Overall, the literature suggests that though localized short-term wage pressures may exist for low-skilled natives, the aggregate impact on wages is modest and mitigated by more significant economic adjustments.

With a declining labor force and slower productivity growth, demographic aging poses an increasing threat to developed economies. As the old-age dependency ratio rises, sustaining economic output increasingly depends on labor market adaptation. Labor migration makes a substantial contribution to expanding the working labor force. Low-skilled migrants fill essential roles in labor-intensive sectors, while high-skilled migrants drive innovation, entrepreneurship, and productivity in knowledge-based industries. Low-skilled immigrants typically do not have a major detrimental effect on the labor market in high-income nations and only slightly affect native wages. Hence, migration flows not only address demographic imbalances but also enhance labor productivity and long-term growth potential.

4. Labor market pressures and remittance dynamics in low-income countries

According to the publication of the International Labor Organization's Global Employment Trends for Youth, only 20% of young adults (ages 25–29) in low-income countries hold secure paid jobs, with the majority working in informal or precarious employment. This trend has hardly changed since 2000. Though 76% of young adults in high-income countries have secure jobs, up to one-quarter of young workers in some regions are affected by the growing global youth temporary labor rate. There is still a lot of pressure on the youth labor markets in the Arab States and Africa. In North Africa and the Arab States, youth unemployment exceeds one-third, and employment rates are very low, particularly for young women. In sub-Saharan Africa, most young adults remain in insecure, low-paid, or agricultural work; this trend has not changed since the early 2000s. By 2050, more than 72.6 million young people are anticipated to join the workforce, making the creation of good jobs a crucial issue for both the local and international communities.

These persistent labor market pressures have contributed to an increase in emigration from low-income countries. In turn, remittances from migrant workers are becoming an increasingly important source of household income, helping to support

economic development in their home countries. For example, Adams and Page [13] estimate that a 10% increase in per capita remittances results in a 1.6% decrease in the number of people living in poverty, demonstrating a strong correlation between remittances and poverty reduction. According to Combes and Ebeke [14], remittances also play a crucial role in providing insurance by mitigating the effects of a range of external and economic shocks, including financial crises, fiscal volatility, and natural disasters. They also significantly reduce household consumption instability in developing nations. Similarly, Yang [15] highlights the role of remittances as informal insurance mechanisms by using exchange rate shocks that impact Filipino migrants to demonstrate how they increase investments in durable goods and education. However, Chami and Jahjah [16] point out that remittances may primarily fund consumption rather than profit-driven capital flows, limiting their contribution to long-term growth. Overall, the literature emphasizes remittances as important stabilizers for migrant-sending households, with positive short-run welfare effects but mixed evidence regarding long-term developmental impacts.

Over the past two decades, global remittance inflows have grown substantially, rising from \$188 billion in 2003 to over \$822 billion in 2023, as shown in **Table 2**. Middle-income nations, led by the Philippines, Mexico, and India, now receive the majority of international remittances, and the growth in remittance flows has been particularly noticeable in these nations. In absolute terms, India remains the top recipient, with inflows surpassing \$119 billion in 2023. On the other hand, low-income countries still account for a small share of global remittance volumes, reflecting structural barriers to international labor mobility. As a share of GDP, remittances remain critically important for low-income and migrant-sending countries. For example, in 2023, remittances comprised 8.9% of GDP in the Philippines, 3.7% in Mexico, and 3.4% in India. In addition, several small and low-income economies, such as Tajikistan, Nepal, Honduras, Nicaragua, and Samoa, are among the most remittance-dependent countries in the world. Remittances in these countries surpass 25–35% of their GDP, underscoring their critical function in maintaining macroeconomic stability and household income. Remittances are far more economically significant for poorer, smaller economies, where they serve as a financial lifeline, even

Country/group	Remittances received (USD billions)			Percent of GDP (%)		
	2003	2013	2023	2003	2013	2023
World	188	528	823	0.5	0.7	0.8
Middle income	115	361	607	1.9	1.5	1.6
High income	69	156	196	0.2	0.3	0.3
India	21	70	120	3.5	3.8	3.4
Mexico	17	24	66	2.2	1.8	3.7
Philippines	10	27	39	11.8	9.4	8.9
France	12	27	37	0.7	1.0	1.2
China	5	18	29	0.3	0.2	0.2
Low income	4	10	20	4.0	2.7	3.2

Source: World Bank, Personal Remittances data. Extracted from the World Development Indicators database.

Table 2.
Personal remittances received and percent of GDP, 2003–2023.

though middle-income countries account for the majority of remittances in absolute dollar terms. Global remittance flows are concentrated in major emerging economies, but they have the greatest developmental impact in low-income, remittance-dependent nations.

In short, growing labor market pressures in low-income countries and demographic aging in high-income countries are intensifying global labor imbalances, making international labor migration not only likely but increasingly necessary. High youth unemployment, pervasive informality, and limited access to decent work in low-income countries serve as powerful push factors driving labor outflows. Simultaneously, aging populations, labor shortages, and sector-specific demand in high-income countries act as strong pull factors. Remittances are crucial in this regard, acting as a stabilizing factor for economies beset by enduring employment disparities and underdevelopment as well as a financial lifeline for households in migrant-sending countries.

5. Immigration, trade openness, and offshoring

Early empirical studies by Head and Ries [17] and Gould [18] show that immigration increases bilateral trade flows by creating ethnic ties that lower transaction costs. As shown by Rauch and Trindade [19] and Casella and Rauch [20], this trade-creating effect is particularly strong in differentiated goods, which emphasizes that group ties increase aggregate trade and income. More recent studies broaden this framework by providing evidence from a variety of national contexts, demonstrating the robustness of the immigration-trade nexus across different institutional and economic settings. Hatzigeorgiou [21] finds that immigration in Sweden has a positive effect on trade flows. Bandyopadhyay et al. [22] and Iranzo and Peri [23] highlight the role of immigrant networks in facilitating exports, especially in light of Eastern-Western European integration. Ottaviano et al. [24] conducted a firm-level analysis in the United Kingdom and found that labor force diversity improves service trade performance, indicating that immigrant presence is associated with productivity gains. Gandal et al. [25] demonstrate how immigration influences labor market adjustments in Israel by interacting with trade and technology. Complementing this evidence, Peri and Requena-Silvente [26] find that immigration to Spain boosts both imports and exports, especially in sectors that depend on relationship-based transactions. Overall, these studies highlight how immigration consistently improves trade through labor market complementarities, network formation, and information diffusion in a variety of national contexts. **Table 3** presents a summary of the empirical literature exploring the linkages between international trade and immigration, highlighting country-specific studies, methodological approaches, and key findings.

Beyond trade, immigration also plays an important role in shaping foreign direct investment flows. According to Beata et al. [31], migrant networks strengthen bilateral FDI by mitigating informational barriers and improving institutional familiarity. It has been demonstrated that liberal immigration policies increase productivity and global competitiveness, while restrictive immigration laws restrict innovation and hiring flexibility in multinational enterprises [7, 32]. Furthermore, Kugler and Rapoport [33] suggest that migration and capital flows may be complements or substitutes depending on relative labor costs and market structures. Another related research by Dustmann et al. [34] explores the impact of labor migration on global value chains, indicating that firms may substitute migration with offshoring or adjust

Study	Country/ context	Method	Main findings
[18]	The United States	Panel regression with country-pair fixed effects	A 10% increase in immigrants increases exports by 0.2–0.4%; stronger effect for differentiated goods.
[17]	Canada	Gravity model with immigrant stock	A 10% increase in immigrants leads to 1% increase in exports and 3% in imports.
[27]	Canada	Panel regression by province	A 10% rise in immigrants increases exports by 1% and imports by 1.5%. Stronger effects in provinces with higher immigrant diversity.
[19]	Global (Ethnic Chinese)	Cross-country regression with ethnic network proxies	Ethnic Chinese networks increase trade in differentiated goods by over 60%.
[20]	Global	Model with group-based trust metrics	Market ties and group affiliations increase international trade in trust-intensive sectors.
[25]	Israel	Interaction model with technology and labor data	Immigration affects labor market adjustment <i>via</i> trade and technology linkages.
[28]	The United States	State-level gravity model	Immigration's trade effect is stronger when migrants are geographically close to their host countries.
[29]	The United States	Bilateral gravity model	Immigrants raise both imports and exports with a stronger effect on differentiated goods.
[22]	The United States	Gravity model with ethnic networks	Immigrant communities enhance US exports to origin countries.
[23]	Eastern and Western Europe	Theoretical and empirical model	Migrant networks enhance trade between East and West Europe post-integration.
[24]	The United Kingdom (firms)	Firm-level fixed effects regression	A 10% increase in bilateral immigrant share reduces intermediate service imports by 1–2%.
[21]	Sweden	Gravity model with controls	10% increase in immigrant stock boosts exports by 7% and imports by 9%.
[26]	Spain	Firm- and province-level gravity models	Immigration significantly boosts trade in differentiated products.
[30]	The United States	Gravity model with occupational data	Immigration increases US trade; the effect varies by immigrant occupation.

Table 3.
Empirical studies on immigration and trade.

supply chain strategies in response to labor constraints. Therefore, immigration plays an important economic role both as a source of labor and as a channel for strengthening cross-border integration through trade and foreign investment.

Whereas most studies examine the impact of immigration on trade or FDI separately, a smaller but growing body of research explores the interlinked dynamics of all three channels. Specifically, migrant networks can simultaneously promote international trade and FDI by reducing information frictions, fostering trust, and transmitting knowledge across borders. Javorcik et al. [31] illustrate that migrant communities not only facilitate trade but also boost bilateral FDI flows from OECD to developing countries, particularly in contexts with weak formal institutions. Kugler and Rapoport [33] also develop a theoretical framework to show that immigration, trade, and FDI

are interdependent. In some cases, migration and FDI act as complements, especially when firms invest abroad to access migrant-linked markets. Similarly, Flisi and Murat [35] find that both immigrant and emigrant networks in the European Union enhance trade and FDI flows, suggesting the presence of “network externalities” that jointly support cross-border economic integration. Hence, it is crucial to examine immigration, trade, and foreign direct investment as interdependent elements of global economic connectivity rather than as distinct phenomena.

6. Immigrant labor and multinational enterprise activity across US industries

As the world economy becomes increasingly integrated into the global supply chain, understanding how immigrant labor interacts with multinational enterprise (MNE) activity is essential for evaluating the dynamics of labor demand, productivity, and innovation. The literature examining the relationship between labor migration and international business emphasizes how multinational corporations both influence and react to cross-border labor mobility. A core focus is their role in facilitating skilled migration through intra-firm transfers, global talent recruitment, and visa sponsorship [3]. These high-skilled migrants often drive innovation, enable knowledge transfer, and support the expansion of firms into global markets.

Moreover, immigrants make a significant contribution to international business dynamism. They have a disproportionately high likelihood of starting globally focused businesses, especially in high-tech industries [4, 5]. Meanwhile, skilled migrants are frequently hired by multinational corporations to take advantage of their familiarity with domestic markets. By using their transnational networks to lessen informational and cultural barriers, migrants, particularly those in managerial or technical positions, also play a crucial role in promoting trade and FDI [31, 36]. In this way, both MNEs and immigrant workers serve as powerful agents of globalization, reinforcing one another’s roles in linking host and origin economies.

Given the United States’ role as the world’s largest destination for both foreign direct investment and skilled immigrants, examining the industry-level distribution of MNE activity offers valuable insight into how global labor and capital flows intersect in a key advanced economy. **Figure 3** presents the industry-level breakdown of MNE activity in the United States, showing each sector’s share of total MNE affiliates, net income, value added, and employment. Despite representing just under 30% of affiliates, manufacturing stands out as the most significant sector, accounting for nearly 40% of MNE value added and employment. Professional and scientific services and retail trade also contribute notably to MNE employment, reflecting labor demand across both high- and lower-skilled occupations. In contrast, the finance and mining sectors generate disproportionately high income and value added relative to their smaller workforce shares, which indicates that they have a high capital intensity. Nearly half of all MNE net income comes from the “other industries” category, which probably includes high-margin industries like utilities and real estate. These patterns align closely with the distribution of immigrant workers in the United States, who are primarily found in labor-intensive MNE sectors like manufacturing, retail, and professional services. This highlights their vital role in sustaining the productivity and competitiveness of foreign-owned firms operating in the United States.

Complementing the patterns of MNE activity, the distribution of foreign-born workers across US industries provides additional insight into the sectors most reliant

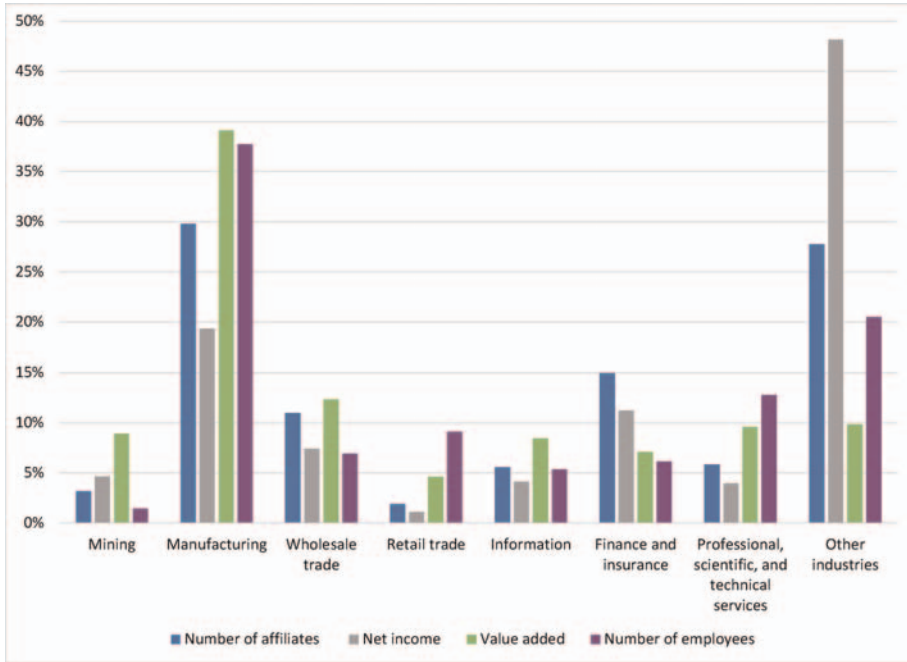


Figure 3. Distribution of MNEs activity by industry, share of total MNEs in the United States, 2022. Source: Bureau of Economic Analysis. *Activities of US Affiliates of Foreign Multinational Enterprises, 2023.*

on immigrant labor and the skill composition of the workforce supporting globally engaged firms. **Figure 4** highlights the significant role of foreign-born workers across major US industries in 2023, with the highest concentrations found in educational services, healthcare, and social assistance, followed by professional, scientific, and management services. These two sectors account for nearly 40% of all immigrant employment. Other key sectors include manufacturing, construction, retail trade, and

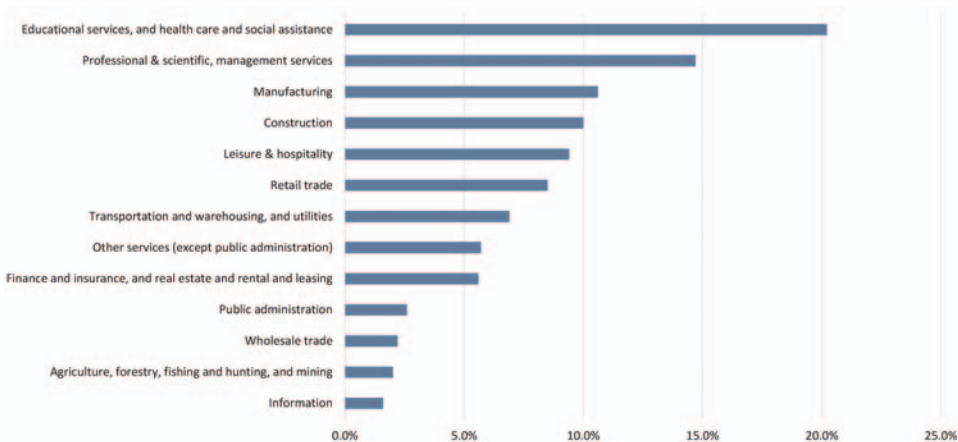


Figure 4. Foreign-born population by industry in 2023, %. Source: US Census Bureau, US Department of Commerce. *“Selected Characteristics of the Native and Foreign-Born Populations.” American Community Survey, ACS 1-Year Estimates Subject Tables, Table S0501.*

accommodation and food services, all of which are labor-intensive and traditionally reliant on immigrant workers.

There is a noticeable overlap in industries with high foreign-born employment and MNE presence when compared to the distribution of MNE activity in the United States, especially in manufacturing, professional and scientific services, and retail trade. For example, manufacturing makes up the largest portion of both MNE value added and immigrant employment, highlighting the industry's dual dependence on migrant labor and global capital. Professional services also play a major role in skilled migrant employment and MNE productivity. However, sectors like healthcare and social assistance, which have the largest share of foreign-born workforce, are less represented in MNE activity, because they are more domestically oriented. Conversely, finance and insurance, which are capital-intensive and central to MNE profits, employ relatively few immigrants. This illustrates a divergence between capital flows and labor composition. These patterns show how MNE presence and immigration shape industry dynamics in both overlapping and distinct ways.

7. The causal impact of immigration on bilateral trade flows

In this section, I utilize a panel dataset of immigration and trade with 116 countries from 2004 to 2018 as used in Ref. [37]. Immigration in this exercise is measured by the foreign-born population in the United States, and data are from the US Census Bureau's American Community Survey (ACS) 1-Year Estimates Public Use Microdata Sample. According to the gravity model, control variables include GDP and population figures for both the United States and the countries of origin, as well as the geographic distance between the United States and each origin country. These variables are obtained from the gravity database compiled by the Research and Expertise on the World Economy (CEPII). Bilateral trade data, including exports and imports between the United States and each origin country, are collected from the United Nations Comtrade Database (UN-WITS).

To estimate the causal impact of immigration on US trade with origin countries, I first use a fixed effect panel OLS:

$$\log(\text{Trade}_{it}) = \beta \cdot \log(\text{Imm}_{it}) + X'_{it}\theta + \delta_i + \delta_t + \varepsilon_{it} \quad (1)$$

where

- $\log(\text{Imm}_{it})$ denotes immigration from origin country i to the United States in year t .
- Trade_{it} is either US exports to country i , or US imports from country i .
- X_{it} is a vector of control variables, such as the GDP and population.
- θ is the corresponding coefficient vector for X_{it} .
- δ_i and δ_t are country and year fixed effects, respectively.
- ε_{it} is the error term.

Using panel OLS with country and year fixed effects, we find that immigration from the origin country i to the United States significantly increases both imports and

	Import regression	Export regression
Dependent Var	log(Import)	log(Export)
log(Imm _{it})	1.096 *** (0.114)	0.649 *** (0.085)
log(GDP, US)	-0.121 (0.103)	0.245 ** (0.076)
log(Population, US)	-0.461 (0.346)	0.271 (0.253)
Observations	1694	1699
Adj. R ²	0.9836	0.9849
Within R ²	0.4091	0.3937

Notes: Clustered standard errors in parentheses.
 Origin-country GDP and population were excluded due to collinearity with country fixed effects.
 Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4.
 Panel OLS estimates of the impact of immigration on trade.

exports between the United States and that country. As shown in **Table 4**, the estimated elasticity of imports with respect to immigration is 1.10, implying that a 1% increase in immigration is associated with a 1.10% increase in US imports from that country. Similarly, for exports, the elasticity is 0.65, indicating a 0.65% increase in US exports for every 1% rise in immigration. These results suggest a strong positive trade-immigration linkage.

While the panel OLS results reveal a strong positive association between immigration and bilateral trade, this approach may be subject to endogeneity concerns. Thus, I also employ a two-stage least squares (2SLS) strategy using a Bartik (shift-share) instrument to strengthen causal interpretation. In the first stage, immigration from country i to the United States in year t is regressed on a Bartik instrument. The Bartik instrument is constructed by scaling the base-year immigrant stock from country i by the national growth in total US immigration. It isolates plausibly exogenous variation in immigration driven by national-level immigration shocks and historical settlement patterns, so it helps address endogeneity concerns. The second stage estimates the effect of predicted immigration on US bilateral trade with country i . Both regressions include country and year fixed effects and control for origin-country characteristics to ensure robust identification of the causal effect.

First stage: Predict immigration

$$\text{Immigration}_{it} = \lambda \cdot \text{Bartik}_{it} + X'_{it}\theta + \delta_i + \delta_t + u_{it} \quad (2)$$

Second stage: Impact on trade

$$\text{Trade}_{it} = \beta \cdot \hat{\text{Immigration}}_{it} + X'_{it}\gamma + \delta_i + \delta_t + \varepsilon_{it} \quad (3)$$

where

- i indexes origin countries and t indexes years.
- Immigration_{it} is the observed number of immigrants from country i to the United States in year t .

- Bartik_{it} is the predicted immigration from country i using the shift-share instrument.
- $\widehat{\text{Immigration}}_{it}$ is the fitted value from the first stage.
- Trade_{it} is either US exports to country i , or US imports from country i .
- X_{it} is a vector of control variables.
- δ_i and δ_t are country and year fixed effects.
- u_{it} and ε_{it} are error terms.
- All variables are log-transformed in the regression specification.

Using two alternative Bartik constructions serves as a robustness check, allowing me to assess the sensitivity and consistency of the results across different instrumental variable strategies. The two versions of the Bartik instrument to predict immigration from each origin country to the United States. The first is the growth-based Bartik, which combines each country's initial immigrant share in 2004 with the annual growth in immigration from all other countries. This approach captures how global immigration shocks, excluding the country of interest, influence its immigration to the United States. The second is the level-based Bartik, which instead combines the same initial immigrant share with the total level of immigration from other countries in each year, not just the change. Both instruments aim to isolate exogenous variation in immigration from each country.

7.1 Growth-based Bartik instrument

Let $\text{Imm}_{i,2004}$ denote the number of immigrants from origin country i in the United States in the year 2004. The share of immigrants from origin i is computed as:

$$\text{ImmShare}_{i,2004} = \frac{\text{Imm}_{i,2004}}{\sum_i \text{Imm}_{i,2004}} \quad (4)$$

Let $\text{Imm}_{i,t}$ denote the total immigrant inflow from origin i to the United States in year t . The annual change in immigrant inflow from country j is:

$$\Delta \text{Imm}_{j,t} = \text{Imm}_{j,t} - \text{Imm}_{j,t-1}. \quad (5)$$

Next, define the national-level change in immigrant inflows *excluding origin* i as:

$$\Delta \text{Imm}_{-i,t} = \sum_{j \neq i} \Delta \text{Imm}_{j,t}. \quad (6)$$

The Bartik instrument for origin country i in year t is constructed by interacting the immigrant stock from i in 2004 with the aggregate immigration shock from all other countries:

$$\text{Bartik}_{it}^{\text{growth}} = \text{ImmShare}_{i,2004} \times \Delta \text{Imm}_{-i,t}$$

7.2 Level-based Bartik instrument

Let $Imm_{i,2004}$ denote the number of immigrants from origin country i residing in the United States in 2004. The share of immigrants from origin i is given by:

$$ImmShare_{i,2004} = \frac{Imm_{i,2004}}{\sum_i Imm_{i,2004}}.$$

Let $Imm_{i,t}$ denote the immigration inflow from origin i to the United States in year t , and Imm_t the total immigration inflow to the United States in year t . Then immigration from all other origins is:

$$Imm_{-i,t} = Imm_t - Imm_{i,t}.$$

The level-based Bartik instrument for origin i in year t is constructed as:

$$Bartik_{it}^{level} = ImmShare_{i,2004} \times Imm_{-i,t}.$$

In the first stage, both the growth-based and level-based Bartik yield a statistically significant coefficient on the instrument, according to **Tables 5** and **6**. The negative sign indicates that growth in immigration from other countries is negatively correlated with immigration from i , possibly due to substitution effects or competition in migrant inflows. In the second stage, both instruments indicate a positive and statistically significant effect of immigration on trade. For imports, the estimated elasticity using the growth-based Bartik instrument is 1.07, while the level-based Bartik yields a comparable estimate of 1.16. This implies that a 1% increase in immigration from country i to the United States is associated with approximately a 1.07% increase in US imports from that country under the growth-based specification, and a 1.16% increase under the level-based specification. For exports, the estimated elasticities are 0.51 and 0.66, respectively, indicating that immigration also has a positive and economically meaningful effect on US exports to origin countries.

	First stage	Second stage: import	Second stage: export
Dependent Var	log(Imm)	log(Import)	log(Export)
$\log(Bartik_{it}^{growth})$	-0.280** (0.106)	—	—
$\log(Imm_{it})$	—	1.073** (0.384)	0.508** (0.165)
$\log(GDP, US)$	0.464*** (0.102)	-0.163 (0.239)	0.338** (0.110)
$\log(Population, US)$	-0.688* (0.328)	-0.631 (0.575)	0.203 (0.418)
Observations	1243	1243	1243
Adj. R ²	0.9879	0.9737	0.9862
Within R ²	0.0920	0.0275	0.1377

Notes: Clustered standard errors in parentheses.

GDP and population for country i are excluded because they are absorbed by country fixed effects.

Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5.
 IV regression results using growth-based Bartik instrument.

	First stage	Second stage: import	Second stage: export
Dependent Var	log(Imm)	log(Import)	log(Export)
$\log(\text{Bartik}_{it}^{\text{level}})$	-13.89* (6.95)	—	—
$\log(\text{Imm}_{it})$	—	1.164* (0.565)	0.661* (0.282)
$\log(\text{GDP, US})$	0.386*** (0.109)	-0.151 (0.330)	0.241* (0.143)
$\log(\text{Population, US})$	-0.616 (0.324)	-0.413 (0.653)	0.268 (0.412)
Observations	1694	1694	1694
Adj. R ²	0.9866	0.9733	0.9850
Within R ²	0.1024	0.0372	0.1292

Notes: Clustered standard errors in parentheses.
 GDP and population for country *i* are excluded because they are absorbed by country fixed effects.
 Significance: ****p* < 0.01, ***p* < 0.05, **p* < 0.1, *p* < 0.1.

Table 6.
 IV regression results using level-based log Bartik instrument.

These findings imply that immigration enhances bilateral trade, especially by promoting US imports to origin countries. Moreover, the similarity of the trade elasticities estimated using both the growth-based and level-based Bartik instruments—with import elasticities of 1.07 and 1.16, respectively—suggests that the results are robust to alternative instrument constructions. This consistency across two distinct

	log(Import)	log(Export)
<i>Growth-based Bartik instrument</i>		
Observations	1243	1243
$\log(\text{Imm}_{it})$	1.123*** (0.094)	0.420* (0.233)
First-stage F-stat	6.59	6.59
Wu-Hausman p-value	0.933	0.406
Adj. R ² (second stage)	0.9827	0.9900
Within R ²	0.3613	0.3756
<i>Level-based Bartik instrument</i>		
Observations	1694	1694
$\log(\text{Imm}_{it})$	1.081*** (0.055)	0.798*** (0.136)
First-stage F-stat	81.8	81.8
Wu-Hausman p-value	0.985	0.181
Adj. R ² (second stage)	0.9834	0.9905
Within R ²	0.4023	0.4501

Notes: Clustered standard errors in parentheses. Significance: ****p* < 0.01, ***p* < 0.05, **p* < 0.1.
 The Wu-Hausman test evaluates the endogeneity of immigration. First-stage F-stat >10 indicates a strong instrument.

Table 7.
 IV estimates of immigration’s effect on trade: growth-based vs. level-based Bartik.

identification strategies reinforces the credibility of the findings and indicates that the observed positive impact of immigration on trade is not driven by a particular specification of the instrumental variable, but rather reflects a stable and economically meaningful relationship.

Given that the first-stage F-statistic for the two-stage IV estimation using the Bartik instrument was below the conventional threshold of 10, I proceed with the one-step IV estimation. This approach estimates both stages simultaneously within a single regression framework, allowing for correctly adjusted standard errors and enabling formal tests of instrument strength and endogeneity, such as the first-stage F-test and the Wu-Hausman test. According to **Table 7**, using the level-based Bartik instrument, the estimated elasticity of imports with respect to immigration is 1.08, indicating that a 1% increase in immigration from country *i* leads to a 1.08% increase in US imports from that country. For exports, the immigration elasticity is estimated at 0.80, also statistically significant at the 1% level, suggesting that immigration significantly promotes US exports to origin countries. In addition, the level-based Bartik shows strong first-stage relevance ($F = 81.8$), while the growth-based Bartik is a weak instrument ($F = 6.6 < 10$). Though immigration has a positive and significant effect on both imports and exports, estimates are more precise and robust with the level-based instrument. Moreover, Wu-Hausman tests suggest no significant endogeneity in immigration (p-values > 0.1), but IV is still preferred for causal interpretation.

8. Conclusion

Economic globalization, changing demographics, and the expansion of legal and educational pathways have all contributed to the growth in both the scale and complexity of global labor mobility. The number of international migrants has nearly doubled since 1990, with Europe and Asia leading the increase in absolute terms. The United States remains the largest single destination, but other countries, including Germany, Saudi Arabia, and the United Kingdom, have also experienced significant migrant inflows.

In addition to addressing labor shortages, immigrants increasingly contribute as entrepreneurs and business founders, particularly in high-growth, innovation-driven sectors. Their overrepresentation among startups and venture-backed firms underscores their role in driving job creation, technological advancement, and economic dynamism. At the same time, international student migration has become a crucial means of human capital transfer, particularly from countries like China and India to leading education destinations in the United States, the United Kingdom, and Australia. These trends show that migration is becoming more important for maintaining economic competitiveness, balancing demographics, and strengthening global connections.

To support these broader insights with data, the chapter also provides new empirical evidence on the causal relationship between immigration and trade. Using instrumental variable techniques based on alternative Bartik instruments, the analysis shows that immigration significantly increases both imports and exports between the United States and migrants' origin countries.

These findings have some important takeaways for policy. Immigration should not just be seen as a way to fill labor gaps or manage borders, but it is also a powerful tool for driving economic growth and boosting global trade. By making it easier for both low- and high-skilled workers to move across borders, countries can improve their

international competitiveness, support innovation, and strengthen trade ties with the rest of the world. Policies that attract and retain immigrant talent, such as more efficient visa processes, support for immigrant entrepreneurs, and clearer pathways from education to employment, can have big payoffs. They help grow the economy, increase productivity, and make countries more connected and competitive in the global market.

Future research should explore the long-term impacts of immigration on trade and investment, particularly at the firm and sectoral levels, to better understand how migrant labor shapes global business over time. There is also a need to examine policy shocks and natural experiments to more precisely identify causal effects. Additionally, as the global economy becomes increasingly digital, future work should examine how digitalization, remote work, and the rise of AI-driven technologies are reshaping labor mobility, trade in services, and cross-border economic activity. AI has the potential to both complement and substitute for migrant labor, especially in sectors like manufacturing and customer service, while also creating new opportunities for high-skilled migration in fields such as data science and AI development. These shifts may alter the scale, direction, and nature of global labor mobility, raising new questions about the role of labor migration in economic integration.

Conflict of interest

The authors declare no conflict of interest.

Additional information


JEL Classification: F22, J16, J11, F24, F15, F16, F23.

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References

- [1] Feyrer J. Demographics and productivity. *The Review of Economics and Statistics*. 2007;**89**(1):100-109
- [2] Maestas N, Mullen KJ, Powell D. The effect of population aging on economic growth, the labor force, and productivity. *American Economic Journal: Macroeconomics*. 2023;**15**(2): 306-332
- [3] Kerr SP, Kerr WR, Lincoln WF. Skilled immigration and the employment structures of US firms. *Journal of Labor Economics*. 2015;**33**(S1):S147-S186
- [4] Kerr SP, Kerr W. Immigrant entrepreneurship in America: Evidence from the survey of business owners 2007 & 2012. *Research Policy*. 2020;**49**(3): 103918
- [5] Azoulay P, Jones BF, Daniel Kim J, Miranda J. Immigration and entrepreneurship in the United States. *American Economic Review: Insights*. 2022;**40**(1):71-88
- [6] Hunt J, Gauthier-Loiselle M. How much does immigration boost innovation? *American Economic Journal: Macroeconomics*. 2010;**2**(2):31-56
- [7] Hunt J. Which immigrants are most innovative and entrepreneurial? Distinctions by entry visa. *Journal of Labor Economics*. 2011;**29**(3):417-457
- [8] Peri G, Sparber C. Task specialization, immigration, and wages. *American Economic Journal: Applied Economics*. 2009;**1**(3):135-169
- [9] Borjas GJ. The labor demand curve is downward sloping: Reexamining the impact of immigration on the labor market. *The Quarterly Journal of Economics*. 2003;**118**(4):1335-1374
- [10] Ottaviano GIP, Peri G. Rethinking the effect of immigration on wages. *Journal of the European Economic Association*. 2012;**10**(1):152-197
- [11] Card D. Is the new immigration really so bad? *The Economic Journal*. 2005;**115**(507):F300-F323
- [12] Dustmann C, Frattini T, Preston IP. The effect of immigration along the distribution of wages. *Review of Economic Studies*. 2013;**80**(1):145-173
- [13] Adams RH Jr, Page J. Do international migration and remittances reduce poverty in developing countries? *World Development*. 2005;**33**(10):1645-1669
- [14] Combes J-L, Ebeke C. Remittances and household consumption instability in developing countries. *World Development*. 2011;**39**(7):1076-1089
- [15] Yang D. International migration, remittances and household investment: Evidence from Philippine migrants' exchange rate shocks. *The Economic Journal*. 2008;**118**(528):591-630
- [16] Chami RCF, Jahjah S. Are immigrant remittance flows a source of capital for development? *IMF Staff Papers*. 2005;**52**(1):55-81
- [17] Head K, Ries J. Immigration and trade creation: Econometric evidence from Canada. *Canadian Journal of Economics*. 1998;**31**(1):47-62
- [18] Gould DM. Immigrant links to the home country: Empirical implications for US bilateral trade flows. *The Review of Economics and Statistics*. 1994;**76**(2): 302-316
- [19] Rauch JE, Trindade V. Ethnic Chinese networks in international trade.

Review of Economics and Statistics. 2002;**84**(1):116-130

[20] Casella A, Rauch JE. Anonymous market and group ties in international trade. *Journal of International Economics*. 2002;**58**(1):19-47

[21] Hatzigeorgiou A. Does immigration stimulate foreign trade? Evidence from Sweden. *Journal of Economic Integration*. 2010;**25**(2):376-402

[22] Bandyopadhyay S, Coughlin CC, Wall HJ. Ethnic networks and US exports. *Review of International Economics*. 2008;**16**(1):199-213

[23] Iranzo S, Peri G. Migration and trade: Theory with an application to the Eastern–Western European integration. *Journal of International Economics*. 2009;**79**(1):1-19

[24] Ottaviano GIP, Peri G, Wright GC. Immigration, trade and productivity in services: Evidence from UK firms. *Journal of International Economics*. 2018;**112**(1):88-108

[25] Gandal N, Hanson GH, Slaughter MJ. Technology, trade, and adjustment to immigration in Israel. *European Economic Review*. 2004;**48**(2):403-428

[26] Peri G, Requena-Silvente F. The trade creation effect of immigrants: Evidence from the remarkable case of Spain. *Canadian Journal of Economics/Revue canadienne d'économique*. 2010; **43**(4):1433-1459

[27] Wagner D, Head K, Ries J. Immigration and the trade of provinces. *Scottish Journal of Political Economy*. 2002;**49**(5):507-525

[28] Herander MG, Saavedra LA. Exports and the structure of immigrant-based networks: The role of geographic

proximity. *Review of Economics and Statistics*. 2005;**87**(2):323-335

[29] White R. Immigrant-trade links, transplanted home bias and network effects. *Applied Economics*. 2007;**39**(7): 839-852

[30] Mundra K. Immigration and Trade Creation for the U.S.: The Role of Immigrant Occupation. IZA Discussion Papers 7073. Institute of Labor Economics (IZA); 2012

[31] Javorcik BS, Özden Ç, Spatareanu M, Neagu C. Migrant networks and foreign direct investment. *Journal of Development Economics*. 2011;**94**(2):231-241

[32] Bound J, Braga B, Golden JM, Khanna G. Recruitment of foreigners in the market for computer scientists in the United States. *Journal of Labor Economics*. 2015;**33**(S1):S187-S223

[33] Kugler M, Rapoport H. International labor and capital flows: Complements or substitutes? *Economics Letters*. 2007;**94**(2):155-162

[34] Dustmann C, Glitz A, Vogel T. Employment, wages, and the economic cycle: Differences between immigrants and natives. *European Economic Review*. 2010;**54**(1):1-17

[35] Flisi S, Murat M. The hub continent. Immigrant networks, emigrant diasporas and FDI. *The Journal of Socio-Economics*. 2011;**40**(6):796-805

[36] Docquier F, Lodigiani E. Skilled migration and business networks. *Open Economies Review*. 2010;**21**:565-588

[37] Shao C. International trade, immigration and macroeconomic dynamics. In: Working Paper 4807929. SSRN (Social Science Research Network); 2025. DOI: 10.2139/ssrn.4807929

Section 2

Sustainable Business Practices

Chapter 3

Interrelation of Sustainability Indicators and Sustainable Solutions in Road Freight Transportation: A Review of Innovative Practices and Implementation Challenges

Elena Kaledinova and Ngoc Bao Tran

Abstract

The transition to sustainable road freight transportation is a complex process, whereas comprehensive knowledge about sustainability indicators (SIs), corresponding solutions and recommendations, and challenges in implementing SIs becomes crucial. The research and review articles were selected using the semi-systematic literature review method and then analysed considering their relevance to the topic of this study. The authors created an overview of SIs and corresponding sustainable solutions categorised by sustainability domains, discussed the sustainability improvement cycle (SIC) and challenges in implementing SIs, and outlined future research directions focusing on the practical application of SIs in road freight transportation. This research is vital to understanding the interrelations of SIs and sustainable solutions and their importance for the company sustainability improvement cycle.

Keywords: road freight transportation, sustainability indicators, transportation sustainability, sustainable solutions in transportation, sustainability improvement cycle, semi-systematic review

1. Introduction

The review highlights sustainability indicators and sustainable solutions described in academic articles to enhance the sustainable transformation of road freight transportation companies. Transitioning to sustainable transportation is crucial for reducing greenhouse gas emissions (GHGs) and achieving other sustainability goals. Although numerous SIs and sustainable innovative practices are already described in academic articles, substantial barriers remain, particularly in implementing and using SIs at companies. The research aims to provide stakeholders in the road freight transportation sector, such as policymakers, decision-makers, and scholars, with overviews of sustainable solutions related to specific SIs and challenges in implementing SIs. The authors discuss the company sustainability improvement cycle

emphasising the relevance of SIs and sustainable solutions to this cycle, and provide an example of how to apply this cycle at a company (the Review section).

Sustainability is an integral concept encompassing the relationships between economic activities, society, and ecology. The United Nations (UN) formulated the sustainable development goals (SDGs) to address urgent global environmental, political, and economic challenges facing our world [1]. The 'Climate Action' goal aims to mitigate human-induced climate change. According to the United Nations [2], the transportation sector still relies on fossil fuels, contributing to a quarter of global greenhouse gas emissions. These emissions are expected to rise, exacerbating climate change that involves rising temperatures, melting ice and snow, ocean acidification, extreme weather events, changes in ecosystems, etc. There is a need to incorporate strategies for preventing climate change directly into economic activities and to use reliable and valid measurements of air quality (e.g., measuring CO₂ or other emissions) in various economic sectors, including transportation. Other aspects of sustainability also play an important role in the sustainable development of road freight transportation. A good example of this is social sustainability, which involves such indicators as employment opportunities, safety practices (e.g., regular vehicle maintenance), government regulations, training and development (e.g., regular training in traffic and driving management), and others [3].

The significance of sustainability indicators is that they measure the current performance and provide businesses with the data needed to improve sustainability. Besides that, they can help with decision-making when it comes to selecting solutions enhancing sustainability. While the transportation sustainability topic was discussed in numerous studies, some aspects are still to be investigated, such as the interrelation of SIs and sustainable solutions and mapping out challenges in implementing SIs. Sustainability indicators and sustainable solutions can be used in a company sustainability improvement cycle (SIC). SIs assess the company's sustainable performance and help identify areas requiring improvement. For example, carbon emissions can indicate air quality issues. Sustainable solutions such as optimising routes or choosing fuel-efficient vehicles can be developed/identified and then adopted to solve the air quality issues. The reassessment should be done after a while to determine the effectiveness of these solutions. It may happen that new adjustments should be done to further improve air quality. In this way, SIs and sustainable solutions interact with each other. Thus, the whole sustainability improvement cycle includes five phases that can be continuously repeated: (1) assessment using SIs; (2) development/identifying sustainable solutions; (3) adoption of sustainable solutions; (4) reassessment using SIs; and (5) adjustment of solutions to address remaining issues. This cycle helps understand how SIs and sustainable solutions interact with one another and can be applied to improve a company's sustainability.

Road freight transportation companies can use SIs to measure their progress towards sustainability, so it is important to identify relevant SIs that already exist. This study provides overviews of SIs, sustainable solutions and recommendations, and challenges in implementing SIs at road freight transportation companies (the Review section). Traditionally, sustainability has environmental, economic, and social domains, but they do not allow comprehensively assessing transportation sustainability, and there is the need to incorporate additional domains [4]. The overview of SIs and sustainable solutions is based on information from scientific articles or reports and considers five sustainability domains: environmental, economic, social, technological development, and sustainability governance.

The study focuses on the following: (1) identifying the interrelation of SIs and sustainable solutions and recommendations; (2) outlining challenges in the context of

implementing SIs and sustainable solutions; and (3) discussing the gaps and opportunities for future research directions.

The study objective is to review articles and reports on SIs and sustainable solutions enhancing road freight transportation sustainability and highlight relationships between them, so research questions are formulated as follows: (1) What are the existing SIs? (2) What is the interrelation of SIs and sustainable solutions, and how can they be applied in the sustainability improvement cycle? (3) What are the challenges in implementing sustainability indicators?

The research questions are answered in the Discussion section.

2. Methodology

The study thoroughly examines the literature by conducting a semi-systematic literature review that offers a structured approach to the reviewing process while providing greater flexibility in considering a broader range of articles. According to Snyder [5], this approach is helpful and appropriate for overviews research areas, tracking development over time, and synthesising the state of knowledge. Snyder suggests four phases in conducting a literature review independent of the approach used (systematic, semi-systematic, or integrative): (1) designing the review (search strategy for identifying relevant articles); (2) conducting the review; (3) analysis; and (4) writing up the review. **Figure 1** shows these phases specifically for the article's focus.

The four phases are described in the 'Search strategy, conducting the review and analysis' and 'Review' sections below.

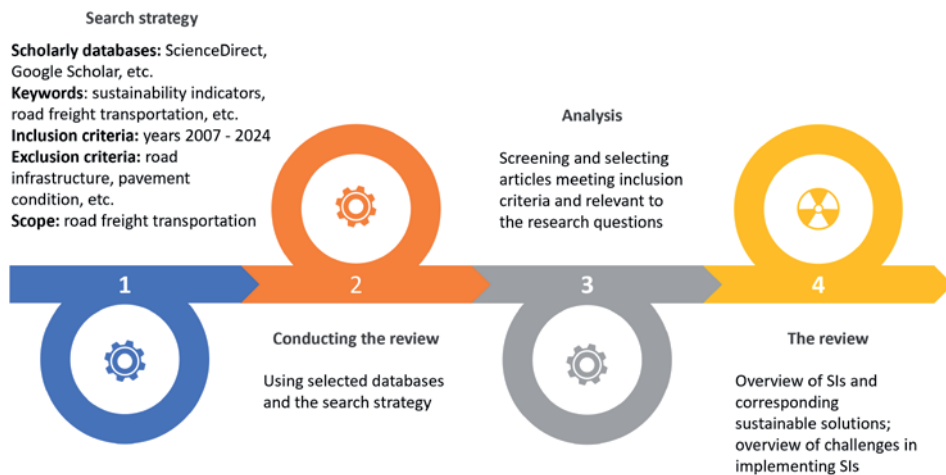


Figure 1. A semi-systematic review of SIs and sustainable solutions in road freight transportation (made by the authors based on the approach of Snyder [5]).

3. Search strategy, conducting the review and analysis

The search strategy of the semi-systematic literature review implies the selection of databases, search terms, inclusion and exclusion criteria, and scope and limitations [5].

The general search strategy in this study is identified as follows:

1. Scholarly databases: ScienceDirect, Google Scholar, ResearchGate, MDPI, OECD and UN digital libraries, Wiley, etc.
2. Search terms and keywords: sustainability indicators, sustainability assessments, road freight transportation, transportation sustainability, challenges in implementing sustainability indicators.
3. Inclusion criteria for including articles in the review: (1) publication date: from 2007 to 2024; (2) relevance: articles or reports related to sustainability indicators and sustainable solutions in road freight transportation.
4. Exclusion criteria: road infrastructure, pavement condition, public transportation.
5. Scope and limitations: (1) economic sector: road freight transportation; (2) the lack of studies in the field of the practical application of SIs in road freight transportation.

The search strategy in the semi-systematic literature review may or may not be systematic [5]. This means that the choice of some articles relevant to the study topic can be based on the research questions.

The ‘Conducting the review’ phase involves using selected databases and searching for relevant articles according to the search strategy. The authors used the ScienceDirect, Google Scholar, ResearchGate, MDPI, OECD and UN digital libraries, Wiley, and other databases and considered the search terms ‘*sustainability indicators*’, ‘*sustainability assessments*’, ‘*road freight transportation*’, ‘*transportation sustainability*’ and ‘*challenges in implementing sustainability indicators*’ to ensure that articles or reports relevant for the study topic and research questions will be included. The authors considered publications from 2007 to 2024 and the following types of studies: research articles, review articles, and reports. The search process resulted in a sample of over two hundred articles.

The ‘Analysis’ phase (**Figure 1**) involves screening and selecting articles meeting inclusion criteria and relevant to the research questions. It is found that the sustainability indicators in research and review articles represent different sustainability domains and vary depending on the focus points of the authors and the types of assessments (single indicators or composite indices). The authors of this study also used reports of European Union and United Nations commissions discussing road freight transportation sustainability. The authors identified 23 of the most common sustainability indicators in road freight transportation, collected information about solutions and recommendations related to SIs (**Table 1**), categorised them by five sustainability domains, and identified challenges in implementing SIs (**Table 2**). **Tables 1** and **2** are included in the Review section below.

4. Review

The 56 articles and reports selected after screening provide valuable information about indicators for measuring the companies’ transition to sustainable performance, sustainable solutions and recommendations, and challenges in implementing SIs. The authors created an overview of the most common SIs in road freight transportation and sustainable solutions and recommendations related to specific SIs, categorising them by sustainability domains (**Table 1**).

#	Sustainability indicator	Sustainable solutions and recommendations
I. Environmental sustainability		
1	CO ₂ emissions (measuring the carbon footprint of freight operations)	French freight carriers can obtain compliance certification after an independent audit if carbon dioxide (CO ₂) emissions have been reduced during three consecutive years; carriers should be obliged to calculate their CO ₂ impact; freight carriers should adhere to the ISO 14001 standard that requires taking proactive measures to minimise their environmental footprint [6]. Evaluation of the amount of CO ₂ a vehicle produces [7].
2	Fuel consumption (measuring fuel efficiency of vehicles)	Setting targets for fuel consumption reduction; monitoring fuel consumption with telematics devices [6]. Improvement in vehicle fuel efficiency [7].
3	Emission standards (ensuring compliance with emission standards)	Adaptation to EURO 6 fuel quality standards introduced by the European Union [8] to reduce harmful emissions from vehicles [9]. Adaptation to the EURO 7 standard aims at cleaner vehicles and improved air quality. This standard limits various pollutants, including tyre abrasion emissions, particulate matter, and other harmful emissions [10]. The Euro 7 standard replaces the current Euro 6 standard and comes into effect on the 1st of July 2025.
4	Driver behaviour (monitoring and improving driving practices)	Measuring driver performance and vehicle efficiency by remotely monitoring speed, braking, gear-shifting, idle time, and out-of-route miles [11].
5	Logistical efficiency (optimising route planning and load management)	Reducing long-distance freight travel through improving production efficiency [12]. Intermodal transport can positively influence environmental performance [13]. Applying sustainability in Logistics Index for a quick assessment of the transportation activities of a company throughout using sustainability metrics such as CO ₂ emissions, route optimisation, vehicle utilisation, number of trips, etc. [14]. Promoting intermodality in freight transport [15].
6	Noise pollution (measuring and mitigating noise level)	Using market-based regulations (e.g., cap and trade, incentives) helps reduce noise in the production stage of road vehicles. The European Environmental Noise Directive 2002 [16] required and supported the development of systematic methods to monitor, map, and plan for noise abatement [17].
7	Air quality (assessing the impact on local air quality)	After the introduction of vehicle emission standards in Europe [18], manufacturers had to introduce a range of engine and fuel system design options with exhaust emission controls (diesel particulate filters (DPFs), selective catalytic reduction (SCR), etc.) to meet the standards. Carrying out tests to maintain air quality, such as vehicle steady-state tests for heavy-duty vehicles and in-service tests for light-duty vehicles [19].
8	Energy consumption (measuring total energy use in road freight operations)	Use of the Avoid-Shift-Improve framework: (1) Avoid the need for travel; (2) Shift to more energy-efficient modes; (3) Improve efficiency through vehicle technology [20]. Measuring the energy efficiency of the road freight transport sector in EU countries using the Data Envelopment Analysis (DEA) method [7]. Smart grids and IoT-enabled devices can dynamically manage electricity distribution and promote the integration of renewable energy sources [21]. IoT stands for Internet of Things. Implementing the Industry 4.0 concept to reduce energy consumption [22]. The Industry 4.0 (the fourth industrial revolution) concept refers to integrating digital technologies to create more efficient and automated processes.

#	Sustainability indicator	Sustainable solutions and recommendations
9	Load factor (measuring the efficiency of load utilisation)	Using SIs such as volume optimisation (target 80% of truck capacity or higher) and double-deck loading [6]. Setting weight limits for vehicles [23].
10	Modal shift (encouraging a shift to more sustainable transport modes)	Using hybrid electric vehicles (HEV) and plug-in hybrid vehicles (PHEV) [24]. Development of policies for mandatory electric vehicle (EV) usage [9]. Using rail travel to reduce highway traffic load [25]. Amending regulations on alternative fuel infrastructure to increase its capacity [7]. Countries should introduce incentive policies to stimulate the adoption of electric/low-carbon vehicles [21].
11	Renewable energy use (measuring the use of renewable energy sources)	Implementing low-carbon fuel such as bioethanol or biodiesel to reduce greenhouse gas (GHG) emissions [24]. The renewable fuel standards (RFS) enacted in 2005 in the US set the minimum level of annual biofuel consumption to be blended into transportation fuel up to 2022 [26].
12	Waste management (monitoring and reducing waste generated by road freight operations)	Application of reverse logistics, for example, reuse of packaging [27]. Reducing fuel waste through green transport practices such as route optimisation, fleet renewal, fuel efficiency, etc. [28]. Application of the Industry 4.0 concept aimed at reducing the number of materials used, increasing the share of reused, recovered, and recycled materials, as well as reducing the total amount of waste [22].
13	Land use (assessing the impact of road freight operations on land use)	The implementation of the ‘increased density’ or ‘proximity’ principle. This principle means that shorter travel distances result in reduced land and energy requirements [29]. Creating patterns of land use to reduce trip lengths and encourage journeys to be made with the most sustainable modes. This can be determined via (1) settlement size, (2) strategic development location, (3) strategic transport network, (4) mixed land use, and (5) urban realm design and layout [19]. Using road freight transport connectivity (the seamless movement of freight across regions supported by infrastructure, policies, etc.) to enhance sustained economic growth, supply chain efficiency, and transport system resilience [13].
14	Biodiversity impact (measuring the impact on local biodiversity)	Local legislation on environmental impact assessment needs to meet the international requirements on biodiversity conservation formulated by the European Commission in 2001; use of the models for calculation of the spread of pollutants from roads for current and newly projected roads [30]. Road pre-construction planning, habitat connectivity, road permeability, financial expense, and post-implementation monitoring should be considered for biodiversity conservation; Road menders take photos of road-killed animals and send them to professionals for identification; Studies on the correlation between natural habitat and road presence; Wildlife crossing structures (planning in the early stages of new road construction projects); Installation of wildlife fences for safety; Introduction of Habitat Suitability indices [25]. Using electrified barriers to deter black bears from entering fenced roads in the US; Identification of collision hotspots, applying warning signs [31].
II. Economic sustainability		
15	Economic efficiency (assessing the economic efficiency of road freight operations)	The sustainability assessment of road infrastructure projects should prioritise the inclusion of indicators that can secure natural and environmental capital and manage its long-term changing state [32]. Balancing economic growth with environmental protection [33].

#	Sustainability indicator	Sustainable solutions and recommendations
16	Climate resilience (assessing the resilience of freight operations to climate change)	Developing adaptation strategies to improve road freight resilience against the effects of climate change (e.g., using cool pavements to respond to heat waves, using fast communication and information technologies for fire safety, etc.) [34].
17	Resource efficiency (measuring the efficiency of resource use in road freight operations)	Using an Excel-based calculator (the Sustainability Enhancement Tool) to quantify the performance measures and assess sustainability [35]. Development of smart charging infrastructure for electric vehicles [21].
III. Social sustainability		
18	Social impact (measuring the social impact of road freight operations)	Reduction in car ownership and usage; Increase in use of telecommunications instead of physical travel [12]. Increasing vehicle-restricted areas in public places [19]. Computing the social sustainability index based on 74 social sustainability attributes (employment opportunities, safety practices, training and development, etc.) to assess the freight transportation social sustainability [3]. Shared mobility platforms, remote work, and digital communication [21]. Optimisation of freight vehicle deliveries to end consumers by using pick-up (lockers) systems [36].
19	Safety (Monitoring and improving safety measures)	Developing effective safety measures and policies [37]. Introducing accelerated fleet turnover programmes that stimulate the use of newer vehicles, likely ensuring safety and road transport sustainability; Funding for mass transit, compact urban development, traffic management, and mode-shifting freight [38].
IV. Technological development		
20	Technological development in the transportation sector (the adoption of new technologies)	IT innovations: sophisticated engines; computers to measure fuel efficiency; computerised routing and scheduling software with global positioning systems (GPS); and tracking adverse weather or traffic conditions [11]. The implementation of truck platooning involves linking multiple trucks in a convoy using connected vehicle technology. Once connected, the trucks maintain a predefined distance between each other for as long as they are connected. The front truck takes the lead, and the connected trucks react automatically to changes in the movement of the front truck with minimal to no intervention from the drivers following the front truck [39]. Applying a weight-in-motion system that improves the efficiency of traditional weight stations by installing sensors along highways and at strategic locations along the transport network. This helps speed up the process of weighing truck cargo and reduces freight vehicle queues/congestion (e.g., data is transferred to multiple dedicated weight stations). Furthermore, advances in satellite navigation provide real-time information on vehicle location and what is loaded in the vehicles, estimating arrival times and improving overall efficiency [13]. Using paperless solutions (e.g., electronic bill payments) [11]. Integrating blockchain technology to improve sustainability: case study Walmart Food Supply Chain and IBM Food Trust [40]. Encouraging the use of clean energy and innovative technologies in transportation that can help reduce pollutant emissions and promote environmental sustainability [33]. The integration of predictive models and Artificial Intelligence (AI) in preventing wildlife-vehicle collisions (WVC), processing data collected from camera traps with deep learning algorithms to detect and identify species near linear transport [31].

#	Sustainability indicator	Sustainable solutions and recommendations
21	Technology adoption assessment (assessing the adoption of new technologies)	Using the transportation technology sustainability index (TTSI) to assess the impact of artificial intelligence (AI) on transportation sustainability [41]. Assessing and guiding the adoption of information and communication technologies (ICTs) to support road freight transportation management, including fleet management, pollutant emission monitoring, and vehicle routing [42].
V. Sustainability governance		
22	Policy compliance (ensuring compliance with relevant policies and regulations)	US Corporate Average Fuel Economy (CAFE) and similar regulations in other countries drive technology progress and pressure the automakers to shift the fleet mix to smaller and more fuel-efficient vehicles [26]. Using data envelopment analysis (DEA) to calculate and compare the road transport sustainability performance of EU countries, the results can be used for benchmarking and improvement in underperforming countries [43]. Adopting transportation policy to reduce greenhouse gas emissions and promote clean transportation in EU countries; removal of tax breaks for fossil fuels [7].
23	Stakeholder engagement (measuring the level of stakeholder engagement)	Multi-stakeholder initiatives for achieving sustainable transport objectives, such as Clean Cargo, Global Fuel Economy Initiative (GFEI), etc. The Clean Cargo initiative involves major brands, cargo carriers, and freight forwarders dedicated to reducing the environmental impacts of global goods transportation and promoting responsible shipping. The GFEI is a partnership established to improve global automotive fuel efficiency [44]. A programme of the French Ministry of the Environment to increase sustainability awareness by shippers and carriers: since shippers entrust their merchandise to carriers, they should also be cognisant of the CO ₂ emissions generated by their freight operations [6].

Table 1.
Solutions and recommendations related to SIs in road freight transportation.

The overview in **Table 1** presents sustainability indicators in road freight transportation and corresponding sustainable solutions and recommendations in the field of technical and technological improvements, policies and regulations, etc. This table can help understand how to apply the sustainability improvement cycle described in the Introduction section. For example, the fuel consumption SI shows a high consumption level. Based on this data, a sustainable solution like setting targets for fuel consumption reduction (route optimisation, driver behavioural aspects, etc.) is identified and then adopted by a company. After implementing this solution, the fuel consumption indicator can be reassessed. If this shows persisting issues, other solutions (e.g., alternative transport modes) can be considered and adopted to ensure fuel consumption reduction.

Numerous authors of articles describe SIs, mentioning the challenging process of their implementation. This could slow down the process of transition to sustainable road freight transportation. Therefore, it is vital to identify challenges that prevent the successful implementation of SIs and determine future research on how to overcome them. **Table 2** summarises challenges in implementing SIs for measuring sustainable performance of road freight transportation companies or organisations. The challenges can be categorised using the following categories: environmental, economic and financial, social, biodiversity, business and operations, technological, policy and regulations, and stakeholder engagement.

#	Category	Challenges in implementing SIs
1	Environmental	<p>Lack of data availability, accessibility, and accuracy for measuring and assessing the impact of road freight transportation on the environment [3, 9, 14, 33, 45, 46].</p> <p>Freight transport in Asia remains heavily dependent on fossil fuel and has not yet fully adapted to using cleaner alternative energy sources. Together with the oil price volatility and surges in prices, it increases the vulnerability of developing countries and slows down the progress towards sustainable road freight transport [13].</p> <p>Keeping up with evolving regulations regarding emission standards, e.g., transition to the new EURO 7 standard [10].</p>
2	Economic and financial	<p>Funding limitations/Resource constraints [44, 47, 48].</p> <p>Truck overloading due to lack of consistent regional rules and technical standards [13].</p> <p>Dependency on trade openness and government efficiency (e.g., political stability) [21].</p> <p>Small or medium-sized companies find it difficult to invest in technology advances to achieve sustainable targets [48].</p> <p>The complex and fragmented nature of the supply chain in the transport industry [49].</p> <p>Low willingness to invest in electric freight trucks or freight trucks using alternative fuels because of uncertainties [50].</p>
3	Social	<p>Environment SIs are more popular/common than social SIs [51].</p> <p>Ageing commercial fleet influences road transport safety [13].</p>
4	Biodiversity	<p>Lack of data regarding local land use [26]. The type and intensity of land use can influence biodiversity.</p> <p>Prioritising economic and social benefits rather than preserving biodiversity [25].</p> <p>Data collection to assess the impact on biodiversity [33].</p>
5	Business and operations	<p>A large number of potential indicators; indicators can only capture specific aspects of the transport systems, making it hard to achieve a comprehensive assessment [45].</p> <p>Requirement for fundamental changes in a wide variety of different aspects, as well as the constant monitoring of the current conditions in terms of sustainability transition [51].</p> <p>The intricate interconnections between various components in the transport system [9].</p> <p>Lack of a continuous sustainability assessment capacity and monitoring tools that freight transporters can adopt to evaluate sustainable practices [6].</p> <p>Lack of empirical case studies or real-world applications of SIs [33].</p>
6	Technological	<p>Rapid technological changes and a fundamentally transformative impact of AI on our world [52].</p> <p>Data security and privacy concerns when using AI applications [41].</p> <p>While new technologies hold potential for sustainability, they also exacerbate environmental challenges such as increasing energy and raw materials consumption, greenhouse gas emissions, e-waste, etc. [53].</p> <p>Overlooking the importance of human oversight and intervention when using AI [54].</p>
7	Policy and regulations	<p>Need for regulatory frameworks to drive sustainability in road freight transportation [55].</p> <p>The persistent lack of improvement in environmental practices among hauliers despite the setting of ambitious climate goals [56].</p> <p>Need to promote more sustainable transport choices for both people and moving freight [57].</p> <p>Need for such policy measures as carbon pricing that can encourage a move away from the most carbon-intensive fleets and make low-carbon fuels more cost-competitive [58].</p> <p>Need for comprehensive energy and environmental strategies that support sustainable transportation [33].</p> <p>Keeping up with evolving national and international regulations, for example, with current regulatory guidelines when it comes to applying AI applications [41].</p>

#	Category	Challenges in implementing SIs
8	Stakeholder engagement	Balancing stakeholder opinions and priorities [45]. Resistance to change from stakeholders due to the potential impact on the economy [9]. Investors, among other stakeholders, now expect full disclosure of companies' performance on a range of environmental, social, and governance factors [59]. Multi-ministerial and multi-stakeholder policy making, which takes into account various aspects such as land use planning, community considerations, etc. [44].

Table 2.
Challenges in implementing SIs.

The authors of this review also analysed the articles and reports in the context of topics and research interests of scholars. Articles about SIs and possible solutions and recommendations for sustainable road freight transportation fall mainly into five domains of sustainability: environmental (e.g., CO₂ emissions), social (e.g., safety), economic (e.g., costs and benefits), technological development (new technologies), and sustainability governance (e.g., policy compliance) (**Table 3**).

#	Sustainability domain, Topic
1	Environmental sustainability/CO ₂ emissions Article: Moving towards environmental sustainability: information and communication technology (ICT), freight transport, and CO ₂ emissions [15]
2	Social sustainability/Employment opportunities, safety, training Article: Development of social sustainability index for freight transportation system [3]
3	Economic sustainability/Cost-effectiveness Article: Development and Deployment of Sustainable Transportation [12]
4	Technological development/AI Article: The assessment of the impact of artificial intelligence on transportation sustainability [41]
5	Sustainability governance/Policy compliance Article: Economic, Energy and Environmental Efficiency of Road Freight Transportation Sector in the EU [7]

Table 3.
Examples of topics in articles about SIs and sustainable solutions in road freight transportation.

This table illustrates the variety of topics and research interests in the field of transportation sustainability. The study types in the reviewed articles are also quite different; they vary from literature reviews to research articles using qualitative, quantitative, or mixed methods. The geographical context of articles and reports selected for this review is represented by regions and countries such as the European Union (France, Germany, Lithuania, Netherlands, Portugal, etc.), Brazil, Asia and the Pacific (India, Malaysia, etc.), OECD countries (e.g., Japan, South Korea), the Republic of South Africa, and others.

5. Discussion

In this section, the authors discuss the answers to research questions, the relevance and implications of the findings, and address research gaps and future research

directions. The authors used the semi-systematic review method to answer three research questions. The answer to the first research question, ‘What are the existing SIs?’ is presented in the Sustainability Indicator column of **Table 1**, where the authors identified the most common SIs in road freight transportation. These SIs are essential for monitoring sustainable development. In general, they can be used as follows: (1) measuring sustainable performance and identifying sustainable solutions and recommendations; (2) using in the sustainability improvement cycle; and (3) the company’s internal and external benchmarking.

The research also answers the second question, ‘What is the interrelation of SIs and sustainable solutions, and how can they be applied in the sustainability improvement cycle?’. The authors analysed articles about SIs and assessments in road freight transportation and mapped sustainable solutions using specific SIs (**Table 1**) to highlight the interrelation of SIs and sustainable practices. The significance of the table is that it informs stakeholders about existing SIs and corresponding sustainable solutions in road freight transportation and gives ideas for making decisions in the field of sustainability improvements. Besides that, SIs and corresponding sustainable solutions can be used in the company sustainability improvement cycle (see example in the Review section). The variety of solutions and recommendations can be explained by diverse research topics (see examples in **Table 3**), differences in research objectives, and research approaches and methods. The overview in **Table 1** shows scholars’ significant interest in solutions and recommendations to improve sustainability at the company level, however, the examples of implementing SIs and sustainable solutions in real-world business are mostly missing. Reports of European Union and United Nations commissions (e.g., Economic and Social Commission for Asia and the Pacific) discuss various solutions such as planning noise abatement, building transport system resilience, technology adoption and others that can enhance sustainable development, but there is a lack of up-to-date data showing sustainability improvements in road freight transportation over time.

The authors answered the third research question, ‘What are the challenges in implementing sustainability indicators?’ by summarising challenges in **Table 2**. The table represents general implementation challenges, including challenge categories. The answer to this question is important for understanding the process of implementing SIs and using the sustainability improvement cycle that heavily depends on SIs.

Although some implementation challenges discussed in articles can be easily resolved, persistent challenges may hinder the application of SIs at companies and, therefore, require organisational change management. The implementation of SIs at a company involves the following: (1) operational changes; (2) data availability and quality across the complex supply chain in road freight transportation; (3) unification of SIs integration approaches customised per organisation; and (4) financial and manpower resources. Sdoukopoulos et al. [51] suggested that integrating SIs requires fundamental changes in a wide variety of different aspects, as well as the constant monitoring of the present conditions. The existing workflows may not be capable of adapting to change, such as identifying and collecting appropriate data for measuring sustainability indicators. There are also constraints related to the deployment of the measurements due to the lack of coherence in using criteria for developing indicators [32]. Touratier-Muller and Jaussaud [6] stated that SIs are sometimes quite difficult to quantify since data availability, accessibility, and

accuracy are still low because internal systems of individual organisations within the chain in road freight transportation are not interconnected or do not communicate with each other. This could stem from technical incompatibility of the existing systems and data security and privacy concerns. Furthermore, freight transporters might experience a lack of sustainability assessment capacity to evaluate sustainable solutions continuously [6]. According to Kaledinova and Boeldak [41], integrating AI applications to enhance sustainability in transportation requires substantial investment in the company's digital infrastructure, training programmes for employees, etc. Other research also highlighted that funding limitations may significantly constrain the implementations of SIs. Besides the financial factor, the willingness of all involved stakeholders to implement SIs is essential for a successful implementation. Castillo and Pitfield [45] stated that it is challenging to balance multiple stakeholders' opinions and priorities when it comes to a potential change in workflows and processes. Azlan et al. [9] agreed that resistance to change from stakeholders should be expected. Besides that, more strategies for implementing SIs are needed, and more data should be analysed to evaluate the real effectiveness of SIs considering the synergy and possible trade-offs among multiple factors influencing the implementation process. In case of a change in the workflows, stakeholders should receive proper training and be willing to take on the new responsibilities [54].

All in all, the challenges are identified by researchers, but often, it is not clear how they can be overcome in practice. There is a need for empirical research and case studies on data availability, accessibility, and accuracy to measure sustainability, and on using automated tools to monitor SIs over time. Additionally, fast strategies should be developed to ease the implementation of SIs and sustainable solutions in road freight transportation.

Based on the analysis of the information in **Table 2**, it can be concluded that the main challenges stakeholders might face in measuring sustainability and implementing SIs are data-related challenges.

It is found that more research should be done for SIs and sustainable solutions related to water and raw materials consumption, biodiversity preservation, land use planning, road infrastructure, pavement condition, transport system resilience, and technology adoption.

Additionally, the company sustainability improvement cycle based on SIs and sustainable solutions can also be used to improve the sustainability of companies in other economic sectors (e.g., manufacturing or construction), thus, further research might be needed to identify the interrelation of SIs and corresponding solutions specific to those sectors.

Articles were screened and selected using the inclusion and exclusion criteria described in the search strategy for writing this semi-systematic literature review. It can cause a selection bias, meaning that a sample does not fully represent the topic of research interest, so future research can be done using a broader search strategy for articles about SIs and sustainable solutions in road freight transportation.

Furthermore, future research should discuss the implementation of SIs at companies or organisations and strategies for maintaining the integration of the SIs in road freight transportation after implementation (SIs post-implementation). Finally, more research on costs and financial trade-off opportunities should be conducted as an important step to get different stakeholders on board for implementing SIs and sustainable solutions.

6. Conclusion

This study outlines the interrelation of SIs and sustainable solutions, summarises the main challenges in the transition process to sustainable road freight transportation, and provides recommendations for future research directions.

Main conclusions based on the analysis of the article about sustainability indicators and sustainable solutions are the following: (1) sustainability indicators are essential for monitoring sustainable performance and maintaining transparency in data associated with company sustainability goals; (2) sustainability indicators can be used for evaluating the results of sustainable solutions and making decisions in the context of improving sustainability; (3) sustainable solutions should be related to sustainability indicators to enable the company sustainability improvement cycle.

The overview of challenges in implementing SIs draws attention to possible obstacles in sustainable development, such as the lack of data availability, accessibility, and accuracy for computing SIs and the priority of economic and social benefits rather than nature preservation. Researchers should focus more on case studies and empirical research on integrating sustainability indicators and sustainable practices in real-world business and applying a sustainability improvement cycle. The outcomes of this study might be advantageous for stakeholders, as the study provides extensive information about existing SIs and corresponding sustainable solutions and highlights their relevance for the sustainability improvement cycle at road freight transportation companies.

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Conflict of interest

The authors declare no conflict of interest.

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References

- [1] United Nations. Sustainable Development Goals [Internet]. New York: United Nations Sustainable Development; 2023. Available from: <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>
- [2] UN News. Embrace Innovation “to Make Sustainable Transport a Reality for all” [Internet]. New York: UN News; 2024. Available from: <https://news.un.org/en/story/2024/04/1148666>
- [3] Kumar A, Anbanandam R. Development of social sustainability index for freight transportation system. *Journal of Cleaner Production*. 2019;**210**:77-92
- [4] Ayadi H, Benaissa M, Hamani N, Kermad L. Assessing the sustainability of transport systems through indexes: A state-of-the-art review. *Sustainability* [Internet]. 2024;**16**:1455 Available from: <https://www.mdpi.com/2071-1050/16/4/1455>
- [5] Snyder H. Literature review as a research methodology: An overview and guidelines. *Journal of Business Research* [Internet]. 2019;**104**:333-339. Available from: <https://www.sciencedirect.com/science/article/pii/S0148296319304564>
- [6] Touratier-Muller N, Jaussaud J. Development of road freight transport indicators focused on sustainability to assist shippers: An analysis conducted in France through the FRET 21 programme. *Sustainability*. 2021;**13**(17):9641
- [7] Domagała J, Kadłubek M. Economic, energy and environmental efficiency of road freight transportation sector in the EU. *Energies*. 2022;**16**(1):461
- [8] ICCT. A Technical Summary of Euro 6/VI Vehicle Emission Standards [Internet]. Washington: International Council on Clean Transportation; 2016. Available from: https://theicct.org/sites/default/files/publications/ICCT_Euro6-VI_briefing_jun2016.pdf
- [9] Azlan S, Rahman H, Faizal A, Wahid SM. Greenhouse Gas (GHG) Emissions from Land Transports in Malaysia: Modelling and Policy Analysis [Internet]. Southfield: IEOM Society International; 2019. Available from: <https://ieomsociety.org/pilsen2019/papers/456.pdf>
- [10] European Commission. Commission Proposes New Euro 7 Standards to Reduce Pollutant Emissions from Vehicles and Improve Air Quality [Internet]. Brussels: European Commission; 2022. Available from: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6495
- [11] Ruamsook K, Thomchick E. Sustainable freight transportation: A review of strategies. In: 53rd Annual Transportation Research Forum, Tampa, Florida. 2012. DOI: 10.22004/ag.econ.207083
- [12] Satoh K, Lan LW. Development and deployment of sustainable transportation. *International Journal of Sustainable Transportation*. 2007;**1**(2):69-71
- [13] United Nations. Economic and Social Commission for Asia and the Pacific. Review of Sustainable Transport Connectivity in Asia and the Pacific: Addressing the Challenges for Freight Transport [Internet]. New York: United Nations; 2019. Vol. Sales No. E.20.II.F.2. Bangkok. Available from: https://www.un.org/ohrrls/sites/www.un.org.ohrrls/files/lldcs_publications/review-of-sustainable-transportation.pdf
- [14] Lyamina O, Kaledinova E, Jansen J, Mangul A, Piskunov S, Sikorskaya T,

et al. Study of sustainability in logistics at the company level, transport aspect. Development of a company quick scan. In: Davankov A, editor. Golikov Readings Collection of Scientific Works. Chelyabinsk: Chelyabinsk State University; 2009. pp. 120-128. ISBN 978-5-93216-354-2; Available from: https://www.researchgate.net/publication/303984440_issledovanie_ustojcivosti_v_logistike_na_urovne_firmy_transportnyj_aspekt_razrabotka_sistemy_bystroj_ocenki_predpriatia

[15] Chatti W. Moving towards environmental sustainability: Information and communication technology (ICT), freight transport, and CO₂ emissions. *Heliyon*. 2021;7(10):e08190

[16] European Union. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 Relating to the Assessment and Management of Environmental Noise - Declaration by the Commission in the Conciliation Committee on the Directive Relating to the Assessment and Management of Environmental Noise [Internet]. Brussels: European Union; 2002. Available from: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0049>

[17] Kuehne LM, Habtour E, Echenagucia TM, Orfield SJ. Technology-forcing to reduce environmental noise pollution: A prospectus. *Journal of Exposure Science & Environmental Epidemiology*. 2024;35:6-15

[18] European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Clean Air Programme for Europe [Internet]. Brussels: European Commission; 2013. Available from:

<https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0918:FIN:EN:PDF>

[19] Hitchcock G, Conlan B, Kay D, Brannigan C, Newman D. Air Quality and Road Transport: Impacts and Solutions [Internet]. London: RAC Foundation; 2014. Available from: https://www.racfoundation.org/wp-content/uploads/2017/11/rac_f_ricardo_aea_air_quality_report_hitchcock_et_al_june_2014.pdf

[20] Bongardt D, Stiller L, Swart A, Wagner A. Sustainable Urban Transport: Avoid-Shift-Improve (A-S-I) [Internet]. Düsseldorf: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; 2019. Available from: https://www.transformative-mobility.org/wp-content/uploads/2023/03/ASI_TUMI_SUTP_iNUA_No-9_April-2019-Mykme0.pdf

[21] Kwilinski A, Lyulyov O, Pimonenko T. Environmental sustainability within attaining sustainable development goals: The role of digitalization and the transport sector. *Sustainability* [Internet]. 2023;15(14):11282. Available from: <https://www.mdpi.com/2071-1050/15/14/11282>

[22] Poberezhna Z. Formation of business sustainability of the transport industry in the context of innovative transformations. *Scientific Journal of Silesian University of Technology Series Transport* [Internet]. 2024;124:143-156. Available from: https://sjsutst.polsl.pl/archives/2024/vol124/143_SJSUTST124_2024_Poberezhna.pdf

[23] Gomes SV, Fontul S, Knight I, Breemersch T. The effect of overweight vehicles on road pavements and safety. *Transportation Research Procedia*. 2023;72:4010-4017

[24] Streimikiene D, Baležentis T, Baležentienė L. Comparative assessment

- of road transport technologies. *Renewable and Sustainable Energy Reviews*. 2013;**20**:611-618
- [25] Andersen D, Jang Y. Biodiversity and transportation infrastructure in the Republic of Korea: A review on impacts and mitigation in developing the country. *Diversity*. 2021;**13**(11):519
- [26] Mo F, Wang D. Environmental sustainability of road transport in OECD countries. *Energies*. 2019;**12**(18):3525
- [27] Nunes B, Bennett D. Green operations initiatives in the automotive industry. *Benchmarking: An International Journal*. 2010;**17**(3):396-420
- [28] Atz F. Logistics management practices in road freight transport companies. *International Journal of Entrepreneurship* [Internet]. 2019;**23**(3):1-16. Available from: <https://www.abacademies.org/articles/Logistics-management-practices-in-road-freight-transport-companies-23-3-296.pdf>
- [29] Campaign to Protect Rural England. Proximity Principle: Why we Are Living Too Far Apart. London: Campaign to Protect Rural England; 2008. Available from: www.cpre.org.uk/resources/housing-and-planning/housing/item/1939
- [30] Vaiškūnaitė R, Mierauskas P, Špakauskas V. Biodiversity impact assessment in road development in Lithuania. *Transport*. 2012;**27**(2): 187-195
- [31] Papp CR, Seiler A, Bhardwaj M, François D, Dostál I. Mainstreaming biodiversity into transport networks by connecting stakeholders across sectors. *Nature Conservation*. 2024;**57**:1-8
- [32] Suprayoga GB, Bakker M, Witte P, Spit T. A systematic review of indicators to assess the sustainability of road infrastructure projects. *European Transport Research Review*. 2020;**12**(1). DOI: 0.1186/s12544-020-0400-6
- [33] Ouni M, Abdallah B, Ouni F. The nexus between indicators for sustainable transportation: A systematic literature review. *Environmental Science and Pollution Research*. 2023;**30**:95272-95295
- [34] de Abreu VHS, Santos AS, Monteiro TGM. Climate change impacts on the road transport infrastructure: A systematic review on adaptation measures. *Sustainability*. 2022;**14**(14):8864
- [35] Ramani TL, Zietsman J, Knowles WE, Quadrifoglio L. Sustainability enhancement tool for state departments of transportation using performance measurement. *Journal of Transportation Engineering*. 2011;**137**(6):404-415
- [36] Comi A, Fancello G, Piras F, Serra P. Towards more sustainable cities: Tools and policies for urban goods movements. *Journal of Advanced Transportation*. 2024;**2024**(1). DOI: 10.1155/2024/1952969
- [37] Elvik R, Høye A, Vaa T, Sørensen M. The contribution of research to road safety policy-making. In: *The Handbook of Road Safety Measures*. Leeds: Emerald Publishing Limited; 2009. pp. 117-141
- [38] Luoma J, Sivak M. Interactions of environmental and safety measures for sustainable road transportation. *European Transport Research Review*. 2012;**4**(4):189-199
- [39] ACEA. EU Roadmap for Truck Platooning [Internet]. Brussels: ACEA - European Automobile Manufacturers' Association; 2017. Available from:

<https://www.acea.auto/publication/eu-roadmap-for-truck-platooning/>

[40] Park A, Li H. The effect of blockchain technology on supply chain sustainability performances. *Sustainability* [Internet]. 2021;**13**(4):1726. Available from: <https://www.mdpi.com/2071-1050/13/4/1726>

[41] Kaledinova E, Boeldak D. The assessment of the impact of artificial intelligence on transportation sustainability. *Scientific Journal of Silesian University of Technology Series Transport*. 2024;**125**:101-113. DOI: 10.20858/sjsutst.2024.125.7

[42] Callefi MH, Miller G, Filho MG, Ribeiro E, Osiro L, Reis V. A roadmap for prioritising technology-enabled capabilities in road freight transportation management. *International Journal of Logistics Research and Applications*. 2024;1-26

[43] Shen Y, Bao Q, Hermans E. Applying an alternative approach for assessing sustainable road transport: A benchmarking analysis on EU countries. *Sustainability*. 2020;**12**(24):10391

[44] United Nations. Sustainable Transport, Sustainable Development. Interagency Report for Second Global Sustainable Transport Conference [Internet]. New York: Department of Economic and Social Affairs; 2021. Available from: https://sdgs.un.org/sites/default/files/2021-10/Transportation%20Report%202021_FullReport_Digital.pdf

[45] Castillo H, Pitfield DE. ELASTIC – A methodological framework for identifying and selecting sustainable transport indicators. *Transportation Research Part D: Transport and Environment*. 2010;**15**:179-188

[46] Ayadi H, Benaissa M, Hamani N, Kermad L. Selecting indicators to assess

the sustainability of urban freight transport using a multi-criteria analysis. *Logistics* [Internet]. 2024;**8**(1):12. Available from: <https://www.mdpi.com/2305-6290/8/1/12>

[47] Institute for Environment and Sustainability. Indicators to Assess Sustainability of Transport Activities [Internet]. Luxembourg: Publications Office of the European Union; 2007. Available from: <https://op.europa.eu/en/publication-detail/-/publication/ba11f7f1-368b-464f-987f-3e571be6f678>

[48] Mlambo M, Mageto J, Thaba S. Environmental sustainability and operational performance in the road freight sector. *Acta Logistica*. 2024;**11**(1):1-12

[49] Matos F, Perello-Marin MR. Circular economy challenges within the road freight transport: Case study of Portuguese companies. *Procedia Computer Science*. 2024;**232**:2181-2190

[50] Kallionpää E, Nair S, Liimatainen H. Perspectives of using electric - and alternatively fuelled freight transport vehicles among road haulage companies in Finland. *Transportation Research Procedia*. 2023;**72**:1894-1901

[51] Sdoukopoulos A, Pitsiava-Latinopoulou M, Basbas S, Papaioannou P. Measuring progress towards transport sustainability through indicators: Analysis and metrics of the main indicator initiatives. *Transportation Research Part D: Transport and Environment* [Internet]. 2019;**67**:316-333. Available from: <https://www.sciencedirect.com/science/article/pii/S1361920918308204>

[52] Roser M. Technology over the Long Run: Zoom out to See How Dramatically the World Can Change within a Lifetime [Internet]. Oxford: Our World in

Data; 2023. Available from: <https://ourworldindata.org/technology-long-run>

<https://web-assets.bcg.com/f1/cc/09c53be740f9a6f68ba27a9ebc93/bcg-reduce-carbon-and-costs-with-the-power-of-ai-jan-2021-climate-cover.pdf>

[53] Ukpanah I. Environmental Impact of Technology: Stats, Trends and Insights [Internet]. Market Harborough: GreenMatch.co.uk; 2024. Available from: <https://www.greenmatch.co.uk/blog/technology-environmental-impact>

[54] Sanghavi K. Revolutionizing Transportation with AI: Benefits, Use Cases, Examples [Internet]. Middletown: Syndell Technologies; 2024. Available from: <https://syndelltech.com/ai-in-transportation/>

[55] Meyer T, von Hartmann E. Technology foresight for sustainable road freight transportation: Insights from a global realtime Delphi study. *Futures & Foresight Science* [Internet]. 2021;4. DOI: 10.1002/ffo2.101

[56] Pöllänen M, Liljamo T, Kallionpää E, Liimatainen H. Is there progress towards environmental sustainability among road haulage companies? *Sustainability* [Internet]. 2021;13:5845. DOI: 10.3390/SU13115845

[57] Commission for Integrated Transport. Planning for Sustainable Travel Summary Guide Commission for Integrated Transport [Internet]. Richmond: Commission for Integrated Transport; 2009. Available from: https://discovery.ucl.ac.uk/id/eprint/10056551/1/cfit_summary_guide.pdf

[58] ITF. ITF Transport Outlook 2023 [Internet]. Paris: OECD Publishing; 2023. DOI: 10.1787/b6cc9ad5-en

[59] Degot C, Duranton S, Frédeau M, Hutchinson R. Reduce Carbon and Costs with the Power of AI [Internet]. Boston: BCG (Boston Consulting Group); 2021. Available from:

Chapter 4

Sustainable Entrepreneurship in European Petrochemical Industry

Maria Bartekova

Abstract

In response to climate policies such as the European Green Deal and Paris Agreement, petrochemical companies are increasingly integrating environmental goals into business strategies. This chapter explores sustainable entrepreneurship in the European petrochemical industry, focusing on the transition from fossil fuels to biofuels. Using the triple bottom line framework, the study analyzes how sustainability adoption varies across regions with different economic conditions. Based on 5 years of sales data (2020–2024) from a multinational company operating in Central, Western, and Eastern Europe, the research investigates the relationship between gross domestic product (GDP) and the share of biobased components in diesel fuel. The results show that higher GDP regions, particularly in Western and Central Europe, report greater adoption of biofuels, while Eastern regions lag behind. Statistical analysis confirms significant regional differences in both GDP and biofuel use. The study also examines adoption by customer segment, finding that agriculture and transportation sectors show the highest biofuel integration, whereas wholesale customers—despite large sales volumes—lag in sustainability performance. These findings highlight the uneven progress in sustainable energy across Europe and emphasize the need for regionally tailored policy support to ensure inclusive and effective energy transition in the petrochemical sector.

Keywords: sustainable entrepreneurship, petrochemical industry, biofuels, European energy transition, triple bottom line

1. Introduction

The imperative for sustainable development is reshaping industries across Europe, with the petrochemical sector facing heightened scrutiny due to its significant environmental footprint. As global and regional frameworks—such as the European Green Deal and the Paris Agreement—push for decarbonization, petrochemical companies are increasingly adopting sustainable entrepreneurship models to meet regulatory demands and societal expectations [1, 2].

Sustainable entrepreneurship in this context refers to the integration of environmental, social, and economic goals into core business practices—commonly conceptualized through the triple bottom line framework [3]. In the European petrochemical industry,

this is exemplified by the gradual transition from fossil-based fuels to biofuels. Biofuels, derived from renewable biological sources, present a promising alternative by reducing greenhouse gas emissions and enhancing energy security [4, 5].

However, the adoption of sustainable practices is not uniform across regions. Economic conditions, regulatory environments, and technological infrastructure vary significantly across Central, Western, and Eastern Europe. Research has shown that higher national income levels often correlate with greater investment in environmental innovations and renewable energy adoption [6, 7].

This chapter investigates the motivations, obstacles, and trends in sustainable entrepreneurship within the European petrochemical industry, drawing on fuel sales data from a leading multinational company operating across diverse economic regions. Through comparative analysis of biofuel adoption and GDP levels, the study reveals how economic strength influences environmental transitions. The findings highlight both the opportunities for leadership in sustainability among wealthier nations and the support needed to bridge adoption gaps in less developed regions.

2. Literature preview

2.1 Sustainability of petrochemical industry

The petrochemical industry, a cornerstone of global manufacturing and energy supply, is simultaneously one of the most carbon-intensive sectors. As environmental regulations and societal expectations grow, integrating sustainability into petrochemical operations has become not only a regulatory necessity but also a strategic imperative.

2.1.1 Conceptualizing sustainability in petrochemicals

Sustainability in the petrochemical industry encompasses three core dimensions: economic viability, environmental responsibility, and social equity, often framed as the triple bottom line. Companies are increasingly expected to align their practices with these principles to remain competitive and compliant with international frameworks such as the UN Sustainable Development Goals (SDGs) and the Paris Agreement [1, 2]. The triple bottom line framework, first conceptualized by Elkington, advocates for balancing profit with positive contributions to people and the planet [3].

2.1.2 Environmental innovations and biofuels

Environmental innovations are central to sustainability efforts in petrochemicals. One major focus is the substitution of fossil-based products with biobased alternatives, especially in fuels. Biofuels, derived from renewable sources like plant oils and waste biomass, can significantly reduce greenhouse gas (GHG) emissions if managed sustainably [4, 5]. The International Energy Agency reports that advanced biofuels, particularly hydrotreated vegetable oil (HVO) and second-generation bioethanol, are gaining traction due to their compatibility with existing infrastructure and lower lifecycle emissions [4].

However, not all biofuels are equally sustainable. First-generation biofuels, often made from food crops, pose ethical and environmental concerns such as

deforestation and food insecurity [5]. Research emphasizes the need for advanced generations of biofuels (e.g., from algae or agricultural waste), which mitigate these trade-offs [5].

2.1.3 Economic drivers and barriers

Financial performance is both a motivator and a barrier to sustainability in the petrochemical industry. A study by Saavedra García found that executives increasingly recognize sustainability as a driver of financial success, integrating it into business strategies to meet investor and consumer expectations [6]. Conversely, high initial investment costs, uncertain return on investment, and the long payback periods of eco-innovations remain significant barriers to implementation, particularly in less economically developed regions [6, 7].

Moreover, empirical studies have demonstrated that countries with higher GDP levels show stronger correlations with sustainable fuel adoption in the petrochemical sector, suggesting that economic development is a key enabler of environmental innovation [7].

The fundamental distinction between biofuels and fossil fuels lies in their renewability. Fossil fuels are finite resources formed over millions of years, and current extraction rates are unsustainable in the long term. As reserves diminish, reliance on crude oil for fuel production becomes increasingly unsustainable [4]. In contrast, biofuels are derived from renewable biological sources such as oilseed crops (e.g., rapeseed) or organic waste, offering a way to supplement and gradually reduce fossil fuel consumption [5, 8].

For biofuels to be a viable substitute, they must meet critical criteria: cost competitiveness, infrastructure compatibility, and comparable energy density to conventional fuels. Biofuels such as FAME and HVO have been engineered to blend with or directly replace fossil diesel without requiring major modifications to current engines and distribution networks [9]. These fuels can provide near-equivalent energy output and are already being integrated into existing supply chains.

The benefits of biofuels are multifaceted. They offer significant greenhouse gas (GHG) emission reductions, improved energy security, and economic diversification, particularly by reducing dependency on volatile foreign oil markets [4].

In response to these trends, the company examined in this study has increased its use of biocomponents in fuel formulations, aligning with broader European goals to promote low-carbon fuels and reduce environmental impact.

In this context, the alignment between national innovation systems and sustainability goals becomes a key success factor. Regional disparities in innovation capacity directly impact the pace of biocomponent adoption, particularly in Central and Eastern Europe, where fragmented governance and limited R&D investment have historically constrained transition efforts [10].

Furthermore, the dynamics of multi-level governance and cross-sectoral coordination are identified as bottlenecks in the implementation of EU sustainability goals. According to Hunyadi and Varga (2023), cohesive policy frameworks that bridge energy, agriculture, and industry can unlock synergies necessary for the circular economy and renewable energy deployment [11].

Lastly, financing mechanisms, such as the European Green Deal's Just Transition Fund, are recognized as critical in reducing regional disparities. Targeted financial tools help bridge the investment gap in less developed regions, thus enabling sustainable entrepreneurship to flourish more evenly across Europe [12].

3. Data and methodology

This chapter investigates the adoption of sustainable practices—specifically the use of biofuels—within the European petrochemical industry, focusing on the relationship between national economic conditions and the share of biobased fuel components in sales.

3.1 Data collection and preparation

The analysis is based on internal five-year sales data (2020–2024) from a multinational petrochemical company operating in Central, Western, and Eastern Europe. The dataset includes:

- Yearly volumes of diesel fuel sold,
- Composition of each fuel batch (including the share of biocomponents),
- Sales disaggregated by six customer segments: retail stations, B2B fleet partners, agriculture, wholesalers, state institutions, and internal company use.

Data preprocessing involved standard cleaning procedures such as removing incomplete records, excluding non-fuel products, and converting quantities to consistent units. This phase ensured data accuracy and comparability across time and geography [13].

3.2 Analytical framework

The methodological framework follows a quantitative, comparative approach using both descriptive and inferential statistics. The dependent variable is the bio-component share in diesel fuel, and the primary independent variable is GDP per capita, sourced from Eurostat [14].

Descriptive statistics were first used to assess trends in biofuel integration across time, customer types, and regions. To analyze regional differences, a nonparametric one-way ANOVA (Kruskal-Wallis test) was applied, due to non-normal data distribution and unequal variances across groups [15]. This test is robust for ordinal and non-normally distributed data.

Post-hoc pairwise comparisons were conducted using the Dwass-Steel-Critchlow-Fligner test, which controls for type I error when comparing multiple independent groups.

The effect size was quantified using epsilon squared (ϵ^2), which represents the proportion of variance explained by regional groupings [16].

3.3 Software and reproducibility

All statistical analyses were conducted using Jamovi 2.4, an open-source statistical platform built on R, ensuring transparency and reproducibility of results. The significance level was set at $\alpha = 0.05$.

4. Results and discussion

This section presents the key findings from the analysis of biofuel adoption across different regions and customer segments within the European petrochemical industry. It highlights the trends observed over the 5-year period (2020–2024) and discusses the implications of regional economic differences on sustainable fuel integration.

4.1 Biofuel adoption trends (2020: 2024)

Over the observed period, the share of biofuels in total diesel sales gradually increased, rising from 6.6% in 2020 to 8.2% in 2024 (**Figure 1**). Although the total volume of fuel sold declined—primarily due to economic downturns and increased energy efficiency—biofuels maintained or slightly expanded their market presence. This indicates a growing interest in sustainable alternatives, likely influenced by regulatory targets, technological advancements, and shifts in consumer preferences.

The analysis revealed that despite moderate growth in biofuel volumes, the overall transition remains slow, with fossil fuels continuing to dominate the fuel mix. However, the steady increase in biofuel share signals incremental progress toward more sustainable energy solutions in the petrochemical sector.

4.2 Customer segment analysis

The customer segment analysis provided additional insight into where biofuel adoption is most prominent. The trucking and farming sectors showed the highest shares of biocomponents in their fuel consumption. These sectors likely experience more direct benefits from the use of biofuels, such as regulatory incentives, improved brand image, and long-term cost savings.

Conversely, wholesalers, despite representing the largest share of overall fuel sales, exhibited relatively low levels of biofuel integration (**Table 1**). This may be due to a focus on cost minimization and the prioritization of volume over sustainability. This gap presents a strategic opportunity for companies to redirect efforts toward customer segments with higher potential for sustainability-driven growth. Biocomponent share within segment refers to the percentage of biobased fuel sold within each customer category, that is, biobased quantity divided by total quantity sold in that segment.



Figure 1.
Share of biofuels in total diesel sales.

Segment	Total quantity (t)	Biocomponent quantity (t)	Biocomponent share within segment	Segment share on total volume
Agriculture	262,649	23,011	8.8%	1.7%
Auth & Municip	266,576	19,318	7.2%	1.7%
C&I	1,664,498	109,583	6.6%	10.8%
CRT	1,893,673	176,495	9.3%	12.3%
Marine	15,682	637	4.1%	0.1%
Reseller	10,332,084	662,914	6.4%	67.0%
White pumper	987,090	57,789	5.9%	6.4%
Total amount	15,422,253	1,049,747	6.8%	100.0%

Table 1.
Customer segment analysis.

Table 2 provides an overview of the total fuel sales (in tonnes), the amount of biocomponent, and the percentage share of biocomponent in motor fuel sales in individual countries, divided into three regions: Western, Central, and Eastern.

Total fuel sales for all monitored countries reached 2,907,904 tonnes, of which 218,447 tonnes were renewable biocomponents, representing an average share of 7.5%. The Western region had the largest sales volume (1,811,115 tonnes) with a bioshare of 7.8%. The highest bioshare was achieved by Austria (8.5%), while Slovenia showed the lowest share within the region (3.4%).

Region	Total amount (t)	Biocomponent (t)	Bioshare
Western	1,811,115	142,073	7.8%
Austria	1,248,092	106,085	8.5%
Germany	497,470	33,787	6.8%
Slovenia	65,552	2201	3.4%
Central	765,592	63,850	8.3%
Czechia	151,358	10,224	6.8%
Hungary	441,676	40,076	9.1%
Slovakia	172,558	13,549	7.9%
Eastern	331,197	12,524	3.8%
Bulgaria	120,027	5089	4.2%
Moldova	30,241	311	1.0%
Romania	142,977	7123	5.0%
Serbia	37,953	0	0.0%
Total	2,907,904	218,447	7.5%

Bold entries are better visualization of summarized information (Eastern, Central, Western region).

Table 2.
Regional analysis.

The Central region recorded sales of 765,592 tonnes of fuels with the highest average bioshare of 8.3%. The share was most significant in Hungary (9.1%), which may indicate more effective implementation of renewable commitments or support for biofuels in legislation.

The Eastern region showed both the lowest sales (331,197 tonnes) and the lowest bioshare—only 3.8%, with extremely low values in Serbia (0.0%) and Moldova (1.0%). These figures indicate a lag in the implementation of biocomponents, which may be related to economic, legislative, or technological constraints.

Nonparametric one-way Kruskal-Wallis analysis of variance was used to test for differences between regions (Western, Central, and Eastern) in terms of economic performance and the share of the biological component (**Table 3**). The results showed statistically significant differences in both variables.

Gross domestic product (GDP) differed significantly between regions ($\chi^2 = 9.2692$, $df = 2$, $p = 0.0097$). The effect size was high ($e^2 = 0.8427$), indicating a strong influence of region on differences in GDP. Subsequent Dwass-Steel-Critchlow-Fligner post-hoc analysis revealed that the differences between Western vs. Central ($p = 0.0545$) and Western vs. Eastern ($p = 0.0545$) were at the border of statistical significance, while the Central vs. Eastern comparison did not show a significant difference ($p = 0.1073$). These results indicate that the Western region tends to have higher GDP values compared to other regions, although the differences were not clearly confirmed at the $p < 0.05$ level after correction.

In the case of the share of the biological component, the differences between the regions were even more pronounced ($\chi^2 = 9.8353$, $df = 2$, $p = 0.0073$), with the size effect again being high ($e^2 = 0.8941$). Post-hoc analysis showed statistically significant differences between the Western vs. Eastern ($p = 0.0354$) and Central vs. Eastern ($p = 0.0222$) regions, while the difference between Western and Central was

Kruskal-Wallis				
	χ^2	df	p	e^2
GDP	9.2692	2	0.0097	0.8427
Biocomponent share	9.8353	2	0.0073	0.8941
Dwass-Steel-Critchlow-Fligner pairwise comparisons				
Pairwise comparisons—GDP				
		W	p	
Western	Central	−3.2660	0.0545	
Western	Eastern	−3.2660	0.0545	
Central	Eastern	−2.8577	0.1073	
Pairwise comparisons—Biocomponent share				
		W	p	
Western	Central	2.8284	0.1123	
Western	Eastern	−3.5034	0.0354	
Central	Eastern	−3.7417	0.0222	

Table 3.
 Nonparametric ANOVA analysis results.

insignificant ($p = 0.1123$). These results indicate that the Eastern region clearly stands out with a lower share of the biological component compared to other regions.

Overall, the analysis confirms that regional affiliation has a significant impact on both the level of GDP and the structure of the biological component in the analyzed context.

The obtained results indicate the existence of statistically significant regional differences in the level of gross domestic product (GDP) and in the share of the biological component, which is in line with previous research on the uneven economic and environmental structure within wider geographical units. In particular, the Eastern region shows significantly lower values in both analyzed indicators compared to the Western and Central regions.

Significant differences in GDP indicate that the economic performance of the regions is still significantly conditioned by historical, industrial, and infrastructural development. The Western region, with a higher level of industrialization and foreign investment, achieves better economic indicators, which is also reflected in the trend of higher GDP. Although post-hoc tests for comparisons between the Western and other regions did not reach the level of statistical significance after correction ($p \approx 0.05$), the trend differences are clear and worthy of further monitoring in expanded samples.

Differences in the share of the biological component are even more pronounced. The significant differences between Eastern and other regions suggest that Eastern regions may be less environmentally diversified or face different conditions for the use of natural resources, which may affect their potential for the development of a circular economy, bioeconomy, and environmentally sustainable policies. The results also support the hypothesis that economic development and the ecological structure of a territory may be interconnected, with less developed regions lagging behind not only economically but also in the area of sustainable resource use.

This knowledge is important for the development of regional economic and environmental policies. It follows from them that there is a need for targeted support measures for Eastern regions—for example, in the form of investments in ecological technologies, infrastructure, and the development of local bioeconomy initiatives. At the same time, it shows that balancing regional differences should go hand in hand with strengthening the environmental diversity and ecological potential of territories.

Despite the benefits of the analysis, it is necessary to point out certain limitations, in particular the sample size and potential differences in defining regional boundaries or classifications. We recommend further research with an expanded dataset, including qualitative indicators, that could better capture the complexity of the relationship between economic performance and environmental factors in individual regions.

4.3 Implications for sustainable entrepreneurship

The results indicate that sustainable entrepreneurship in the petrochemical industry is not uniformly distributed but is closely tied to economic capacity, regulatory frameworks, and sector-specific drivers. Companies operating in wealthier regions or serving environmentally motivated sectors are more likely to invest in and promote biofuels. Conversely, in regions where economic constraints dominate, sustainability initiatives are often deprioritized.

To accelerate the industry-wide transition, a combination of policy support, consumer education, and economic incentives is required. Tailored solutions that account

for regional economic realities can ensure a more equitable and effective shift toward sustainable energy.

5. Conclusions

This study examined the dynamics of sustainable entrepreneurship within the European petrochemical industry, focusing specifically on the transition from fossil fuels to biofuels. By analyzing internal sales data from a multinational company across Central, Western, and Eastern Europe, the research assessed how economic development influences the adoption of biobased fuel components.

The results demonstrate a clear regional disparity in the integration of biofuels. Countries with higher GDP per capita—primarily in Central and Western Europe—show greater adoption rates, indicating that financial capacity plays a critical role in enabling sustainable innovation. In contrast, countries in Eastern Europe face significant barriers due to economic limitations and less developed sustainability infrastructure. This disparity underlines the importance of economic context in shaping the trajectory of sustainable entrepreneurship.

At the customer segment level, the highest biofuel adoption was observed among trucking and agricultural clients, likely due to sector-specific incentives and alignment with regulatory goals. Wholesalers, despite dominating total sales volume, lag behind in sustainability efforts, revealing a gap between economic scale and environmental responsibility.

Overall, the findings confirm that while the petrochemical industry is beginning to embrace sustainability, progress is uneven and largely dependent on regional economic strength. Bridging this gap will require a combination of private sector commitment and public policy intervention. Supportive measures such as financial subsidies, regulatory enforcement, and investment in second-generation biofuels can help create a more balanced and effective transition across the continent.

In conclusion, sustainable entrepreneurship in the European petrochemical sector is no longer optional—it is a strategic necessity. However, its success depends on coordinated efforts that address both technological and socioeconomic barriers, ensuring that all regions can participate meaningfully in the energy transition.

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Conflict of interest


The author declares no conflict of interest.

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References

- [1] United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement. 2015. Available from: <https://unfccc.int/process-and-meetings/the-paris-agreement>
- [2] European Commission. The European Green Deal. 2019. Available from: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
- [3] Elkington J. Partnerships from “Cannibals with Forks”: The triple bottom line of 21st-century business. *Environmental Quality Management*. 1998;**37**(4):5-13. Available from: <https://proppg.ufersa.edu.br/wp-content/uploads/sites/11/2016/10/Referencia-de-Lilian-Giesta-Triple-bottom-line-in-21-century-2.pdf>
- [4] International Energy Agency (IEA). IEA Bioenergy Task 39 Biofuel News, Issue 62. 2023. Available from: <https://www.ieabioenergy.com/wp-content/uploads/2023/09/IEA-BioenergyT39-Biofuel-News-62-final.pdf>
- [5] Singh B. *Biofuel Crop Sustainability*. 1st ed. Chichester: Wiley-Blackwell; 2013. ISBN: 978-1-118-63572-8. Available from: <https://www.wiley.com/en-us/Biofuel+Crop+Sustainability-p-9781118635728>
- [6] Saavedra García ML. Business sustainability and financial performance. *Cuadernos de Administración*. 2022;**38**(72):e4011031. DOI: 10.25100/cdea.v38i72.10835
- [7] Xu M, Xu Q, Wei S, Cong L. The role of organizational resilience in social, economic, environmental and human sustainability: Evidence from Chinese FMCG sector. *Technological and Economic Development of Economy*. 2024;**30**(3):733-752. DOI: 10.3846/tede.2024.20476
- [8] Venus T, Beale C, Villalba R. Innovation and networks in the bioeconomy: A case study from the German coffee value chain. *Circular Economy and Sustainability*. 2024;**4**:1751-1772. DOI: 10.1007/s43615-024-00357-7
- [9] Jager HI, Efrogmson RA, McManamay RA. Renewable energy and biological conservation in a changing world. *Biological Conservation*. 2021;**263**:109354. DOI: 10.1016/j.biocon.2021.109354
- [10] Pylak K, Pizoń J, Łazuka E. Evolution of regional innovation strategies towards the transition to green energy in Europe 2014-2027. *Energies*. 2024;**17**(22):5669. DOI: 10.3390/en17225669
- [11] Streimikis J, Ślusarczyk B, Siksnelyte-Butkiene I, Mura L. Development of circular economy in the Visegrad Group of countries. *Contemporary Economics*. 2024;**18**(3):365-375. DOI: 10.5709/ce.1897-9254.543
- [12] Moesker K, Pesch U. The just transition fund – Did the European Union learn from Europe’s past transition experiences? *Energy Research & Social Science*. 2022;**91**:102750. DOI: 10.1016/j.erss.2022.102750
- [13] Hair JF, Black WC, Babin BJ, Anderson RE. *Multivariate Data Analysis*. 8th ed. Harlow: Pearson; 2019. ISBN: 978-1-4737-5654-0 Available from: https://eli.johogo.com/Class/CCU/SEM/_Multivariate%20Data%20Analysis_Hair.pdf
- [14] Eurostat. Gross Domestic Product (GDP) and Main Components

(Output, Expenditure and Income).
2025. Available from: https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp/default/table?lang=en&category=na10.nama10.nama_10_ma

[15] Ghasemi A, Zahediasl S. Normality tests for statistical analysis: A guide for non-statisticians. *International Journal of Endocrinology and Metabolism*. 2012;**10**(2):486-489. DOI: 10.5812/ijem.3505

[16] Tomczak M, Tomczak E. The need to report effect size estimates revisited: An overview of some recommended measures of effect size. *Trends Sports Science*. 2014;**21**(1):19-25. Available from: https://www.researchgate.net/publication/303919832_The_need_to_report_effect_size_estimates_revisited_An_overview_of_some_recommended_measures_of_effect_size

Critical Dialogs of 3D Printing Waste Recycling in Circular Fashion

Shahbaj Kabir, Yu Li and Young-A Lee

Abstract

With the increasing use of 3D printing (3DP) in the fashion industry, recycling 3DP waste has gained significant attention from the industry professionals. However, little study has critically discussed existing challenges and opportunities of recycling 3DP waste, specifically polylactic acid (PLA) and thermoplastic polyurethane (TPU), for sustainable practices in the fashion industry. Thus, the purpose of this chapter is to provide a platform for critical dialogs about recycling PLA- and TPU-based 3DP waste as biological and technical nutrients while identifying key challenges and opportunities in their recycling process to advance circular waste management. The secondary data from relevant academic literature were used to frame this chapter. The key findings from those identified articles were the foundation to develop the main idea of this chapter. The secondary data analysis found that PLA holds great potential as biological nutrients due to its biodegradability, whereas TPU lacks inherent biodegradability, preventing it from functioning as biological nutrients. Despite certain challenges, both PLA- and TPU-based 3DP waste are highly recyclable, positioning them as ideal candidates as technical nutrients. However, circularity cannot be achieved unless circularity principles and practices are holistically understood and adopted by all stakeholders in the fashion industry. It is critical to engage all stakeholders as change agents to move forwards circularity in the 3DP fashion industry. This chapter deepens the understanding of challenges and opportunities associated with recycling PLA- and TPU-based 3DP waste. The chapter lays the foundation for researchers and industry professionals to further explore PLA- and TPU-based 3DP waste recycling within the circular fashion system.

Keywords: circularity, 3D printing waste, recycling, cradle-to-cradle process, environmental impact, sustainable practices, fashion industry, waste management, circular fashion

1. Introduction

1.1 Background, justification, and aim of the chapter

3D printing (3DP), also known as additive manufacturing, has emerged as a powerful technology across various industries including fashion. It has gained widespread attention

due to its ability to fabricate intricate geometries with greater precision, material cost efficiency, and less waste compared to conventional manufacturing methods [1, 2]. These benefits have driven the rapid growth of 3DP market in recent years, projecting to expand from \$23.41 billion in 2025 to \$101.74 billion in global sales by 2032 [3].

In the fashion industry, 3DP has been used as a groundbreaking design technology, empowering designers with capabilities to develop wearable products that can be customized based on the user needs and preferences [4, 5]. The 3D printed wearable products today include an extensive array of fashion items ranging from accessories, footwear, and gloves to luxurious, high-end clothing [4].

With the continuous growth of 3DP use, the demand for virgin raw materials to produce 3D printed objects has been increasing, which leads to the increased risk of resource depletion [6, 7]. With the fast-paced expansion of the 3DP integration in the wearable product development, the question has been evolving about where all the byproducts of 3DP land after their use. The growth in 3DP carries the potential risk of adding plastic waste to the environment in addition to what has already been caused by the conventional plastic sector [8]. The significant amount of plastic waste is generated by failed prints and/or 3DP support structures during the printing process [8]. Studies suggest that the current success rate for 3D printed products could range from 30 to 50%, implying that nearly half of the 3D prints are wasted due to failed prints, excess support materials, or post-processing errors [9]. This 3DP waste contributes to substantial environmental burdens such as pollution in oceans and landfills, harm to wildlife, and greenhouse gas emissions [2]. Recycling 3DP waste offers a promising solution to reduce plastic waste generated by 3DP, decrease the dependence on virgin 3DP filaments, and minimize overall plastic waste accumulation [2].

While 3DP can utilize a variety of materials, the most commonly used materials for creating 3D printed wearable products are polylactic acid (PLA) and thermoplastic polyurethane (TPU) [10, 11]. PLA is one of the most predominant materials for 3DP due to its mechanical properties, relatively low melting points and most importantly its biodegradability and/or eco-friendliness [12]. On the other hand, TPU is a novel material known for its outstanding mechanical properties, particularly flexibility, which has helped gain significant momentum in developing wearable products using 3DP [13, 14]. Therefore, PLA and TPU have become key contributors to generate the waste while producing 3D printed wearable products [15]. Thus, deepening the understanding of PLA and TPU waste recycling and addressing the challenges encountered by researchers and industry professionals while recycling are fundamental for proposing sustainable solutions of 3DP waste management in the fashion industry that align with consumer demands while minimizing the negative environmental impact.

To the best of our knowledge, little study has critically discussed current challenges associated with recycling PLA- and TPU-based 3DP waste for sustainable practices. Thus, this chapter aims to provide a platform for critical dialogs about recycling PLA- and TPU-based 3DP waste as a strategy to minimize environmental pollution and dependency on virgin materials. This chapter specifically highlights the significance of 3DP waste management in the circular fashion system while identifying key challenges and opportunities that should be addressed during the 3DP waste recycling process.

1.2 Methodological approach

This chapter presents theoretical and conceptual reflection through synthesizing relevant literatures about 3DP and its waste management, viewed through the

lens of sustainability practices in the fashion industry. The secondary data served as the foundation for this chapter. A comprehensive literature search was conducted across different academic research databases, including Google Scholar, ProQuest, and PubMed, using the keywords such as 3D printing waste, 3D printing materials, PLA, TPU, circular fashion, and 3DP waste recycling. The key findings from those selected articles were extracted and organized to highlight the significance of 3DP waste management in circular fashion system along with its primary challenges and potential opportunities.

2. Circular fashion

2.1 Circular economy principles

As technology continues to advance, we are stepping into a transformative era where innovation in manufacturing is redefining the way we produce and consume goods [16]. These innovations in manufacturing facilitate the adoption of sustainable practices, which are essential for the well-being of people, the planet, and economy [17]. Circular economy (CE) is a sustainable model that has drawn significant attention over the past decades, aiming to eliminate waste by retaining resources in continuous circulation through practices such as reusing, recycling, and composting [16, 18]. CE is the opposite of the traditional production system which operates following a ‘take-make-dispose’ model, where raw materials are transformed into products, consumed uncontrollably, and ultimately discarded as waste [19], leading to resource depletion and environmental pollution.

The core principle of CE is to maintain a circular flow of materials within a closed-loop system, aiming to minimize the use of virgin resources and eliminate waste generation [19, 20]. The closed-loop system of CE replaces the traditional end-of-life concept by continuously recycling material waste throughout the production and consumption phases, thereby ensuring environmental quality, economic prosperity, and social equity for the benefit of both current and future generations [21, 22]. By embracing CE, industries can minimize material consumption through the efficient resource management and the use of renewable energy, while also decreasing toxic waste generation and resource depletion through thoughtful design and recycling [23].

2.2 Cradle-to-cradle process model

McDonough and Braungart’s Cradle-to-Cradle (C2C) process model provides a framework that guides designers and developers in achieving a closed-loop goals, closely aligning with CE principles [24, 25]. The C2C process model seeks to maximize benefits to the ecological system while prioritizing eco-efficiency by minimizing ecological harms [26]. According to the C2C process model, products should be responsibly designed to benefit not only people, but also the planet and economy [27, 28]. In this C2C process model, waste does not exist; the waste of one organism becomes food for another organism [27], retaining materials within a closed-loop system where they are continuously reused and recycled [29, 30]. Contrary to the conventional linear “cradle-to-grave” process model, which generates a significant amount of waste, the C2C model considers materials as either “technical nutrients” that continuously circulate as pure and valuable materials

within a closed-loop system, instead of being downcycled into lower-grade materials, or “biological nutrients” that reenter to nature through the biodegradation process, serving as nutrients [31].

Technical nutrients, commonly including synthetic or non-organic materials, circulate within a continuous closed-loop industrial system of manufacturing, and recycle without losing their quality [26]. They are usually non-biodegradable, and when discarded as waste, they can persist in the environment for hundreds of years, leading to pollution, harm to ecosystems, and the risk of soil and water contamination [27]. As a result, technical nutrients are recycled or reused to provide a new life for raw materials as new products, preventing resource depletion and minimizing environmental pollution. For materials to qualify as technical nutrients, it is essential to retain consistent mechanical properties both during and after the manufacturing and recycling processes [28]. For example, non-biodegradable polymers that can retain their consistent mechanical quality during and after the recycling process could serve as technical nutrients [32].

Biological nutrients are non-hazardous, biodegradable materials that can safely return to the soil and nourish natural processes through biodegradation [26]. More specifically, at the end of their lifecycle, after serving what they were initially designed for, they typically biodegrade, becoming food for plants and animals, and contribute nutrients to the soil [25]. For example, biodegradable materials such as carpet trimming, clothing, packaging materials and even polymers can serve as biological nutrients. At the end of their initial lifecycle, they can decompose into the soil, enriching it with nutrients that serve as food for plants [26]. **Figure 1** illustrates how biological and technical nutrients circulate within the C2C process model.



Figure 1.
Biological and technical cycles of the product in the C2C process model.

3. 3D printing waste in the fashion industry

Fused deposition modeling (FDM) is one of the most commonly used, user-friendly 3DP methods in the fashion industry. Despite its accessibility and popularity, FDM frequently requires support structures during the printing process that are discarded after production by manufacturers, resulting in significant material waste [33]. The majority of this 3DP waste is non-biodegradable and cannot decompose properly, leading to pollution, microplastic contamination, and resource depletion [34]. The main sources of 3DP waste generated through FDM are PLA- and TPU-based waste, as they are the predominantly used materials in the creation of 3D printed wearable products [10, 11].

PLA, the primary material used in FDM 3DP method due to its affordability and favorable mechanical properties, has been increasingly adopted by designers to develop wearable products in recent years [5, 35]. TPU, as a novel flexible 3DP material, is gaining significant interest for creating 3D printed wearable products due to its excellent flexibility and elasticity [13, 14]. In recent years, various fashion designers have used TPU as their source of materials for 3DP [36, 37]. Additionally, acrylonitrile butadiene styrene (ABS), a rigid and hard polymer, has also been used by designers; however, its application has been largely limited to prototyping accessories and jewelry, and it has not been widely used as PLA and TPU [5, 14]. Thus, this chapter limits to address 3DP waste from PLA and TPU, which are most commonly used in the fashion industry. It is essential to identify an effective method for managing this growing waste [38].

The effective management approach of 3DP waste varies depending on the material's biodegradability. Decomposing biodegradable 3DP waste is one direct way to manage such waste, as they naturally break down through the action of microorganisms and environmental factors, reducing waste and nourishing nature as biological nutrients [39–41]. In contrast, for non-biodegradable 3DP waste, continuous recycling as technical nutrients has been identified as the most effective solution to minimize 3DP waste and dependency on virgin materials [38, 42].

There are two primary recycling methods: mechanical and chemical. Mechanical recycling, the more widely used approach, involves physical processes such as sorting, cleaning, and melting to extrude new filaments. In contrast, chemical recycling is less frequently used and involves breaking down polymers into their chemical blocks for reuse in new chemical processes [12]. While mechanical recycling of 3DP waste as technical nutrients offers opportunities to mitigate environmental pollution and enhance material efficiency by reducing the usage of virgin materials, it also presents several technical challenges including downgrading the material's mechanical and thermal properties [12, 43, 44].

As shown in **Figure 2**, in circular fashion, the waste can serve either as technical nutrients that continuously circulate within a closed-loop C2C process without the material property degradation, or as biological nutrients that naturally decompose. Specifically, biodegradable polymers sourced from nature can be used to produce filaments for 3D printed wearable products; the resulting waste can then be decomposed into nature, providing nourishment to the next generation of biological life. On the other hand, the waste from 3D printed wearable products made of non-biodegradable polymers can be recycled to new filaments for the product manufacturing, allowing the polymer to continuously circulate as technical nutrients within a closed-loop system.

Various types of 3DP waste encounter distinct challenges in waste management as either biological or technical nutrients, due to their specific chemical compositions and properties. Although ABS has been used as the 3DP material by a few designers,



Figure 2.
Biological and technical nutrients of 3DP waste in circular fashion.

the main contributors of 3DP waste in the fashion industry nowadays are PLA- and TPU-based materials. Thus, the following section explores challenges and opportunities associated with managing different types of 3DP waste, primarily the byproducts of PLA and TPU, to align with the current circular fashion movement.

4. Challenges and opportunities of 3DP waste

4.1 PLA-based 3DP waste and its recycling

PLA is one of the most prevalent materials in FDM 3DP and is the most commonly used bioplastics due to its excellent biodegradability, which positions it a promising biological nutrient within a closed-loop system [45]. PLA can degrade naturally in the environment, releasing only water and carbon dioxide, making it more environmentally friendly compared to many other 3DP materials such as TPU and ABS [46]. Studies have demonstrated that using PLA as biological nutrients can temporarily replace non-biodegradable 3DP materials, helping to reduce waste in 3DP [47]. Moreover, PLA provides additional environmental benefits, as it is derived from renewable resources such as corn starch, sugarcane, and tapioca roots, significantly reducing reliance on petroleum-based feedstocks [48].

4.1.1 Biodegradability of PLA-based 3DP waste

Although PLA is one among a few 3DP materials that can function as biological nutrients, PLA's biodegradability is conditional. Improper processing can further

result in 3DP waste and environmental pollution [39]. A common misconception among designers is that PLA breaks down rapidly, whereas in reality it can take over a year to degrade at a room temperature; its decomposition rate can accelerate significantly under the industrial composting condition, breaking down within 12 weeks at an elevated temperature [49]. Therefore, the industry professionals and designers must consider key decomposition conditions, particularly temperature and humidity, which are challenging to control outside of the specialized industrial setting [50]. Thus, one of the most critical challenges in managing PLA-based 3DP waste as biological nutrients is its dependency on specific environmental conditions, requiring professional composting facilities to achieve full biodegradability [51]. Despite such challenges, PLA-based 3DP waste still presents great potential as biological nutrients due to its biodegradability and renewability under the assumption that decomposition conditions are properly controlled.

4.1.2 Challenges of PLA-based 3DP waste recycling

While PLA is biodegradable, it is also highly recyclable as technical nutrients, and recycling is by far the most practical approach to manage PLA-based 3DP waste [52]. Recycling PLA byproducts also presents some challenges. PLA is susceptible to thermal, thermo-oxidative, and thermomechanical degradation [12, 53]. Elevated temperatures during recycling causes PLA to degrade thermally. Thermo-oxidative degradation takes place when PLA is exposed to elevated temperatures in the presence of oxygen during the recycling process. Thermomechanical degradation also results from mechanical stress during the recycling process, leading to degrade PLA quality [53]. The challenge to precisely control temperature, oxygen levels and mechanical stress during recycling often results to the PLA quality degradation, leading to deteriorated mechanical and thermal properties [8].

Numerous researchers have recycled PLA-based 3DP waste and examined their mechanical properties to verify reliability of PLA waste recycling and to determine if PLA can be continuously recycled without the quality degradation as technical nutrients. Studies found that mechanical recycling results in the property degradation, particularly when PLA is sourced from the blends of different grades [54]. However, when PLA comes from a high-grade, uncontaminated source, the recycling process only causes minimal degradation to the properties of recycled PLA [8, 54]. Researchers also investigated the effect of repetitive recycling processes on the PLA properties, resulting that both mechanical and thermal properties gradually declined as the number of recycling cycles increased [55].

4.1.3 Opportunities of PLA-based 3DP waste recycling

While previous studies found that the presence of elevated temperature, oxygen, and stress during the recycling process leads to the PLA property degradation, hindering its effective integration into a circular system of 3DP, PLA-based 3DP waste still present great potential to be used as technical nutrients in a closed-loop system [43]. Recycling high-quality, uncontaminated PLA can be a viable option as it does not experience the property degradation due to recycling [8]. In addition, blending a certain percentage of virgin PLA with PLA-based waste during recycling has been found to enhance the mechanical properties of recycled PLA [12]. Moreover, the precious control of parameters including temperature, oxygen levels and stress during recycling can result in recycled PLA with improved mechanical properties [56]. In the

light of these arguments, PLA still holds an excellent promise to function as technical nutrients in the C2C process towards achieving circularity in the 3DP fashion industry.

4.2 TPU-based 3DP waste and its recycling

4.2.1 Biodegradability of TPU-based 3DP waste recycling

TPU, a block copolymer composed of soft and hard segments, has gained significant attention in the 3DP fashion industry due to its excellent mechanical properties [15]. While the soft segments provide flexibility and elasticity, the hard segments can contribute to strength, rigidity, and durability to 3D printed wearable products, all of which are necessary for providing comfort to wearers and withstanding multidirectional forces that textiles experience during daily wear due to body movement [15, 57, 58]. TPU is not inherently biodegradable due to its chemical structure and composition that make it resistant to breakdown naturally [59]. Therefore, TPU-based 3DP waste cannot serve as biological nutrients in the circular fashion system.

4.2.2 Challenges of TPU-based 3DP waste recycling

Although TPU is not biodegradable, it is capable of withstanding thermal processing, making it a highly suitable material for recycling through melting, enabling it to function as technical nutrients within the C2C process [60]. While mechanical recycling is a viable option for managing TPU-based 3DP waste, it presents some challenges. The recycling process often negatively affects the mechanical performance of TPU [61]. Previous studies found that a single recycling does not significantly alter the mechanical and thermal properties of TPU. However, with a repeated recycling, the material begins to exhibit slight mechanical degradation [62]. In contrast, other studies revealed that even after three cycles of TPU recycling, there is no significant change in the mechanical and thermal performance of TPU [63]. Although recycling usually tends to degrade the mechanical properties of TPU, some studies have reported that the repeated cycles of recycling can enhance its mechanical performance, while its thermal properties remain consistent [61]. Such results display great potential for TPU waste recycling without any property degradation.

4.2.3 Opportunities of TPU-based 3DP waste recycling

Given that recycling TPU waste can sometimes lead to slight degradation in its mechanical properties, while in other instances it has no impact or even improves the properties, it is crucial to examine commonly used TPU filaments to determine which ones undergo property degradation and which ones remain unaffected through the TPU-based 3DP waste recycling process. In addition, as recycling high-grade, uncontaminated PLA results in recycled PLA without property degradation, a similar outcome may be achievable for recycled TPU. Furthermore, arguably blending virgin TPU with TPU-based 3DP waste during recycling could potentially yield recycled TPU without any property degradation. Hence, it is recommended for future studies to investigate recycling of high quality, uncontaminated TPU as well as potential benefits of blending virgin TPU while recycling TPU-based 3DP waste.

5. Conclusion

5.1 Summary

This chapter highlights the potential of achieving circularity in the 3DP fashion industry by retaining 3DP waste within a circular closed-loop system. Although 3DP holds great potential to enhance sustainability in the fashion industry, it generates considerable plastic waste. As one of the most widely used 3DP techniques, FDM generates significant amount of waste in the form of failed prints and support structures primarily composed of PLA and TPU. This chapter first introduced the circularity principles and the closed-loop C2C process model, specifically focusing on the potential of managing different types of 3DP waste as biological and technical nutrients by addressing the current issues of 3DP plastic waste in the fashion industry. This chapter also discussed the challenges and opportunities associated with managing PLA- and TPU-based 3DP waste within a circular closed-loop system.

While PLA has the potential to function as biological nutrients in the C2C process, improper processing of PLA-based 3DP waste can result in additional waste and environmental pollution, hindering its effectiveness as biological nutrients. In contrast, TPU is not inherently biodegradable, making it incapable of serving as biological nutrients. However, both PLA- and TPU-based 3DP waste are highly recyclable, which can be used as technical nutrients, offering a promising solution to promote circularity in the 3DP fashion industry. Despite opportunities, the recycling process faces some challenges. The primary challenge in recycling PLA- and TPU-based 3DP waste is the polymer quality degradation, resulting in reduced mechanical performance, which could compromise their effectiveness to function as technical nutrients within the C2C process. Such a challenge can be overcome through precisely controlling the recycling process parameters, preventing contamination, and blending 3DP waste with a certain amount of virgin material during recycling. Such an effort can prevent the degradation of mechanical properties of recycled 3DP materials. In sum, PLA and TPU hold great promises to function as technical nutrients within the closed-loop system towards achieving circularity in the 3DP fashion industry.

5.2 Future research direction

Such proposed strategies to overcome the property degradation of recycled 3DP waste require a thorough practical examination to draw conclusive insights into the effective recyclability of PLA- and TPU-based 3DP waste, which should be the focus in future studies. Thus, the following three key areas are recommended for future studies to enhance the recyclability of 3DP waste towards achieving circular 3DP fashion industry. The future research should investigate the recycling potential of high-quality, uncontaminated 3DP waste to gain a better understanding of their performance. In addition, further research should be conducted to examine the effectiveness of blending virgin materials with 3DP waste to enhance performance and consistency of recycled materials. Moreover, future research should explore the impact of precisely controlled recycling process parameters on the quality and performance of recycled materials.

5.3 Action plan

Despite the potential of managing PLA- and TPU-based 3DP waste as biological and technical nutrients within the circular fashion system, circularity cannot be

achieved unless circularity principles and practices are holistically understood and adopted by all stakeholders involved in the fashion industry, from upstream manufacturers to downstream consumers. It is important to engage all stakeholders as change agents to move forwards circularity in the 3DP fashion industry, as small changes by individuals can create big impacts to the industry. For the betterment of the 3DP fashion industry, collective efforts from everyone need to be gathered, including enhancing production efficiency, minimizing resource depletion, practicing responsible consumption and adopting return, repair, and recycling practices.

In particular, transparency between companies and consumers is crucial to achieve circularity in the 3DP fashion industry. Companies can accelerate circularity within the industry by implementing various sustainability initiatives, while consumers play an essential role as change makers for the sustainability movement. For example, labeling is a crucial part that can bridge brands and consumers. In the case of 3D printed wearable products, labels can offer transparency regarding material types, production process, and recyclability, thereby empowering consumers to make informed decisions. Proper labeling can also assist consumer insights by providing the essential knowledge and guidance on how to responsibly consume, recycle or decompose 3D printed wearable products after their use, which can facilitate circular practices in the 3DP fashion industry. Specifically, when 3D printed wearable products are made of using 3DP materials as technical nutrients, the product labels can guide consumers in keeping them uncontaminated. This is important because uncontaminated 3DP waste can be recycled into filaments without significant loss in mechanical performances. For instance, Patagonia uses recycled TPU in the production of their Black Hole products to reduce dependence on virgin petroleum without compromising the product performance to optimize recycling conditions. Patagonia emphasizes that TPU can only be recycled if it remains uncontaminated and reminds consumers to properly separate it from other polyester materials after the primary use [64]. Care labels also can guide consumers properly decompose biodegradable products without contaminating them with non-biodegradable materials. For example, the fashion brand MATE manufactures all its products from sustainably made, non-toxic, natural, and organic materials which require proper decomposition into the soil as biological nutrients, supporting circularity in the fashion industry [65].

In addition to providing the 3DP waste management information through labeling, brands also have a responsibility to educate both consumers and recyclers through various channels, as they directly participate in 3DP waste management at the end of the product life cycle. For example, companies can promote sustainability initiatives through social media campaigns, share educational and accessible information on their websites, and offer educational workshops and printed materials in physical stores to better engage with consumers and potential recyclers.

Alongside fashion brands and consumers, the government as an external stakeholder also plays a key role in transitioning the 3DP fashion industry towards the circular system. By supporting and regulating the fashion industry, the government can spearhead the sustainability movement in the 3DP fashion industry through implementing eco-friendly policies. For example, the government can proactively promote recycling initiatives by establishing and/or sponsoring recycling facilities and patronizing technologies that enhance recycling efficiency, while also implementing regulations that mandate companies to manage 3DP waste responsibly, eventually raising awarenesses across the fashion industry. Moreover, the government can facilitate sustainability education by providing platforms and financial support, and incorporating sustainable 3DP practices into the curriculum, as young designers are

introduced to 3DP in school, making it an ideal stage to cultivate sustainable practices in 3DP waste management [66].

In sum, every individual in the supply chain must cultivate an awareness and mindset of circularity of 3DP waste, recognizing pollution and waste issues we face today. Thus, sustainability education plays a key role in this process by increasing awareness of 3DP waste and empowering stakeholders to embrace more sustainable practices.


This chapter deepens the understanding of challenges associated with recycling PLA- and TPU-based 3DP waste and their potential opportunities to be considered as biological and technical nutrients in the circular fashion system. By introducing conceptual ideas of 3DP waste management, this chapter stands as a platform for critical dialogs on 3DP material innovation and waste management by holistically integrating the C2C principles towards achieving circularity in the 3DP fashion industry. It establishes the foundation for researchers and industry professionals to further explore PLA- and TPU-based 3DP waste recycling within the circular fashion system. This effort ultimately promotes circularity in the fashion industry by encouraging more responsible use of 3DP materials and the implementation of effective 3DP waste management strategies.

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References

- [1] Bhatia A, Sehgal AK. Additive manufacturing materials, methods and applications: A review. *Materials Today Proceedings*. 2023;**81**:1060-1067. DOI: 10.1016/j.matpr.2021.04.379
- [2] Oladapo BI, Bowoto OK, Adebisi VA, Ikumapayi OM. Net zero on 3D printing filament recycling: A sustainable analysis. *The Science of the Total Environment*. 2023;**894**:165046. DOI: 10.1016/j.scitotenv.2023.165046
- [3] Fortune Business Insights. 3D Printing Market Size, Share & Industry Analysis. 2025. Available from: <https://www.fortunebusinessinsights.com/industry-reports/3d-printing-market-101902> [Accessed: June 5, 2025]
- [4] Lekeckas K, Stirbe J, Ancutiene K, Valusyte R. Testing of 3D printing on textile fabrics for garments application within circular design. *International Journal of Clothing Science and Technology*. 2023;**35**(4):627-647. DOI: 10.1108/ijcst-06-2022-0080
- [5] Wu S, Zeng T, Liu Z, Ma G, Xiong Z, Zuo L, et al. 3D printing technology for smart clothing: A topic review. *Materials*. 2022;**15**(20):7391. DOI: 10.3390/ma15207391
- [6] Hunt EJ, Zhang C, Anzalone N, Pearce JM. Polymer recycling codes for distributed manufacturing with 3-D printers. *Resources, Conservation and Recycling*. 2015;**97**:24-30. DOI: 10.1016/j.resconrec.2015.02.004
- [7] Olawumi MA, Oladapo BI, Ikumapayi OM, Akinyoola JO. Waste to wonder to explore possibilities with recycled materials in 3D printing. *The Science of the Total Environment*. 2023;**905**:167109. DOI: 10.1016/j.scitotenv.2023.167109
- [8] Beltran FR, Arrieta MP, Moreno E, Gaspar G, Muneta LM, Carrasco-Gallego R, et al. Evaluation of the technical viability of distributed mechanical recycling of PLA 3D printing wastes. *Polymers*. 2021;**13**(8):1247. DOI: 10.3390/polym13081247
- [9] Zhu C, Li T, Mohideen MM, Hu P, Gupta R, Ramakrishna S, et al. Realization of circular economy of 3D printed plastics: A review. *Polymers*. 2021;**13**(5):744. DOI: 10.3390/polym13050744
- [10] Xiao Y, Kan C. Review on development and application of 3D-printing technology in textile and fashion design. *Coatings*. 2022;**12**(2):267. DOI: 10.3390/coatings12020267
- [11] Yap YL, Yeong WY. Additive manufacture of fashion and jewellery products: A mini review. *Virtual and Physical Prototyping*. 2014;**9**(3):195-201. DOI: 10.1080/17452759.2014.938993
- [12] Hasan MR, Davies IJ, Pramanik A, John M, Biswas WK. Potential of recycled PLA in 3D printing: A review. *Sustainable Manufacturing and Service Economics*. 2024;**3**:100020. DOI: 10.1016/j.smse.2024.100020
- [13] Kocevar TN. 3D printing on textiles – Overview of research on adhesion to woven fabrics. *Tekstilec*. 2023;**66**(3):164-177. DOI: 10.14502/tekstilec.66.2023055
- [14] Tolmac NT, Işmal OE. A new era: 3D printing as an aesthetic language and creative tool in fashion and textile design. *Research Journal of Textile and Apparel*. 2024;**28**(4):656-670. DOI: 10.1108/rjta-05-2022-0058
- [15] Hossen MI, Wang C. Thermoplastic polyurethane based on the 3D printing

- fashion clothing-conceptual model of the fashion industry. *Fibres and Textiles in Eastern Europe*. 2022;**30**(6):1-11. DOI: 10.2478/ftce-2022-0047
- [16] Despeisse M, Baumers M, Brown P, Charnley F, Ford SJ, Garmulewicz A, et al. Unlocking value for a circular economy through 3D printing: A research agenda. *Technological Forecasting and Social Change*. 2017;**115**:75-84. DOI: 10.1016/j.techfore.2016.09.021
- [17] Thomas A, Mishra U. A sustainable circular economic supply chain system with waste minimization using 3D printing and emissions reduction in plastic reforming industry. *Journal of Cleaner Production*. 2022;**345**:131128. DOI: 10.1016/j.jclepro.2022.131128
- [18] Urbinati A, Franzo S, Sassanelli C, Rosa P, Chiaroni D, Terzi S. Exploiting 3-D printing for designing circular business models: A novel framework. *IEEE Transactions on Engineering Management*. 2023;**71**:9342-9356. DOI: 10.1109/tem.2023.3330682
- [19] Zhong S, Pearce JM. Tightening the loop on the circular economy: Coupled distributed recycling and manufacturing with recyclebot and RepRap 3-D printing. *Resources, Conservation and Recycling*. 2018;**128**:48-58. DOI: 10.1016/j.resconrec.2017.09.023
- [20] Dimitrijevic B, Stankovic M, Anđelkovic T. Synergy between the circular economy and 3D printing. *Ekonomski Signali*. 2023;**18**(2):49-68. DOI: 10.5937/ekonsig2302049d
- [21] Kirchherr J, Reike D, Hekkert M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resources Conservation and Recycling*. 2017;**127**:221-232. DOI: 10.1016/j.resconrec.2017.09.005
- [22] Nunez-Cacho P, Gorecki J, Molina-Moreno V, Corpas-Iglesias FA. What gets measured, gets done: Development of a circular economy measurement scale for building industry. *Sustainability*. 2018;**10**(7):2340. DOI: 10.3390/su10072340
- [23] Chen P, Dagestani AA. What lies about circular economy practices and performance? Fresh insights from China. *Journal of Cleaner Production*. 2023;**416**:137893. DOI: 10.1016/j.jclepro.2023.137893
- [24] McDonough W, Braungart M. *Cradle to Cradle: Remaking the Way we Make Things*. New York: North Point Press; 2002
- [25] Kopnina H. Circular economy and cradle to cradle in educational practice. *Journal of Integrative Environmental Sciences*. 2018;**15**(1):119-134. DOI: 10.1080/1943815x.2018.1471724
- [26] Bjorn A, Hauschild MZ. Cradle to cradle and LCA – Is there a conflict? In: *Proceedings of the 18th CIRP International Conference on Life Cycle Engineering*; 2-4 May 2011; Braunschweig, Germany. Berlin: Springer; 2011. pp. 599-604. DOI: 10.1007/978-3-642-19692-8_104
- [27] Bjorn A, Hauschild MZ. Cradle to cradle and LCA. In: Hauschild MZ, Rosenbaum RK, Olsen SI, editors. *Life Cycle Assessment: Theory and Practice*. Cham: Springer; 2017. pp. 605-631. DOI: 10.1007/978-3-319-56475-3_25
- [28] Toxopeus ME, Koeijer BLAD, Meij AGGH. Cradle to cradle: Effective vision vs. efficient practice? *Procedia CIRP*. 2015;**29**:384-389. DOI: 10.1016/j.procir.2015.02.068
- [29] Fogarassy C, Finger D. Theoretical and practical approaches of circular

economy for business models and technological solutions. *Resources*. 2020;**9**(6):76. DOI: 10.3390/resources9060076

[30] Lahti T, Wincent J, Parida V. A definition and theoretical review of the circular economy, value creation, and sustainable business models: Where are we now and where should research move in the future? *Sustainability*. 2018;**10**(8):2799. DOI: 10.3390/su10082799

[31] Gam HJ, Cao H, Farr C, Heine L. C2CAD: A sustainable apparel design and production model. *International Journal of Clothing Science and Technology*. 2009;**21**(4):166-179. DOI: 10.1108/09556220910959954

[32] Chong S, Chiu H, Liao Y, Hung S, Pan G. Cradle to cradle® design for 3D printing. *Chemical Engineering Transactions*. 2015;**45**:1669-1674. DOI: 10.3303/cet1545279

[33] Huang SH, Liu P, Mokasdar A, Hou L. Additive manufacturing and its societal impact: A literature review. *The International Journal of Advanced Manufacturing Technology*. 2013;**67**:1191-1203. DOI: 10.1007/s00170-012-4558-5

[34] Pasricha A, Greeninger R. Exploration of 3D printing to create zero-waste sustainable fashion notions and jewelry. *Fashion and Textiles*. 2018;**5**:1-18. DOI: 10.1186/s40691-018-0152-2

[35] Li Y, Lee YA. Modularity in 3D printed backpack. *International Textile and Apparel Association Annual Proceedings*. 2022;**78**(1):1-5. DOI: 10.31274/itaa.13456

[36] Mendoza HR. 3D Printed Fashion Presents Dresses Which Are Actually Comfortable. 2014. Available from:

<https://3dprint.com/16385/3d-printed-fashion/> [Accessed: June 5, 2025]

[37] Spahiu T, Canaj E, Shehi E. 3D printing for clothing production. *Journal of Engineered Fibers and Fabrics*. 2020;**15**:1-8. DOI: 10.1177/1558925020948216

[38] Moreno E, Beltran FR, Arrieta MP, Gaspar G, Muneta LM, Carrasco-Gallego R, et al. Technical evaluation of mechanical recycling of PLA 3D printing wastes. *Proceedings*. 2021;**69**(1):19. DOI: 10.3390/cgpm2020-07187

[39] Dananjaya SAV, Chevali VS, Dear JP, Potluri P, Abeykoon C. 3D printing of biodegradable polymers and their composites—current state-of-the-art, properties, applications, and machine learning for potential future applications. *Progress in Materials Science*. 2024;**146**:101336. DOI: 10.1016/j.pmatsci.2024.101336

[40] Faidallah RF, Hanon MM, Szakal Z, Oldal I. Biodegradable materials used in FDM 3D printing technology: A critical review. *Journal of Modern Mechanical Engineering and Technology*. 2022;**9**:90-105. DOI: 10.31875/2409-9848.2022.09.11

[41] Silva RRA, Marques CS, Arruda TR, Teixeira SC, Oliveira TVD. Biodegradation of polymers: Stages, measurement, standards and prospects. *Macromolecules*. 2023;**3**(2):371-399. DOI: 10.3390/macromol3020023

[42] Lanzotti A, Martorelli M, Maietta S, Gerbino S, Penta F, Gloria A. A comparison between mechanical properties of specimens 3D printed with virgin and recycled PLA. *Procedia CIRP*. 2019;**79**:143-146. DOI: 10.1016/j.procir.2019.02.030

[43] Kassab A, Nabhani DA, Mohanty P, Pannier C, Ayoub GY. Advancing plastic

- recycling: Challenges and opportunities in the integration of 3D printing and distributed recycling for a circular economy. *Polymers*. 2023;**15**(19):3881. DOI: 10.3390/polym15193881
- [44] Patti A, Acierno S, Cicala G, Zarrelli M, Acierno D. Assessment of recycled PLA-based filament for 3D printing. *Materials Proceedings*. 2021;**7**(1):16. DOI: 10.3390/iocps2021-11209
- [45] Bhagia S, Bornani K, Agrawal R, Satlewal A, Durkovic J, Lagana R, et al. Critical review of FDM 3D printing of PLA biocomposites filled with biomass resources, characterization, biodegradability, upcycling and opportunities for biorefineries. *Applied Materials Today*. 2021;**24**:101078. DOI: 10.1016/j.apmt.2021.101078
- [46] Vink ET, Davies S. Life cycle inventory and impact assessment data for 2014 Ingeo™ polylactide production. *Industrial Biotechnology*. 2015;**11**(3):167-180. DOI: 10.1089/ind.2015.0003
- [47] Anwajler B, Witek-Krowiak A. Three-dimensional printing of multifunctional composites: Fabrication, applications, and biodegradability assessment. *Materials*. 2023;**16**(24):7531. DOI: 10.3390/ma16247531
- [48] Calvo-Flores FG, Martin-Martinez FJ. Biorefineries: Achievements and challenges for a bio-based economy. *Frontiers in Chemistry*. 2022;**10**:973417. DOI: 10.3389/fchem.2022.973417
- [49] Rudnik E, Briassoulis D. Degradation behaviour of poly (lactic acid) films and fibres in soil under Mediterranean field conditions and laboratory simulations testing. *Industrial Crops and Products*. 2011;**33**(3):648-658. DOI: 10.1016/j.indcrop.2010.12.031
- [50] Emadian SM, Onay TT, Demirel B. Biodegradation of bioplastics in natural environments. *Waste Management*. 2017;**59**:526-536. DOI: 10.1016/j.wasman.2016.10.006
- [51] Amrita MA, Panda RC. Biodegradable filament for 3D printing process: A review. *Engineered Science*. 2022;**18**(7):11-19. DOI: 10.30919/es8d616
- [52] Agbakoba VC, Webb N, Jegede E, Phillips R, Hlangothi SP, John MJ. Mechanical recycling of waste PLA generated from 3D printing activities: Filament production and thermomechanical analysis. *Macromolecular Materials and Engineering*. 2024;**309**:1-14. DOI: 10.1002/mame.202300276
- [53] Cuadri AA, Martin-Alfonso JE. Thermal, thermo-oxidative and thermomechanical degradation of PLA: A comparative study based on rheological, chemical and thermal properties. *Polymer Degradation and Stability*. 2018;**150**:37-45. DOI: 10.1016/j.polyimdegradstab.2018.02.011
- [54] Anderson I. Mechanical properties of specimens 3D printed with virgin and recycled polylactic acid. *3D Printing and Additive Manufacturing*. 2017;**4**(2):110-115. DOI: 10.1089/3dp.2016.0054
- [55] Hong J, Yu T, Park S, Kim Y. Repetitive recycling of 3D printing PLA filament as renewable resources on mechanical and thermal loads. *International Journal of Modern Physics B*. 2020;**34**(22n24):2040147. DOI: 10.1142/s0217979220401475
- [56] Gomes TE, Cadete MS, Dias-De-Oliveira J, Neto V. Controlling the properties of parts 3D printed from recycled thermoplastics: A review of current practices. *Polymer Degradation and Stability*.

2022;**196**:109850. DOI: 10.1016/j.polymdegradstab.2022.109850

[57] Desai SM, Sonawane RY, More AP. Thermoplastic polyurethane for three-dimensional printing applications: A review. *Polymers for Advanced Technologies*. 2023;**34**(7):2061-2082. DOI: 10.1002/pat.6041

[58] Gao X, Qian H, Wang J, Hong Y, Chen Y, Zhao L, et al. Self-reinforced thermoplastic polyurethane composite with excellent mechanical properties, heat resistance and sustainable recycling. *Composites Part B Engineering*. 2025;**297**:112342. DOI: 10.1016/j.compositesb.2025.112342

[59] Kim J, Qudsi YH, Mok J, Lenges C, Simon L. Engineered polysaccharide alpha-1,3-glucan in highly filled thermoplastic polyurethane systems. *Journal of Applied Polymer Science*. 2023;**140**(43):1-13. DOI: 10.1002/app.54051

[60] Kyriakidis IF, Kladovasilakis N, Pechlivani EM, Tsongas K. Mechanical performance of recycled 3D printed sustainable polymer-based composites: A literature review. *Journal of Composites Science*. 2024;**8**(6):215. DOI: 10.3390/jcs8060215

[61] Vidakis N, Petousis M, Mountakis N, David CN, Sagris D, Das SC. Thermomechanical response of thermoplastic polyurethane used in MEX additive manufacturing over repetitive mechanical recycling courses. *Polymer Degradation and Stability*. 2023;**207**:110232. DOI: 10.1016/j.polymdegradstab.2022.110232

[62] Calvo-Correas T, Benitez M, Larraza I, Ugarte L, Pena-Rodriguez C, Eceiza A. Advanced and traditional processing of thermoplastic polyurethane waste.

Polymer Degradation and Stability. 2022;**198**:109880. DOI: 10.1016/j.polymdegradstab.2022.109880

[63] Bugin LAK, Candido LHA. Recycling cycle of materials applied on thermoplastic polyurethane. *International Journal of Advances in Engineering & Technology*. 2019;**12**(1):1-10

[64] Patagonia. Recycled TPU. Available from: <https://www.patagonia.com/our-footprint/recycled-tpu.html> [Accessed: June 19, 2025]

[65] Mate. Dress Clean. Available from: <https://matethelabel.com/pages/about> [Accessed: June 19, 2025]

[66] Stateless. How Can Fashion Designers Partner with Governments to Implement Eco-Friendly Policies in 2024?. Available from: <https://blog.stateless.nyc/how-can-fashion-designers-partner-with-governments-to-implement-eco-friendly-policies-in-2024/> [Accessed: June 19, 2025]

Section 3

Innovative Approaches
to Business

Chapter 6

The Creative Approach in International Business Research (Islamic Context)

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Abstract

The chapter introduces a new and innovative methodology of researching international business in the context of the Islamic world, which has not been explored properly due to the growing world interest in the business ethics of the Islamic world and the widening surface of globalization. Whereas research on international business has advanced in other cultural areas, there is a little understanding on how the groundbreaking system of research can meet and/or support the Islamic tenet. This chapter is based on the systematic review of the available literature and qualitative design of research to examine the intersections of creativity and global business with the Islamic ethical foundations. It suggests the Islamic model of a creative business research that focuses on three main concepts *ijtihad* (independence of reasoning), *istihsan* (judicial preference), and *maslaha* (public interest). The chapter reveals that the practice of these principles leads to the development of both moral integrity and methodological novelty of scholarly work in international business. Besides, it provides experience-based advises to both research agencies as well as practitioners who have to work through the challenges of running business in culturally and religiously varied contexts. Insights into the empirical results add more lenses to the ways in which creativity in cross-cultural business is understood and can thus show how Islamic jurisprudence can introduce ethical and innovative business research practices in global business environment.

Keywords: Islamic finance, *Sukuk*, *Murabaha*, *Ijarah*, *Zakat*, *Waqf*, *Takaful*, *halal* markets, Islamic banking, ethical research, design thinking, financial inclusion, business innovation, transparency, bias reduction

1. Introduction

This is also because in a more globalized world of business, researchers are presented with complex issues requiring solutions beyond normal cultural and religious parameters and therefore requiring creative developments. The point where international business research and Islamic principles meet is a very rich and at the same time unexplored field of research. As there are about 1.8 billion Muslims globally and

Islamic economies currently play an enormous role in the international markets, it has now become critical to know how Islamic systems could be designed in a way that generates creativity among scholars and practitioners [1, 2]. The culture of creativity in business research traditionally promotes innovation, creative thinking, and innovative methods. These methods should, however, be localized into the value system of cultures in which one intends to know. The Holy Quran and Sunnah are the basis of the Islamic principles that form a complete ethical system to govern every behavior in all spheres of life, including business and research activities. The difficulty is in balancing between the modern techniques of research in the art field and these deeply rooted Islamic positions [3].

There are some key questions to be discussed in this chapter: How can innovative research methodologies be implemented in the case of international business, and at the same time be consistent with Islam? How can Islamic thinking be used to aid businesses in developing creativity in research? What are how will researchers avoid the possible conflict between the current research activities and the traditional Islamic values? The relevance of these questions is especially attributable to the fact that the Muslim-majority markets are gaining more and more importance in business, and ethical considerations are becoming more and more important in global business activity.

This chapter has three purposes: first, to critically evaluate available knowledge on creativity in international business studies with particular reference to Islamic communities; second, to come up with a model of research that integrates vital Islamic values; and third, to offer guidelines to usable by scholars on the path of conducting research in this arena of knowledge that is interdisciplinary. This chapter helps in clarifying the theoretical concept of the determination of research methods in international business by observing these objectives.

It is not just an academic piece of work. With a growing interest of businesses in working with various markets, it is becoming a current-day practice to know how to carry out creative research within reasonable cultural boundaries. As much as this chapter addresses the Muslims and non-Muslim researchers, it also provides researchers with reflections on how to carry out research that upholds the Islamic values, ensuring research innovation and creativity with cross-cultural applicability of the research in all aspects.

2. Conceptual foundations of creativity in business research

Business research creativity is a compound phenomenon that has taken a different form in the current decades. In the center, creativity involves creating original ideas, strategy, or methods, which is personally attributable to insights in business phenomena [4]. Creativity, in the research of international business, has more prospective dimensions to follow as it bears the cross-culture complexities and variety in the business dynamics. Conceptualization of creativity typical of the west is usually individualistic, disruptive, and contrarian to authority, factors which can be demanding to recontextualize when transposed in varied cultural domains.

Modern-day studies on business have become aware of the fact that creativity is a crucial element in the solution of complex global issues. Results of this have taken the form of methodological advances in mixed-methods research, participatory research methods, and interdisciplinary methodologies linking formerly distinct spheres [5]. Creative methods in business research represent a more general change in the epistemological awareness that is taking place in business research that is shifting

its predominantly positivist focus in a direction taking heed of socially constructed nature of the business realities, and progress toward more interpretive and constructivist perspectives.

Taking a closer look at creativity in the context of research methodology in particular, there are a couple of important things that can be considered. Unconventional strategies of research can include versatile designs, adjusting to new ideas on the fly, novel data gathering procedures capable of observing phenomena that were previously unseen, and new methods of analysis, which bring patterns and connections into focus otherwise unavailable using standard measures [6]. Such methodological innovations are especially relevant in cases of international business when investigators operate in alien cultural environments and relationships with a variety of multiple stakeholders.

2.1 Divergent thinking

There is a possibility to discuss various potential solutions and search strategies, rather than limiting the focus to already established methodologies. This reflects a readiness to explore alternative ideas and pursue different explanations in business research.

2.2 Interdisciplinary integration

Interrelating existing spheres of knowledge can lead to the creation of new insights. An extensive understanding often emerges when knowledge from other fields, such as psychology, sociology, and economics, is creatively applied in business research.

2.3 Contextual sensitivity

Reconciling research methodologies with cultural, social, and institutional contexts is essential, particularly when conducting international business studies across diverse cultural settings. These conceptual foundations provide the background against which Islamic views on creativity must be examined. The subsequent chapters will explore how these broad definitions of creative research interrelate with, and are subject to modification by, Islamic values and principles, ultimately forming a synthesis that aligns creative innovation with Islamic ethical frameworks.

The latter conceptual grounds present the background in which Islamic views on creativity have to be looked at. The subsequent chapters will introduce the manner through which these broad definitions of the concept of creative research interrelate with and are subject to being modified by the Islamic types of values and principles, creating the foundation of the synthesis that accords with both creative innovation and Islamic types of ethical frames.

3. Islamic perspectives on creativity and knowledge creation

The Islamic view of creativity and generation of knowledge is unique, and it varies substantially with those in the West. Creativity (*ibda*) in Islam can be interpreted as human intellect and imaginations, used by humans within the context of the systems set out by divine guidance. The Islamic view differs from secular perspectives that

often perceive creativity as an act of free or autonomous discovery. In contrast, Islam understands creativity as the process of uncovering or discovering within a divinely ordered cosmos. Unlike the concept of ex-nihilo creation, creating from nothing, which is a power attributed to Allah alone, human creativity is seen as a means of exploring and expressing what already exists within God's creation [7]. This theology has a great influence on the conceptualization and practice of creativity in Islam.

Islamic philosophy of knowledge production is based on some major principles as evidenced in the Holy Quran and Sunnah. *Tawhid* (Divine unity) generates the idea that all knowledge has only one source, namely, Allah, and thus represents a whole and not disintegrated discipline. This comprehensive perspective fosters cross-disciplinary thinking and interconnection of expertise from various fields. *Ilm* (knowledge) is one of the core principles of Islamic thought, and knowledge acquisition is regarded as a religious duty. Importantly, the Islamic school of thought does not define knowledge on a religious-secular boundary but defines it as being beneficial or harmful depending on the effects it has on human well-being [8].

Some of the Islamic jurisprudential ideologies offer platforms to innovative problem-solving and knowledge-building. *Ijtihad* (independent reasoning) is the intellectual endeavor of coming up with answers to new cases that are not commonly tackled in the primary sources directly. The process promotes innovative thinking within the accepted ethical premises. *Istihsan* (juristic preference) enables the scholar to pursue a solution that may technically lead to a technical violation of the established analogies, but is more effective with the spirit of the Islamic law. *Maslaha* (public interest) considers human welfare as a standard to check the novelty of any new concept or way [9]. A combination of these principles creates a structure that not only fosters creativity in thinking but also puts a limit on such ethics.

3.1 Godly criteria of creativity

In Islamic philosophy, creativity in humanity is interpreted as discovery and innovation with the confines set by God as opposed to ex nihilo. This perspective influences the manner in which Muslims go about the business of innovation by looking at innovating wisely, which does not disregard human weaknesses.

3.2 The knowledge as an entirety

Coming about based on tawhid (Divine unity), the Islamic epistemology considers all knowledge to be related and unified in a single origin. This fosters cross-disciplinary research and integrative research in business research as opposed to increased specialization.

3.3 Ethical limits of the innovation

Islamic theories of creativity highlight that an innovation should work within the ethical context based on Quran and Sunnah. This offers a piece of advice to researchers who have to move between creative investigation and ethical responsibility.

All these Islamic views on creativity and generation of knowledge carry enormous implications toward studies in business. They propose a way of thinking that is both

rooted in ethical ground and respects innovation, posits a whole way of thinking among boundaries between disciplines, and accords value to new ideas on the basis of their human welfare rather than economic payoff. This framework presents distinct opportunities in the improvement of creative strategies that can be utilized in international business research with regard to the situations that involve the values of Islam economic dynamics and business operations.

4. Literature review: Creativity in international business research

4.1 Traditional development of creative approaches

The development of the creative methods of international business research is traceable in several stages that can be outlined as a wider transformation of the management thought. The initial research studies on international business (1960s–1970s) were mostly carried out using methodologies that were in the positivist framework, including the study of measurable things like trade movements and foreign direct investment. Creativity was up to the theoretical modeling at the base of the established paradigms [10]. The cultural turn in studies of international business (1980s–1990s) and its most well-known representative, the dimensional model of Hofstede [11] and later refined in the GLOBE project, brought more methodological variety and interdisciplinary conceptualization, and this was named as seeing a growth in novel ways of creative research, cross-disciplinary studies taking into account predominantly anthropological and sociological ideas.

There has been a considerable growth in innovative approaches to the research on international business today. Scholars such as Doz and Birkinshaw et al. consider the practice, which combines the strategies of qualitative and quantitative research, longitudinal analyses, and participatory mechanisms [5, 12]. Incessancy of context-specificity in phenomena of international business has also motivated innovative adaptations of research techniques to various cultural environments. However, new research has emphasized the necessity of indigenous theoretical approaches that oppose the Western-based frameworks and that signify a conceptual resurgence in the production of knowledge in the discipline [13].

4.2 Current state of research at the intersection of creativity, international business, and Islamic contexts

The study of specifically research about creativity in international business in Islamic circumstances is still in its immaturity stage, but there are a few influential works that have been published. Gümüşay discussed the issue of entrepreneurship in the context of the Islamic religion, indicating the influence of religious values on innovations in carrying out business [1]. Ramadani et al. analyzed the effect of Islamic values on family business innovation in Southeast Asian markets [14]. Hassan et al. explored the abilities of innovation in solving problems in Islamic financial institutions and discussed how the need to ensure compliance with *Shariah* limits and induces the innovative thinking process [15].

Evaluation of the existing literature shows several important gaps. To start with, the majority of research dwells on a particular industry (especially Islamic finance) instead of considering the research methods with innovations more generally. Second, it does not go far in considering how the Islamic epistemological viewpoint may even enhance the creativity in research, and not just provide ethical guidelines.

Third, scholars assume uniformity when they generalize the Islamic contexts without considering similarities and differences in the Muslim-majority markets. Lastly, the integration between the Western theories of creativity and Islamic values has proven to be rather inadequate as few studies do consider them a joint field, but rather treat them as distinct ones [3, 16]. This review of the literature suggests an increase in interest in the search of the answers to the question of how the business can become more creative based on Islamic grounds and how huge the potential is of the basic theory development and research. This premise will therefore be the basis of forming up frameworks in the succeeding sections aimed at closing these noted gaps.

5. Theoretical framework: Integrating Islamic principles with creative research approaches

In order to fill the identified gaps in the literature review, in this section, the theoretical framework is proposed that incorporates the Islamic principles into the approaches of the modern creative research in the area of international business. Such an integration must take into account, on the one hand, the basic Islamic ideas applicable to knowledge production and, on the other hand, the main aspects of innovative research practices, trying to find a common ground and effective conflict between these two traditions.

The essence of this paradigm is the theory of *maqasid al-Shariah* (higher objectives of Islamic law), which offers a moral dimension of weighing innovative approaches. Scholar Al-Ghazali, among other scholars, as well as modern translations by Auda [17], seems to assume that *maqasid* involves the conservation and benefaction of religion (*din*), self (*nafs*), mind (*aql*), posterity (*nasl*), and property (*mal*). More recent growths have entailed such concepts as justice, human dignity, and freedom. These goals capture not only the creative possibilities of inquiries but also the moral limits of research practices. As an example, the research methodologies, which advance human welfare and at the same time respect human relations, would meet the *maqasid*, although they would be based on innovative procedures that the classic texts do not directly cover.

5.1 Ethical foundation

Maqasid al-Shariah (concerns of Value).

5.2 Epistemological principles

Tawhid (Unity), *Ilm* (Knowledge), *Amanah* (Trust).

5.3 Methodological approaches

Ijtihad (Independent Reasoning), *Istihsan* (Juristic Preference), *Shura* (Consultation).

5.4 Research applications

Participatory Methods, Mixed Approaches, Contextual Adaptation, Ethical Reflection.

5.5 Practical outcomes

5.5.1 Socially beneficial research, ethical business practices, culturally appropriate innovation, sustainable development

The second layer of the framework refers to the epistemological principles. Divine unity, an Islamic understanding, goes by the name *tawhid*, implies that knowledge is not divided into disciplines, but constitutes one. This augers well with the current trend in international business research, which has been to focus on interdisciplinary studies and systems thinking. The importance of *amanah* (trust) similarly is aimed at researchers as the guardians of knowledge who have a duty to participants, communities, and societies and chimes with modern interest in research ethics and stakeholder involvement. These principles of epistemology define the conceptualization of the role of researchers and their relationship with creating knowledge.

Islamic concepts are also helpful at the methodology level where they could be used to design creative studies or research projects. *Ijtihad* (independent reasoning) warrants innovation in coming up with new methods of research in the case that existing ones are inadequate as long as the new approach does not conflict with essential principles. *Istihsan* (juristic preference) is an aid to methodological decisions that will not follow traditional decisions when this is more suitable to research purposes. *Shura* (consultation) focuses attention on collaborative and participatory research design employing different stakeholders, especially the ones affected by the phenomenon being studied.

This holistic approach would imply various specific courses of actions that would embody creative research within the Islamic context, such as (1) participatory models of research in which the knowledge of the community would be valued and considering the stakeholders as co-researchers rather than as subjects; (2) mixed-method research that would serve the purpose of overcoming the limitation of a single methodology; (3) contextual trending of research tools that would help avoid the dangers of cultural and religious sensitivity of individuals; and (4) explicit consideration of the ethics of the research process. Through this, researchers will be able to find innovative ways of performing the research, which does not compromise the originality of the research that propounds Islamic values that apply to international business practices.

6. Methodology for researching creativity in Islamic business contexts

This part outlines a methodological approach to the culturally competent study of creativity in Islamic international business settings in an exhaustive way. The medley between religion, culture, and business is so complicated that a mixed-methods approach, relying on methods based on qualitative and quantitative research, is suggested as a method for planning to consider depth, as well as to achieve generalizability.

The main research considerations are:

- Having in mind the diversity of the Islamic practices, as well as schools of thought, it is important to consider the following Islamic practices.
- And that, being careful not to generalize about cultures,

- Engaging in reflexivity, particularly of non-Muslim researchers,
- Creation of ethical integrity that is in tandem with Islamic values.

This methodology is designed in a number of steps:

Exploratory phase: The exploratory phase employs qualitative methods such as interviews, focus groups, and observations to identify key themes and cultural underpinnings of creativity.

Instrument development: This is the development or adaptation of items appropriate to the culture and religion so as to fit the needs of the research that is commonly done in cooperation with Islamic scholars and practitioners.

Quantitative investigation: Uses surveys or experiments to examine interrelationships between key variables identified in the precedent quantitative investigation.

Integration and interpretation: a combination of the results of the two methods with an interpretation reducing them to international business theory and Islamic principles.

Good examples of data collection techniques are narratives, case studies, and participatory research (based on the Islamic principle of *shura*). Such approaches bring to life the experiences and moral limitations of Islamic creativity in business.

Thought processes must also account for both intellectual and ethical considerations. These considerations involve methodological approaches such as interpretation, phenomenological analysis, content and comparative analysis, and network analysis. Throughout this process, researchers should remain critically reflective of themselves and the potential biases and positional influences in their research.

To sum up, the presented flexible but solid framework can be used to investigate creativity within Islamic business in a locally contextualized way that must balance the rigor of the methodology and the Islamic ethical and cultural considerations.

7. Ethical considerations in creative business research

The work at the interface between the creative practice and Islamic principles in the research on international business requires the necessity to focus on ethical considerations that go beyond the established norms of research ethics. This part discusses particular ethical issues that occur in this sphere and suggests what principles should be applied to cover those problems in Islamic ethics.

On a fundamental level, Islamic ethics in research is rooted in the broader Islamic moral and legal system, which is based on the Holy Quran and Sunnah. Among its important principles are respect for human dignity (*karamah*), justice (*adl*), beneficence (*ihsan*), and non-maleficence (*la darar*). These values are consistent with most Western research ethics systems, but usually bear some other aspects or priorities. To give an example, the Islamic concept of justice goes beyond procedural fairness toward distributive justice, which involves sharing the benefits of research with the communities that participate in it [18].

In using innovative methods of research in Islamic business, several particular moral obstacles appear. To begin with, the need of innovative research techniques may imply the application of practices that would contradict with Islamic beliefs like deception in the research design, or some kind of incentives that can be interpreted as unethical or tantamount to gambling (*maysir*). Second, a creative way of thinking is often transgressive in terms of disciplines, which may be critical in terms of expertise

and authority, especially in light of a religious power influencing business activities. Third, the power differentials apparent in most research relationships can be compounded by the study of Islamic business in situations where the researchers are non-Islamic, and this poses the issue of representation and interpretation.

7.1 Transparency and informed consent

In addition to the regular informed consent practices, the researchers must be transparent concerning the objects, schemes, and possible applications of the research in the language that participants can understand. This is in line with Islamic propensity toward trustworthiness (*amanah*) and truthfulness (*sidq*).

7.1.1 Dignified observation of religious values

Investigators are required to exhibit respect of the Islamic ideals in case they disagree with their own. This will involve meeting religious observances in provided research (e.g., prayer times), not using research designs that also pose cognitive incompatibility with Islamic ethos, and interpreting them to Islamic scholarship as opposed to use of obtuse paradigms.

7.2 Benefit to the community and information sharing

The research itself must support the communities being studied, and there must be concrete thought about how research can be disseminated to and possibly benefit Muslim business communities. This is based on the Islamic view of *maslaha* (public interest) and covers the case regarding extractive research practice.

7.3 Reflexivity and positionality

The researchers are advised to be critically reflexive concerning their own positionality, especially in religion and culture. This involves accepting the fact that some questions are beyond understanding, and proper consultation is necessary with those who have the lived experience and religious knowledge that may help in answering the questions.

Researchers may take into consideration several pragmatic ways of operationalizing these ethical principles. Forming advisory boards consisting of Islamic scholars and practitioners at the business can help in giving the answers to ethical questions in the entire course of the research process. Putting the Muslim business communities in positions of co-researchers as opposed to experimental subjects in collaborative research designs can help remove the problem of power imbalance. Accountability would be improved when results are reported transparently, together with methods used; thus, this should focus on the implementation of Islamic principles in making research decisions. Lastly, the ethical review process must be extended beyond the institutional needs of the particular Islamic communities within the country.

Through adherence to such ethical considerations, however, researchers can adopt innovative ideas that are sensitive toward the Islamic customs without compromising the useful information to the body of international business knowledge. This ethical framework does give limits to not merely ethical conduct but also positive direction to build research designs that reflect lessons of respect, justice, and beneficence, all of which are values that cut across research traditions with certain forms of expression in the Islamic ethics.

8. Case studies: Creative research approaches in Islamic business contexts

This part comes with three case studies that have some examples of creative research spaces in the Islamic business settings. These examples exemplify that researchers have managed to blend the innovative methodologies and Islamic principles and offer real examples of the theoretical construct demonstrated above. Both cases show various facets of innovation in terms of research design, realization, and transmission of knowledge.

8.1 Case study 1: Islam and participatory action research on microfinance

A team of researchers working on the project entitled Innovation in Islamic microfinance Institutions in Indonesia used the participatory action research (PAR) approach to create new financial products that could better suit the local communities in the rural areas and remain compliant with *Shariah*. Instead of placing their outside models, researchers invited local Islamic scholars, microfinance practitioners, and members of the community to act as co-researchers. Using jointly organized workshops following the Islamic concept of *shura* (consultation), the group came up with conflict areas between current microfinance products and local economies. The process of conducting research allowed *ijtihad* (independent reasoning) by providing participants with an opportunity to observe anew conventional meanings of Islamic financial principles through a prism of contemporary pressures.

The innovative strategy came up with several innovative financial instruments, such as a variant of *mudarabah* (profits-sharing) structure, more appropriate to an agrarian environment where income is seasonal. The research methodology alone was rather innovative, provided that it represents the combination of Western PAR models and Islamic pathways of decision-making methods, visual mapping tools that are available to people with different literacy levels, and the creation of continuative boards of local reviews that could occasionally assess the ethical and religious aspects of the offered innovations. This example shows that even when using science in an Islamic manner, innovations that can be applied in practice and improve the well-being of communities will be created as a result of creative research practices.

8.1.1 Indonesian microfinance participatory methods

Workshops on partnerships involving Islamic scholars, microfinance experts, and community participants are organized to develop *Shariah*, compliant financial products that address local economic needs.

8.1.2 Gulf banking: Ethnographic research

Ethnography in Islamic financial institutions in the states of the Gulf region, studying the process of work of creativity and innovation in highly regulated *Shariah*-compliant systems.

8.1.3 Mixed-methods research Muslim tech entrepreneurs

Combining quantitative measures of creativity and qualitative narrative interviews to find out how Muslim entrepreneurs in the technology area become innovative due to the religious context.

8.2 Case study 2: Islamic banking innovation as an ethnographic research

The longitudinal ethnographic study of the innovation processes in Islamic financial institutions of countries included in the Gulf Cooperation Council showed creativeness in the research design process and approaches to analysis. The researcher was able to go behind the scenes of *Shariah* boards that are usually closed doors sessions, and this could be attributed to the fact that the researcher had built trust within them after they realized he was respectful of the Islamic values as well as understand all his research intentions. The approach to it was shadowing important folks from all the departments, from product development to *Shariah* compliance, and witnessing how ideas went through several approval levels.

The critical imagination was the innovative development of a model of the process with which creative ideas are transformed according to the interaction with the structures of religion. Instead of just naming the *Shariah* constraints as a limiting factor in innovativeness, the analysis indicated the tendency of the religious parameters to impose more innovative solutions than would have arisen in the case of traditional banking. To convey these complicated interconnections between creative and religious sceneries, the researcher formulated visual mapping methods to show the process of accommodation of early thoughts as they were polished but not necessarily accepted or denied. This case shows how innovative research methods can drive out the subtle innovation process of knowledge in religiously informed settings and help dislodge simplistic accounts of religion as a curb on creativity.

8.3 Case study 3: Asking a mixed-methods research to Muslim tech entrepreneurs

A case study on Muslim technology innovators of Malaysia and the United Kingdom adopted a novel mixture of the method research methods to comprehend how religious values informed the innovative development of businesses. The study started with the modified psychometric scales of creativity, which include the dimension of Islamic values, and then the interview study was conducted based on narratives to examine the experience of participants in trying to reconcile conflicts raised by technological advances and religious beliefs. These methods were supplemented by digital ethnography of online communities of the Muslim entrepreneurs, which documented the movement and appraisal of ideas through those networks.

The innovative aspect of this study was the use of approaches and techniques joined together. The researcher's proposal an innovative method of analytical structure that traces associative links among quantitative patterns of creativity and qualitative themes of narrative, locating trend lines in the manner entrepreneurs of diverse creative styles negotiated religious factors. The results overturned the dichotomous characterizations of the so-called traditional and innovative methods and highlighted the importance of the fact that Islamic values were frequently used not as limitations but rather as a source of creativity. The case demonstrates that methodological creativity can help create finer insights about the connection between religious values and business innovation than would have been possible using traditional research designs.

9. Challenges and limitations in applying creative approaches

Although innovative research methods can provide good understanding of the foreign business in the context of Islamic conditions, it has rather significant

epistemological, methodological, and practical limitations that should be of great attention.

9.1 Epistemological challenges

There is a major tension between innovative research paradigm and orthodox Islamic epistemology. Traditional Islam scholarship emphasizes established interpretive systems and agreement (*ijma*) that can be opposed to innovative approaches that seem to focus on novelty instead of orthodoxy [19, 20]. This is more prominent in the areas where the religious and business motives meet as is the case of Islamic finance and the halal industries. Moreover, unlike creative research, Islamic theory of knowledge takes into account the importance of certainty and textual fidelity. In the absence of a proper foundation of Islamic jurisprudence, the risk of researchers becoming excessively inclined toward nonreligious approaches is high.

9.2 Methodological challenges

The inherent assumptions in creative approaches designed in the Western context might not be compatible with Islamic morals, such as conducting a study with deception, a reward system that is similar to *riba* (interest) or *maysir* (gambling), which are both expressly prohibited in Islam. It takes innovation and literacy in religious matters to accommodate these methods to Islamic contextual realities without sacrificing the integrity of research. There are also issues regarding positionality: Muslim researchers can be suspected of bias, and non-Muslim researchers can be ill-versed on cultural and theological levels. Yes, interreligious joint-research partnerships could be a productive middle ground, but power relationships and interpretive control have to be managed [21].

9.3 Practical constraints

Researchers might find conservative business communities hard to access, have little institutional support from secular and Islamic institutions, and have a hard time publishing the religion-oriented studies in the professional journals.

9.4 Ethical dilemmas

The conflicting issue of ethical tension can be seen within the academic freedom and the sacredness of the religious fiber. The proper reflection of the diversity of the Islamic interpretations and the lack of misuse of the findings to create a stereotype is a central issue.

9.5 Issues of knowledge translation

These problems can be associated with the clear expression of findings over the religious and cultural borders and with the formulation of theoretical frameworks that not only are based on Islamic values but also can be applied to mainstream thought. Besides, the criteria of creative research assessment in Islamic environments are not satisfactorily developed.

However, such demerits aside, such impediments should not deter the scholarship research. Instead, they need reflexivity, cultural sensitivity, and development of

conceptually and culturally suitable research designs that not only respect values of Islam but also do not abdicate on the principles of academic integrity.

10. Opportunities for innovation at the intersection of research traditions

However, despite the barriers, the interaction between creative research and Islamic business environments has an appearance of potential contribution to theory and methodology. The tensions between the Islamic traditions and the practice of research today are not the inevitable points where conflicts may appear; they may become rather productive sources of innovation in the study of international business.

The most notable opportunity is the development of new theoretical models, which combine Islamic ethical concepts, including *maslaha* (public interest), *maqasid al-Shariah* (objectives of Islamic law), and tawhid (Divine unity), and the current business theories. These norms promote humanistic and ethical approaches toward innovation and creativity that do not conform to the Western capitalist demonstrated profitability model [1, 3]. As an example, the concept of *maslaha* shifts the grounds of evaluation to consideration of the common good, whereas tawhid associates the concept of a thinking integrated thinking, which provides new opportunities and introduces new perspectives on how to reconsider business creativity and ethical governance.

Methodologically, Islamic ethical restrictions, for example, the rule against deceit or focus on the welfare of the community, may generate more open, involved, and liberating research designs. These modifications not only follow the guidelines of the Islamic precepts but also increase the authenticity, relevance of the research process, and ethical rigor of research [15].

Also, Islamic interpretations continue to vary within geographical and cultural settings, including Southeast Asia, the Gulf, Turkey, and Western Muslim minorities, which is a rich comparative environment. The exploration of the local interpretation and operationalization of Islamic values enables the researchers to go beyond the notion of the concept of Islamic business and to discover situational manifestations of faith-based entrepreneurship [14].

Most importantly, the practical experience with Islamic epistemologies will lead to epistemic inclusivity in the international business study. Offering critical challenge to the hegemonic position of the Western paradigms, scholars will be able to stretch the scope of the possible knowledge creation, moving toward the pluralistic representation of the global business phenomena that are both ethically sound and locally applicable [1].

Hence, this intersection is not a peripheral niche, but a productive space to speculate business theory and practice. Islam-based creative research has the capability of enhancing the international business research discourse in terms of newer knowledge and more accommodating frameworks, both on a global level.

11. Research findings: Patterns of creativity in Islamic business contexts

Empirical research at the intersection of creativity, international business, and Islamic contexts reveals distinctive patterns that reshape prevailing notions of innovation. These patterns reflect a values-driven orientation, collaborative social processes,

and integrative knowledge practices that distinguish creative approaches within Islamic business environments.

11.1 Values-based innovation

Across contexts, innovation in Islamic settings is primarily guided by ethical considerations rooted in Islamic principles rather than purely market-driven logics. For example, research on Muslim entrepreneurs in Malaysia demonstrates that innovation is assessed through the framework of *maqasid al-Shariah*, often leading to the rejection of profitable ideas conflicting with Islamic values, while encouraging the development of ethically compliant alternatives [15].

Similarly, studies in Islamic financial institutions in the UAE reveal that *Shariah* compliance fosters deeper structural innovation by challenging conventional financial assumptions, positioning Islamic principles not as constraints but as creative stimuli [3].

11.2 Collective and collaborative creativity

Islamic business contexts tend to privilege collaborative over individualistic models of creativity. Empirical work from Indonesian Muslim-owned firms highlights the centrality of *shura* (consultation) in innovation processes, wherein collective wisdom is prioritized [14]. This collective ethos extends to external religious networks, such as mosques and charitable bodies, which function as informal innovation ecosystems facilitating knowledge exchange and community-driven idea generation.

11.3 Stages of ethical-creative practice

Innovation unfolds through identifiable stages:

- *Idea generation*: Emerges from community needs, evaluated against Islamic ethical standards.
- *Collaborative refinement*: Ideas are shaped through *shura*, often involving scholars for religious validation.
- *Ethical evaluation*: Projects undergo formal review *via* Shariah boards or consultants.
- *Implementation*: Execution involves ethical oversight and community feedback to ensure ongoing alignment.

11.4 Knowledge integration

A defining feature is the integration of religious knowledge with business, scientific, and technological expertise. Multinational firms developing halal products, for instance, employ structured mechanisms, such as interdisciplinary teams or early-stage religious consultation, to blend R&D with *Shariah* compliance [16]. In the Gulf, Muslim business leaders adopt ambidextrous strategies, maintaining fidelity to Islamic norms while selectively adapting modern business practices [22]. This selective integration fosters context-sensitive innovation that avoids the binary of full assimilation or rejection.

These patterns reflect a distinctive model of creativity shaped by Islamic epistemologies and socio-ethical frameworks. Recognizing these empirical dynamics contributes to both the refinement of international business theory and the development of culturally grounded innovation practices.

12. Implications for international business theory

Theoretical contributions or insights of creative research in Islamic business contexts provide significant contributions in international business research, questioning assumptions prevailing in the international business research carried out in the West.

12.1 Creativity and innovation reconsidered

The Eastern models of ethical creativity exist in Islamic contexts, where innovation is frozen with regard to the religious beliefs and to group consultation, but not to individualism and market disruptiveness.¹ Such results indicate that a Universalist to context-specific theories that take into account cultural and moral aspects of creativity is needed.

12.2 Development of institutional theory

The religious institutions can be easily ignored by the traditional institutional theory. It is observed that actors such as *Shariah* boards and Islamic legal authorities have key influences on how businesses operate, or at least, how finance-related businesses and entrepreneurship businesses are waged [3, 16]. This necessitates models that consider the interrelationships among the religious, market, and state institutions.

12.3 His/her promotion of cross-cultural management

The Islamic conduct of business contests definite cultural limits as it demonstrates the contextually applied practice of religious values. Islamic ethics combine world strategies put on by entrepreneurs and display multi-dynamic and pluralistic contemporaries [14].

In short, innovative work on Islamic environments contributes to the world theory of business by providing ethically based, culture-specific, and institutionally layered points of view.

13. Practical applications for business researchers

The integration of creative and context-sensitive research approaches has significant implications for scholars studying international business in religiously informed environments. For Islamic contexts, methodological rigor must be paired with ethical and cultural sensitivity. Researchers are advised to begin with consultations involving

¹ Gümüşay [1], Hassan et al. [15, 23], and Ramadani et al. [14] offer empirical investigations of how Islamic principles influence business practices, particularly regarding entrepreneurship, innovation, and financial services.

religious scholars and local business actors to identify appropriate methods and potential sensitivities. Mixed-method designs are particularly effective in capturing the complexity of these environments, while ethical reflection should be embedded throughout the research process [21].

Instrument development requires both linguistic and conceptual adaptation. Standard business constructs, such as innovation, risk, or success, may carry different meanings within Islamic worldviews. Researchers should engage in iterative pilot testing with local participants and collaborate with cultural and religious experts to ensure instruments reflect appropriate conceptual frameworks. Instruments should be revised based on participant feedback to maintain both validity and contextual relevance.

During data collection, researchers must respect religious practices, such as prayer times or gender norms, and remain aware of power dynamics between themselves and participants. Flexible, responsive fieldwork strategies are crucial. Incentives and acknowledgments should align with cultural expectations, and researcher behavior must reflect humility and sensitivity to local norms.

Collaborative partnerships with local scholars are vital for enhancing access, interpretation, and ethical legitimacy. These partnerships should be built on trust, mutual respect, and shared ownership of research processes and outcomes. Non-Muslim researchers should avoid extractive approaches and instead engage in inclusive, equitable collaboration that values local epistemologies and acknowledges diverse contributions [24].

Finally, effective dissemination must address both academic and community audiences. Findings should not only extend theoretical debates but also benefit local stakeholders. Translating findings into accessible formats, including summaries in local languages, and aligning with the Islamic ethic of “*ilm nafi*” (beneficial knowledge), ensures research contributes to community welfare. This approach enhances both the scholarly impact and social value of research in global business contexts.

14. Pedagogical implications: Teaching creative approaches

Insights from creative approaches in Islamic business contexts offer valuable contributions to business education, particularly in curriculum development. Rather than limiting Islamic perspectives to niche areas such as Islamic finance, core courses on creativity, ethics, and research methods should incorporate comparative frameworks that reflect diverse cultural and religious understandings of innovation. Practical recommendations include adapting research methods for religiously informed contexts, developing case studies from Islamic settings, and designing interdisciplinary courses that link business with religious studies and international relations [1, 15]. Such curricular integration fosters deeper student understanding of global diversity in business practices.

Innovative teaching methodologies can further support this integration. Comparative case analysis, dialog-based learning, reflexive journaling, and immersive experiences help students critically engage with how values influence business decisions. These methods promote cognitive flexibility and cross-cultural competence by encouraging students to reflect on their assumptions and learn from others. Such approaches not only enrich learning about Islamic contexts but also prepare students for navigating religious diversity in global business environments.

Assessment strategies must align with these pedagogical goals. Instead of relying solely on standardized testing, educators should employ case-based evaluations, reflective writing, and collaborative projects that challenge students to apply diverse

ethical and cultural frameworks. These assessment methods reinforce critical thinking and ethical awareness, equipping students to engage with religiously pluralistic markets and organizations. Collectively, these curriculum and pedagogical reforms ensure business education reflects the complexity of global practice and fosters inclusive, values-informed innovation.

15. Future research directions

The study of Islamic business and creativity leads to the necessity of a more theoretical development. Future studies ought to develop models that explicate the effect of religious values on innovation when the forces of institution and market are utilized. The comparative models of the Islamic tradition and other religious traditions can lead the innovative and joint processes of values-based innovative creativity, and this will enrich the general mainstream theories of innovations [1, 3].

Empirical studies are needed to explore to variability in the creative processes in diverse Islamic environments, which include majority-Muslim nations, minority populations, and cross-national markets. With time series longitudinal studies on innovation, Islamic values on business development stages can be understood, whereas comparison of different religions could identify general trends on issues of morality of an innovating entrepreneur. Incorporation of Islamic insights into the theory of creativity might contribute to the cultural representation and universality thereof.

Methodologically, it can be recommended that in the future, mixed-methods, longitudinal designs, and the collaboration of scientists and practitioners should be used. It is also required to create culturally applicable instruments to gauge creativity in Islamic settings since all available instruments are, in most cases, Western in their assumptions. In parallel, the applied research can investigate the ways of how organizations incorporate religious values into innovation processes, how policies may contribute to the effectiveness of the activities, and how business students can be educated regarding exercising value-sensitive creativity in religiously diverse conditions of global markets (Table 1).

These prospective research directions propose an abundant agenda upon which the knowledge about the creative approaches to international business in the Islamic

Research domain	Short-term priorities	Long-term agenda
Theoretical development	Refine models of how Islamic principles influence specific business domains	Develop comprehensive frameworks integrating religious perspectives into mainstream creativity theory
Empirical studies	Case studies of creative approaches in underexplored Islamic business contexts	Longitudinal and comparative studies across diverse religious and cultural settings
Methodological innovation	Adapt existing research instruments for application in Islamic contexts	Develop new methodological approaches that integrate Islamic epistemological perspectives
Practical applications	Develop guidelines for practitioners navigating creative processes in Islamic contexts	Create and evaluate training programs and organizational systems for religiously diverse business environments

Table 1.
Research priorities for advancing creative business practices in Islamic contexts.

environment may be furthered. With the directions, the scholars will be able to discover new ways of theory development and assist in bridging the gap between theory and practice that can help to improve the business practice in a religiously diverse environment.

16. Conclusion

This chapter reviewed the implementation of creative research methods into international business in the Islamic regions, with the emphasis on meeting of methodological approach novelty, ethical guidelines, and global business strategy. The principles of Islamic theology, including *ijtihad*, *maslaha*, and *istihsan*, are the exact opposite of a contradictory notion and help to establish an ethnically based creativity. The chapter also helped in developing the theory, since it questioned the universality of models of innovation, provided context-specific principles that take into account the role played by religious values, and applied institutional theory by considering religious authorities and religious norms [3, 16, 20]. It also illustrated how modified methods like participatory, value-sensitive, and collaborative methods cover more ethical integrity and research validity of the Muslim business environment.

The empirical evidence highlighted the existence of different values-based innovation, collective creativity, and knowledge integration patterns in Islamic environments compared with the mainstream Western one that is based on individualism and market focus [14, 23]. The insights form the basis of theories and curriculum on inclusive business, which develops global competence of understanding how to live or conduct business in the context of religious diversity. Future research directions, such as comparative and longitudinal research, methodological advancements, and direct applications of the study in business education and organizational design, were also suggested in the chapter. All in all, it places Islamic contexts not in the margins but at the center of developing the internationally relevant theories and practices in international businesses [1, 2, 16].

17. Recommendations for researchers and practitioners

The chapter concludes with specific recommendations to the main stakeholders in the international business involving the Islamic environment. As far as academic researchers are concerned, they have to further learn Islamic ethical principles by studying or working with a scholar and be able to analyze research designs as to whether they are biased toward the West. Establishment of interdisciplinary and culturally diverse research teams, creation of context-sensitive research protocols, and dissemination of research findings to local communities are also in line with the Islamic priorities of seeking "*ilm nafi*" (useful knowledge) [18, 21]. Islamic voices should be considered to be part of the core curriculum by providing updated case studies, experience-based learning, and reflective pedagogies, which will develop cross-cultural competence among business educators [14, 16].

To the business practitioners, effective involvement would imply the transition of compliance-related interpretations of Islamic concepts into the proactive inculcation of religious values into the innovation agenda. The organizations need to allow liaisons between religious councils and the business people to encourage ethically rooted innovativeness [3]. Policy makers, on their part, can assist value-sensitive innovation

by providing adaptive regulation systems, community-relevant investment into R&D, and multi-stakeholder discussion. Collectively, these suggestions foster an inclusive, ethically sensitive business practice that is globally relevant and locally relevant in Islamic settings.

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References

- [1] Gümüşay AA. Entrepreneurship from an Islamic perspective. *Journal of Business Ethics*. 2015;**130**(1):199-208
- [2] Hassan MK, Hippler WJ. Entrepreneurship and Islam: An overview. *Econ Journal Watch*. 2014;**11**(2):170-178
- [3] Iqbal Z, Mirakhor A. *Ethical Dimensions of Islamic Finance: Theory and Practice*. London: Palgrave Macmillan; 2017
- [4] Amabile TM, Pratt MG. The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning. *Research in Organizational Behavior*. 2016;**36**:157-183
- [5] Doz Y. Qualitative research for international business. *Journal of International Business Studies*. 2011;**42**(5):582-590
- [6] Alvesson M, Sandberg J. *Constructing Research Questions: Doing Interesting Research*. London: SAGE Publications; 2013
- [7] Haneef MA. Islam, the Islamic worldview, and Islamic economics. *IIUM Journal of Economics and Management*. 2017;**5**(1):39-65
- [8] Azram M. Epistemology: An Islamic perspective. *IIUM Engineering Journal*. 2011;**12**(5):179-187
- [9] Kamali MH. *Maqasid al-Shariah, Ijtihad and Civilisational Renewal*. Herndon, VA: International Institute of Islamic Thought; 2015
- [10] Buckley PJ, Casson M. *The Future of the Multinational Enterprise*. London: Macmillan; 1976
- [11] Hofstede G. *Culture's Consequences: International Differences in Work-Related Values*. Beverly Hills, CA: Sage Publications; 1980
- [12] Birkinshaw J, Brannen MY, Tung RL. From a distance and generalizable to up close and grounded: Reclaiming a place for qualitative methods in international business research. *Journal of International Business Studies*. 2011;**42**(5):573-581
- [13] Tsui AS. From homogenization to pluralism: International management research in the academy and beyond. *Academy of Management Journal*. 2007;**50**(6):1353-1364
- [14] Ramadani V, Dana LP, Ratten V, Tahiri S. The context of Islamic entrepreneurship and business: Concept, principles and perspectives. *International Journal of Business and Globalisation*. 2015;**15**(3):244-261. DOI: 10.1504/IJBG.2015.071906
- [15] Hassan MK, Kayed RN, Oseni UA. *Islamic Entrepreneurship*. Abingdon, UK: Routledge; 2016
- [16] Khan M, Bhatti MI. Islamic business strategy: Case studies from the GCC. *Journal of Strategy and Management*. 2018;**11**(2):202-218. DOI: 10.1108/JSMA-10-2017-0071
- [17] Auda J. *Maqasid Al-Shariah as Philosophy of Islamic Law: A Systems Approach*. London: International Institute of Islamic Thought; 2008
- [18] Inayatullah S, Boxwell G. *Islamic Futures: The Shape of Ideas to Come*. London: Adamantine Press; 2003
- [19] Haneef MA. *A Critical Survey of Islamization of Knowledge*. Kuala Lumpur, Malaysia: IIUM Press; 2017

[20] Kamali MH. *The Middle Path of Moderation in Islam: The Qur'anic Principle of Wasatiyyah*. Oxford: Oxford University Press; 2015

[21] Hassan R, Hippler J. *Islam and the Search for Social Order in Modern Muslim Societies*. London: Palgrave Macmillan; 2014

[22] Khan MM, Bhatti MI. Islamic banking and finance: On its way to globalization. *Managerial Finance*. 2018;**34**(10):708-725

[23] Hassan MK, Miglietta F, Paltrinieri A, Floreani J. Islamic finance and bank efficiency: International evidence. In: Hassan MK, Rashid M, editors. *Handbook of Empirical Research on Islam and Economic Life*. Cheltenham, UK: Edward Elgar Publishing; 2016. pp. 103-136

[24] Inayatullah S, Boxwell G, editors. *Islam, Postmodernism and Other Futures: A Ziauddin Sardar Reader*. London: Pluto Press; 2003

Frontline Employees' Emotional Displays in Service Encounters: A Framework Enabling Design and Further Research

Florian Urmetzler and Peter Wunderlich

Abstract

We found that emotional displays by frontline employees in labour environments and service interactions are understudied. We focus on the design of environmental factors and body and face movements, which are in line with emotional displays in service interactions. This chapter uses data from opera performers to develop a framework for service managers to manage and design customer emotions during the “moment of truth”. Emotions arising in service interactions strongly influence customer experience and satisfaction. Interviews with opera singers and observations from live opera performances are employed to study emotional displays and factors influencing them among artists. The resulting framework contains a portfolio of diagnostic cues of emotions, provides new insights into the requirements for emotional labour environments and is the first attempt to solve the dilemma of authenticity versus effectiveness in emotional display. It will support further research as well as practitioners understanding.

Keywords: emotions, design, service interaction, service encounter, tool

1. Introduction

Managing and designing customer experience have increasingly been recognized as important strategies for companies, especially service organizations, as they influence customer satisfaction [1, 2]. Satisfaction is generally understood as the comparison between prior expectations and actual perceived performance [3, 4]. The comparison, resulting in customer satisfaction, includes cognitive and affective (emotional) evaluations [5–10]. In turn, customer satisfaction strongly impacts loyalty and positive word-of-mouth [1, 2, 6, 11–16]. Meanwhile, dissatisfaction can lead to switching behavior, negative word-of-mouth and complaints [17–19]. The two above-mentioned effects, loyalty and positive word-of-mouth, can increase companies' profitability through enhanced revenue, decreased costs of gaining new customers, willingness to pay more, and reduced costs of serving clients familiar with

the delivery system [20, 21]. Furthermore, a positive association between customer satisfaction and cash flow [22, 23], and shareholder value, is evident [22].

Hence, customer satisfaction is impactful on companies' profitability – emotions play a key role in customer satisfaction [7, 11, 24–29]. This study seeks to better understand emotional elicitation during service encounters.

1.1 Customer experience

According to Carbone and Haeckel [30], customer experience can be defined as “the takeaway impression formed by people's encounters with products, services, and businesses”. They also propose that sensory information during the encounter is consolidated by humans and produces a perception. This is consistent with Holbrook and Hirschman's [31] description of experience as a reaction to environmental stimulations resulting from participation or observation. Meyer and Schwager [32] state that all aspects of a company's offering influence customer experience: quality of customer care, advertising, packaging, product and service features, ease of use and reliability. Increasingly, firms have developed customer experience in their core offering – a business model called experience-centric services [1, 2, 33, 34]. Experience-centric service companies proactively create customer experiences to craft a distinctive service or product offering [34]. In summary, customer experience can be considered the internal and subjective customer reaction to any direct interaction with an enterprise (purchase, usage or service prompted by customers) or indirect interaction with an enterprise (unplanned interaction with product, services or brands from a company through word-of-mouth, advertising or news reports) [15, 32, 35, 36]. Pullman and Gross [1] consider anticipation, emotional engagement and progression over time crucial parts of experience, with a series of individual experiences culminating in customer satisfaction [32]. These experiences occur intensively and in numerous service encounters, especially in situations where the service component plays a major role in the overall offering [37], such as the hotel industry, entertainment or amusement parks.

1.2 Service encounters

Shostack [38] defines a service encounter as a “period of time during which a consumer directly interacts with a service”. Cook et al. [39] refine it to an “interaction process between the server and the served”. Similarly, Solomon and Surprenant [37] see service encounters as a “dyadic interaction between a customer and service provider”. Thus, during this “moment of truth”, customer experience is created through interaction. A service encounter, however, is not limited to personal interaction; it includes personnel and physical facilities and other tangible elements [40]. Since the evaluation of a service encounter strongly influences the evaluation and perception of the whole organization, factors influencing “the moment of truth” are important, and understanding them is critical [40–42].

1.3 Context of services

Service-providers create a context, the service-scape [40], within which the service encounter takes place and the customer experience occurs. This consists of relational and physical elements [43].

The relational context includes two types of interaction: customer-to-employee and customer-to-customer. The latter impacts through social facilitation and intrusion [44]. Both interpersonal relations not only influence the “moment of truth” and its elicited emotions but also create an emotional context for future encounters. The emotions accruing through this relational context can be seen as a key driver for a positive customer experience and therefore for loyalty.

The physical context comprises all tangible aspects of a service set-up and should compel and engage all five senses: sight, sound, smell, taste and touch [1, 2, 15]. Emotions or affect are also relevant in the physical and relational context [45, 46].

1.4 Emotions, trust and control in services

Dasu and Chase [47] suggest that *emotion*, *trust* and *control* can strongly affect customer evaluation of service experiences. These factors drive or strengthen the assessment of the customer experience and therefore the overall picture of the service provider. To some extent, *emotions* determine what people remember, how they evaluate a service interaction and their decisions. *Trust* triggers a feeling of comfort and engagement and prevents anxiety or frustration. *Control* refers to a fundamental psychological need for certainty, and uncertainty is assessed negatively by customers [47]. Dasu and Chase [47] argue that the “soft side” of customer service should receive the same attention from high-level executives as, for example, supply chain redesign. A solid understanding of these factors enables firms to deliberately design a particular service offering to create and evoke customer *emotions*, *trust* and *control*, resulting in a more positive service perception [1]. Furthermore, Cronin et al. [48] state that emotions are a significant attribute in customer satisfaction.

1.5 Experience design in services

Experience design actively builds an emotional connection with customers through thorough planning of tangible and intangible service elements. Enterprises rely on this approach to find new ways of achieving competitive advantage through managing customer experiences [1]. Vargo and Lusch [49] argue that customer experience is co-created rather than designed, while Forlizzi and Ford [50] state that situations can be designed for a desired experience through co-creation. Hence, organizations may not design customer experiences directly; however, services, or parts of a service, can be designed to enhance customer experience [39, 50, 51].

1.6 Service managers can benefit from environments where strong emotions occur

In summary, customer satisfaction and experience are crucial for service companies, having implications for revenue, profit, and shareholder value. Emotions occurring in service interactions seem to strongly influence perceived quality and customer satisfaction. A service, or parts of a service encounter, can be designed to enable an enhanced customer experience in which emotions are key. Therefore, it is critical to understand how emotions can be displayed, elicited and detected by employees and what the influencing factors are. This can help to improve customer experience and enhance evaluations of services and service organizations as a whole. Investigating and learning from environments where strong emotions are evoked, such as opera, is a promising research area in service management.

Using a grounded theory approach, this study seeks to provide managers in the field of service operations with a clearer understanding of how emotions are displayed and detected during service encounters, and the factors influencing service staff who interact with customers directly. These factors are particularly important, since service interaction is emotional labour and driven by human interaction [52, 53].

Hence, the objective of this research is twofold. First, it seeks to provide a portfolio of diagnostic cues for emotions. Second, it looks for internal or external factors that can hinder or enhance employees' emotional engagement within a service encounter. This perspective aims to help managers create a better work environment for service staff, thereby enhancing customer experience through a more sophisticated service operation.

2. Literature review

This section describes the process and content of the Literature Review. In the first section, emotions, mood and affect, and conceptualizations of emotions, are discussed. The next section reviews detailed literature on the influence of emotions on customer service evaluations. Furthermore, the concept of emotional contagion and its occurrence in services are investigated. In the next section, we introduce opera as an emotionally intense form of art, discussing research on emotions in opera. As a significant gap in scholarship emerges from this review, a research question is designed to fill the gap.

2.1 Literature review approach

The rigorous three-step process of Tranfield et al. [54] is not entirely suitable for this study because of its highly interdisciplinary character and the numerous semi-independent or autonomous sub-fields and outliers observed. It is therefore necessary to adjust this three-step approach to ensure a structured review process. The following literature review includes three stages: planning and conducting the review, analysis and reporting.

2.1.1 Planning the review

Prior to the review, discussions and meetings were held with experienced researchers with practical experience in the field of servitization. Four major literature areas were identified in this process: service, design, emotions and opera.

2.1.2 Conducting the review

The systematic review began with the definition of search strings. Synonyms and related topics for the four areas (service, design, emotions and opera) were added to the search string, which was designed to find literature that is important for one distinctive category or includes at least two of the four major areas. Then, a keyword search was carried out in two databases: Web of Science and Scopus.

A first list of resulting literature was created and narrowed down through a holistic elimination process of title and abstract screening. The resulting list was complemented through backwards snowballing [55], and the new literature was further investigated. Finally, based on knowledge gained through the literature review,

a second investigation of the first list was conducted, to counteract initial biases, resulting in three papers being added to the second list.

2.1.3 Analysis and reporting

The last step broke down literature into its constituent parts and extracted key ideas, theories and concepts. Connections were drawn between the ideas, theories and concepts, and the information was re-cast into new or different arrangements. Finally, a table with the most important papers on emotional studies in service encounters was created to investigate measures and used emotions. This table provided further evidence of the research gap.

2.2 Emotion, mood and affect

Before focusing on the connection between emotions and customer behavioral intentions, it is crucial to understand and characterize emotions, mood and affect. There is currently no general consensus among organizational behavior researchers on a definition of emotions, and there are various theoretical perspectives [56–58]. Bagozzi et al. [59] define emotions as “mental states of readiness that arise from appraisals of events or one’s own thoughts”. This is consistent with the perspective offered by Oatley [60] and Lazarus [61]. Most definitions of emotion assume that an external stimulus influences a human being, leading to a physiological or psychological change. Emotions should be distinguished from moods, which are characterized by lower intensity and last longer [59]; they are usually not associated with an external stimulus, object, event or referent [59, 62]. Both Bagozzi et al. [59] and Erelles [62] understand “affect” as an overarching term encompassing emotions and mood.

2.3 Conceptualizations of emotions and scales for measuring emotions

Marketing and behavior scholars have expressed different opinions on the conceptualization of emotions and the approach of measuring customer emotions [57]. This may be partly because of a lack of general agreement on the definition of emotions. Researchers have identified various sets of distinct categories of experiences and expressions with unique features. Important studies on the conceptualization of emotions are: Plutchik [63], Ekman and Friesen [64], Izard [65], Watson et al. [66] and Richins [67]. Service, marketing or management literature often uses these five studies, parts of them, or a combination of at least two. Using these studies in empirical research on emotions occurring in services, customers are usually asked, using a Likert scale, how often, or to what extent, they have experienced certain emotions during a service encounter.

2.3.1 Plutchik's conceptualization of emotions

It seemed reasonable to use one complete emotional conceptualization in the interviews to gain a holistic view on this topic, although certain literature in servitization tends to use only parts of a conceptualization, or combines parts of different concepts, because of prior knowledge in this research field.

This study uses Plutchik’s conceptualization of emotions for several reasons. It is a prototype for other conceptualizations; preliminary informal interviews with artists indicated that this conceptualization was the most promising framework; and in the

interviews, it seemed feasible to ask artists about eight different emotions. Plutchik [63] identified in his psycho-evolutionary theory of emotions eight “primary” emotions (see **Figure 1**). The framework includes: fear, anger, joy, sadness, anticipation, surprise, trust and disgust. These emotions are interrelated and can be seen as prototype sources for all other states observed in animals and humans.

2.3.2 Four additional conceptualizations of emotions

The following briefly describes the remaining four conceptualizations of emotions. Ekman and Friesen [64] propose the term “basic emotions” for the following states: anger, disgust, fear, happiness, sadness and surprise. They consider these six states when describing emotional families with shared characteristics.

Izard [65] introduced the differential emotions scale (DES), which is driven by a biological perspective and assumes that survival instincts affect emotions. It includes 30 items representing 10 fundamental emotions: anger, disgust, fear, contempt, joy, shame, guilt, surprise, sadness and interest. Plutchik [63] sees contempt as a combination of anger and disgust. He also states that fear and disgust lead to shame, while fear and joy lead to guilt. It seems reasonable to conclude that Plutchik’s conceptualization is the basis for DES. Watson et al. [66] developed the positive affect negative affect scale (PANAS), consisting of 10 positive and 10 negative items.

Richins [67] argues that most of the commonly used emotion scales developed by psychology and behavior researchers are not well suited to studies investigating consumption-related emotions because they do not capture certain emotions

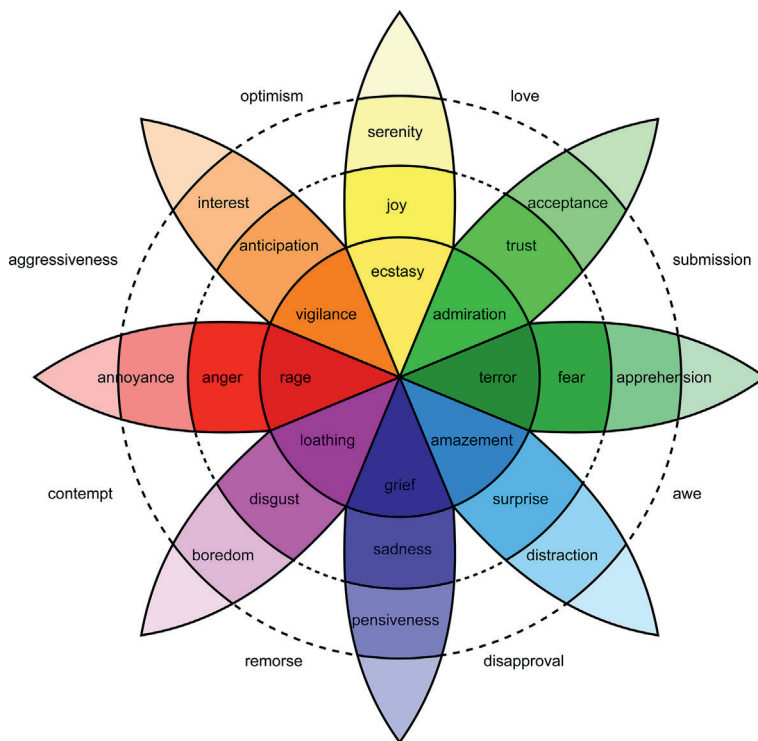


Figure 1.
Emotional wheel of Plutchik (2001).

occurring in consumption situations, and they include irrelevant emotions [67]. To overcome these limitations, Richins developed the consumption emotions set (CES), including 17 emotions and “other items” such as guilt, relief, pride and eagerness. She suggests that CES better represents emotions experienced by consumers in consumption situations.

2.4 Influence of emotions on customer evaluations during service encounters

Pine and Gilmore [15] state that in the “experience economy” an exceptional experience is distinctive, personal, engaging, memorable and sustainable over time. By contrast, Arnould and Price [24] characterize extraordinary experiences as emotionally intense. The far-reaching, influential role of emotions for consumer behavior and decision-making has increasingly been recognized by marketing scholars [59]. Earlier studies have insisted on the positive correlation between customer mood and evaluations and satisfaction [8, 69]. Several studies propose that customer satisfaction and perception of service experience are significantly influenced by emotions evoked during service interactions [7, 11, 24–29]. In their research on retailers, Menon and Dubé [26] propose that customers’ perception of treatment by sales staff and the types of emotion displayed by employees influence customer emotions.

During a service encounter, customers often experience negative and positive emotions. Experiencing negative emotions does not necessarily lead to dissatisfaction [7, 24, 26]. In their study on river rafting, Arnould and Price [24] suggest that some of the people experiencing strong negative emotions during the activity were very satisfied with the service encounter. This is consistent with findings by Liljander and Strandvik [7]. Customers experiencing negative emotions of sadness or anger during movies, operas or live music performances may evaluate the service as satisfying [7].

Liljander and Strandvik [7] further propose that negative emotions have a stronger impact on customer satisfaction than positive emotions. They are among the few researchers to argue that the influence of strong positive emotions on customer satisfaction is negligible, a claim rejected by most scholars.

Services can be divided into two sub-categories: hedonic and utilitarian [70]. Hedonic services focus on the consumption experience [31], while utilitarian services focus on the functional nature of the service delivery.

In hedonic service businesses, such as luxury, entertainment and tourism, customer emotions are considered very important for quality evaluation and customer satisfaction [11, 24, 42, 53, 71–73]. Kim et al. [72] discuss strategies to manage customer emotions in luxury retail, Arnould and Price [24] investigate the impact of emotions on customer satisfaction in white-water river rafting, and Jani and Han [71] find positive correlations between emotions and loyalty in the industry.

In utilitarian services, such as health care or basic banking services [74], emotions still play a noticeable role in experience and satisfaction, although less than hedonic services [14, 27, 75–77]. In their study on brief and mundane service encounters, Mattila and Enz [76] argue that customer evaluations of service encounters correlate with their displayed emotions, creating affects during the service and mood states directly after the interaction. Ladhari et al. [14] show that in an optometry clinic positive emotional satisfaction is associated with high perceived quality, loyalty and recommendation intention. Wong [77] presents the positive association of emotional satisfaction and perceived service quality in a study in a departmental store chain. However, Rust and Oliver [78] propose that delight, a very positive emotion, cannot be evoked in customers without a top performance by the firm or its staff.

Hochschild [79], Price et al. [42] and Rafaeli and Sutton [80] state that a dilemma exists in emotional displays in service encounters. There are two conflicting characteristics in emotional displays: on the one hand, an authentic emotional display is important; and, on the other hand, the effectiveness of an emotional display should be ensured. To date, none of the researchers have stated specific actions to solve the dilemma.

2.5 Influence of emotional contagion on emotion elicitation

Emotional contagion is among the reasons why customer emotions are elicited. Emotional contagion describes the phenomenon of a corresponding emotional change in a person following exposure to displayed positive or negative emotions from another person [81].

Organizational behavior studies have shown that emotional contagion occurs in work situations among employees, and between employers and employees [82, 83]. Pugh [84] discusses the occurrence of this phenomenon in service encounters between customers and employees. His study shows that positive emotions displayed by service-providers positively affect customers' emotional states. In turn, this influences evaluation of the service quality favorably.

Further studies in service marketing have also investigated emotional contagion. Tsai [85] demonstrates the rewarding impact of positive emotions displayed by retail employees. Through laboratory studies, Luong [86] demonstrates that positive perceived service display leads to higher positive moods and lower negative moods in customers, while Du et al. [87] suggest that negative emotional contagion also occurs in service encounters.

Du et al. [87] and Mattila and Enz [76] propose that effective emotional training of frontline employees should be provided by companies, because of their rewarding impact on customer emotions through emotional contagion. However, neither study mentions specific training content.

2.6 Opera as an emotionally intensive form of art

Brown and Novak [88] describe art as “a conduit for emotion, a vessel for transmitting feelings, beliefs and values between the creators and performers of the work and the audience”, and live art performances arguably strengthen these characteristics [88]. The researchers also assess motivations for attending live performances such as plays, musicals, classical concerts, ballet or opera. The second most important reason for the 19,000 respondents attending live performances was “to be emotionally moved or inspired”, and the more often they attended performances, the more important the emotional component was. Performances with music, such as classical concerts or operas, tend to be compared emotionally to dance or theater plays [88]. O'Neill et al. [89] researched what opera-lovers most appreciate and why they attend opera performances. The regular opera-goers who were interviewed displayed a strong emotional connection to opera, and three key reasons for attending emerged: emotion, truth and other people.

The art of opera is a combination of libretto, music, singing and production (stage, play and light) [90] and can be considered one of the most complex and esthetic forms of art [89]. Opera includes several dimensions, and one can assume that it multiplies the mechanisms of emotional induction in listeners [91]. This is in line with Felsner [92], who considers opera the most intense and emotional form of art and argues that emotions constitute the core of operas. It seems reasonable to

assume that live opera performances represent an environment where strong emotions are triggered.

2.7 Research on emotions occurring in operatic live performances

Baltes and Miu [93] conducted a study on the influence of live opera performances on listeners' emotional states. The study was conducted with 120 participants at a live performance of Giacomo Puccini's opera *Madama Butterfly* at the Romanian National Opera House in Cluj-Napoca. The two main contributions of Baltes and Miu [93] may illustrate the generally intense emotional experience and offer proof of feasibility for emotional investigations in live performances. However, no research has been done on how artists skilfully or deliberately induce emotions in visitors in an operatic context. Hence, scholars lack a scientific understanding of this process [93].

2.8 Research gap

Literature has described and measured the occurrence of emotional changes in service encounters. Emotional contagion is seen as one of the reasons for emotional change in customers. Customer emotions during the "moment of truth" impact service satisfaction and evaluations, in turn impacting loyalty, word-of-mouth and companies' financial success. Isolated studies have attempted to explore the impact of employees' behavior delivering the service, for example, Pugh [84] and Tsai [85].

The literature review discussed 22 studies on service encounters with a specific measure for emotions. Twenty set the customer as the unit of analysis. They measured customer emotional states or affect before and after the service encounter through questionnaires answered by customers on a Likert scale. The PANAS emotional scale was used six times and the DES emotional scale four times exclusively, or in combination with other scales. The rest used other scales or single emotions without any obvious reasoning. Researchers sought to investigate customers' emotional changes, their impact on service evaluation and their further implications. The reasons for emotional change were not investigated.

Only Pugh [84] and Tsai [85] connect employee behavior with changes of customer emotional states and set the employee as the unit of analysis. When measuring the impact of employee behavior, however, the two studies use the rudimentary measures provided by Rafaeli and Sutton: greeting, smiling, eye contact and thanking [94, 95]. These four measures are hardly connected to emotional display by the employee. So far, scholarship has not developed an effective strategy to measure the impact of emotional display by employees. This may be because of the absence of a portfolio of diagnostic cues to help observers assess the emotional display of service employees. Hence, the process whereby emotions can be consciously displayed and created by service-deliverers has not been fully understood.

Literature about emotions in opera has focused on the customer, audience and emotions elicited during a performance, or on identifying why people attend opera. Thus, the unit of analysis has been the customer. Opera can be seen as an extreme case of emotional elicitation, combining several different forms of art, potentially making it worthwhile to study. The ways in which opera actors can skilfully display or create emotions during opera performances have not been investigated.

Neither literature stream, in service management and opera, has conducted investigations with service-deliverers as the unit of analysis. Scholars have acknowledged

this gap and emphasized the importance of pursuing such research. An additional lacuna exists in opera and management literature about internal and external factors influencing employees or artists performing. This study is the first attempt to fill these gaps and seeks to understand emotional display in operatic live performances and its influencing factors.

2.9 Research question

This study seeks to answer the following question: Can frontline employees in service environments authentically display emotions and better assess emotional states through diagnostic cues in the context of operatic live service encounters? And what are the internal and external factors influencing the emotional labour of service-deliverers?

Answering this question may produce novel and rewarding findings, which could be applied and transferred as a best-practice approach to service industry. Apart from service industry, the vast majority of companies that sell any kind of product to customers have a company-customer interaction. Since emotions play a crucial role in customer experience, which influences customer satisfaction, a better understanding of emotional elicitation during an interaction is beneficial for a company's financial success.

3. Methodology

This section outlines my general research philosophy and the specific research methodology adopted for this study. The methodological fit of this research is discussed and research instruments chosen accordingly. For this study, semi-structured interviewees with a research protocol were introduced as the main research instruments. This section also describes additional sources of data and data triangulation. The next sections introduce the methodology whereby data was coded and analyzed and how hypotheses were shaped and theory developed. Finally, the limitations of the methodology are critically reflected. **Figure 2** provides an overview of the methodologies adopted in each stage of this study. In the following section, these methodologies are analyzed in more detail.

3.1 Methodological fit of this research with prior knowledge

Both theory and research are nascent in the field of emotional design in opera with artists as the unit of analysis. The aim of this study was to provide a description and generate a grounded theory of emotional design in opera, which represents a novel research context. The investigation of the methodological fit of this study with the methodology used followed Edmondson and McManus [96]. The researchers compared, in a structured manner, prior theories and research with the objective of planned studies.

Eisenhardt [97], Voss et al. [34] and Yin [98] consider qualitative research, especially case studies, an appropriate approach for developing theories, gaining new insights and creating knowledge in fields without existing theories. Additionally, case-study research is appropriate in the context of this project, which includes complex processes and constructs that are hard to measure [97]. Eisenhardt [97], Voss et al. [34] and Yin [98] also state that qualitative data is especially valuable for finding

Human Displays of Emotion in Frontline Service Encounters:

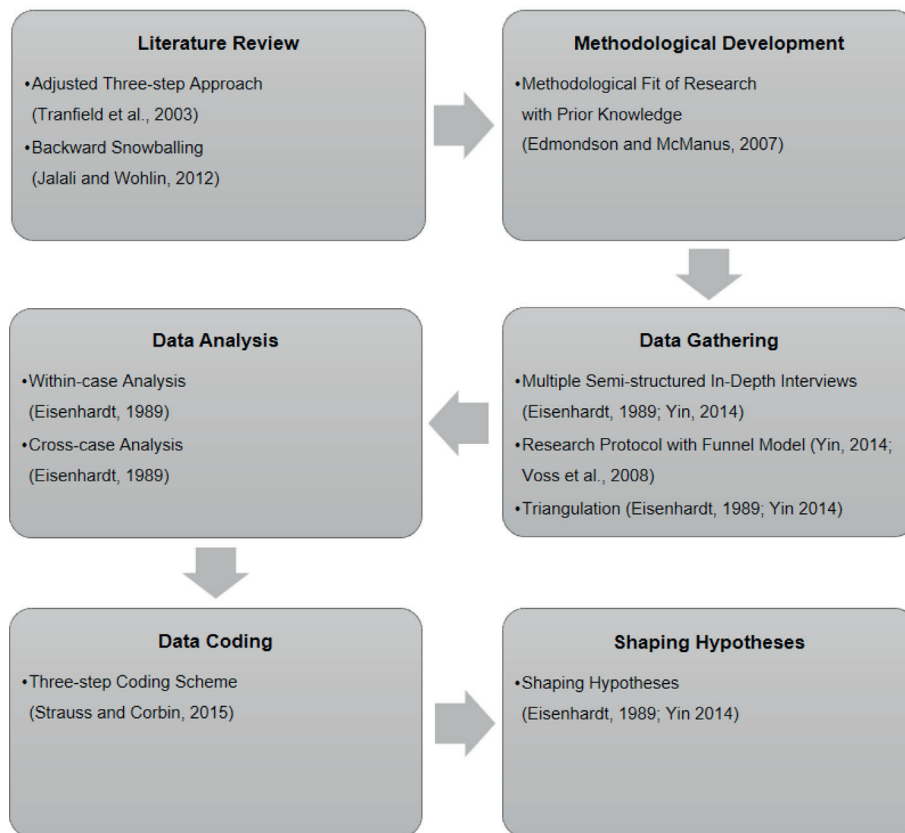


Figure 2.
Methodologies used in this study.

answers to “how” and “why” questions. Data was gathered through semi-structured interviews because this kind of interview provides rich, detailed and evocative data [96]. The grounded theory resulting from inductive case-study research is presumably empirically valid because of the intimate linkage with empirical evidence [97]. Therefore, it is likely that the emerging theory accurately reflects empirical observations.

3.2 Research instruments

The main research instrument for this study was multiple semi-structured interviews with a research protocol – a typical prime source of data in this research methodology [34]. Replication logic was applied and cases selected with the rationale of predicting similar results to achieve robust findings and strengthen conclusions [97, 98]. This process is characteristic of the grounded theory approach [99]. Theory-building case research offers the possibility to adjust and alter the data-collection process should new and promising lines of thinking emerge. These new insights can strengthen the resulting theory [96]. In this study, the processes of data collection and analysis overlapped to provide a better resulting theory.

3.3 Interviewees

The aim of this study was to investigate how emotions are displayed in opera; opera singers were the unit of analysis and the interviewees. Singers are an essential part of the “moments of truth” in opera performances. Orchestral music is another essential component influencing emotions during opera. Interviews with orchestra musicians were also carried out to assess their influence on emotional elicitation.

Interviewees were opera singers or orchestra musicians associated with leading opera houses in central Europe, whose performances are appreciated by international critics. Hence, it may be assumed that artists working with these opera houses are among the most skilled, trained and qualified in their field, who can be considered experts, thereby enhancing the study’s reliability.

3.4 Additional sources of data and triangulation

Additional sources of data were used, on the one hand, to develop and adjust the research protocol, and, on the other hand, to triangulate data [97, 98]. Informal conversations with orchestra musicians and opera singers contributed to shaping the research protocol and provided a deeper understanding of the topic. In addition, further data was collected through observation to triangulate the primary data. The investigator attended 26.5 hours of opera performances to assess and validate in a structured manner information given by interviewees.

3.5 Research protocol

In this study a research protocol was used to enhance the data’s reliability and validity [98]. An additional objective of the protocol was to provide prompts to the interviewer and to ensure that all planned aspects were covered during interviews [34]. The research protocol consists of a set of interview questions and was built following the notion of the funnel model, starting with broad and open-ended questions and gradually moving to more specific questions during the interview [34].

The open questions were designed to find internal and external factors influencing actors’ performances. The more specific questions sought to determine how the eight emotions introduced in Section 2 could be displayed. The interview ended with an open-ended question about ideas, knowledge and thoughts not previously addressed.

The set of interview questions was informed by current literature, informal conversations with artists, knowledge from past opera visits, and workshops with experienced service-management researchers. Yin [98] lists the essential skills that are needed by the field researcher. Prior to conducting the interviews, the author was trained by experienced researchers to obtain such skills.

3.6 Methodology of data coding

Data coding was conducted through the three-step coding scheme recommended by Strauss and Corbin [100]. In the first step – open coding – collected data was fragmented or broken down into separate parts. Open coding is a process used to identify basic concepts, which are assigned names and rearranged into categories. The second step was axial coding, which includes regrouping and linking the data in a new and rational manner. Finally, selective coding chose core categories and related other categories to the core category [100].

3.7 Methodology of data analysis

The data analysis was twofold. Following the suggested approach of Eisenhardt [97], analysis was conducted through within-case analysis and then cross-case analysis.

The general notion of within-case analysis regards each case as a standalone entity, understands each case properly and identifies patterns within cases. Then, a generalization across all cases was carried out [97]. Within-case analysis provided the researcher with an in-depth understanding that was required for the second step [34].

Cross-case analysis is a crucial step in case research, since it is key for generalizing conclusions resulting from individual cases and enhancing internal validity. It also allowed the researcher to move beyond initial impressions through structured and diverse lenses [97]. Cross-case analysis was conducted by selecting case pairs and checking for similarities and differences [34, 97]. Looking for similarities also produced a more sophisticated understanding of the findings and captured possible novel findings in the data [97].

3.8 Shaping hypotheses and developing theory

The research objective was to formulate hypotheses and develop a theory in the field of study. This was achieved through an iterative cross-case analysis of constantly comparing arising themes with data drawn from the within-case analysis. This iterative process created a tight link with the collected data and enhanced internal validity [97]. The rationale behind this approach is replication logic, whereby a series of cases is treated as a series of experiments. Each case is tested to confirm or disconfirm the hypotheses that emerged [98]. Cases that confirm the emerging theory enhance confidence in the theory, while disconfirming cases provide an opportunity to adjust or extend the theory [97].

3.9 Limitations of the methodology

The first limitation lies in the intensive use of empirical evidence, which may lead to an overly complex theory [97]. Additionally, building a theory from individual cases may lead to narrow theories, which only describe and apply to a very idiosyncratic phenomenon or lack overall perspective, since it is a bottom-up approach [97]. Qualitative data does not provide statistical significance, with decision-makers in industry tending to make decisions depending on statistics and figures.

Furthermore, case-study research that requires interview transcription is time-consuming and expensive if travel is also required. Therefore, the number of interviews was limited. In future, additional interviews may enhance the reliability of both data and findings.

The interviewing skills of the investigator impact the knowledge gained from the interview [97]. Gaining tacit knowledge from artists during an interview can be considered the key challenge in this regard. The information gap between the interviewee and interviewer might limit insights drawn from the conversation. Furthermore, interviewees may decide to deliberately provide specific information to cast themselves in a good light or to hide certain details. Hence, data reliability might be reduced.

Most of the interviews were conducted by a single investigator. Additionally, data coding, data analysis, and the formulation of hypotheses were carried out by one investigator. This may limit creativity and the convergence of observations because of a lack of multiple perspectives. In turn, it may decrease confidence in the findings [97].

4. Data collection

The following section discusses how the topic of this project was identified, how the interviews were structured and conducted, and the research protocol developed. **Figure 3** provides an overview of the data-collection process. Before data was gathered, preliminary informal talks were held with singers, musicians and dramaturges. The main data collection consisted of two data-gathering instruments, the first being semi-structured in-depth interviews. Two interview stages were carried out. First, three interviews with opera singers and two interviews with orchestra musicians were conducted; and second, five opera singers were interviewed. The second data-gathering instrument was observation. Furthermore, the author attended seven operas to triangulate primary data.

4.1 Development of the research topic

The first data set for this research was gathered through preliminary informal conversations with people involved in opera productions, such as singers, musicians or dramaturges, in March 2018 and May 2018. These conversations revealed that emotional display in opera is unconscious, something that has never been investigated or discussed in the industry. Additionally, these talks suggested that singers have tacit

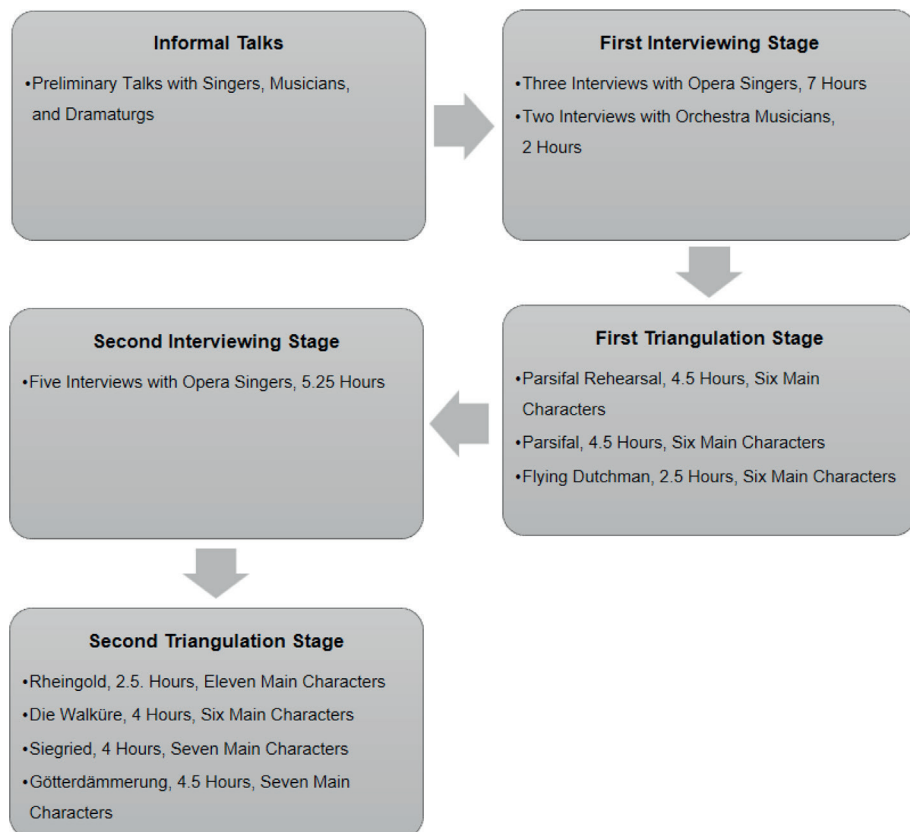


Figure 3.
Overview of data-gathering process.

knowledge of this unconscious process. These findings triggered further interest in the field.

4.2 Conducted interviews

The main research instrument were multiple semi-structured in-depth interviews; overall, 10 interviews were conducted. The research protocol was sent to interviewees prior to interview so that they could prepare [34]. The interviews were conducted in person, *via* phone or Skype. They were voice-recorded with interviewees' consent, and relevant sections were transcribed and translated into English. Apart from the recording, notes were taken by the investigators when required. Following the interviews, the principal investigator listened to the recordings to identify ambiguities, detect gaps in the data and formulate follow-up questions. **Table 1** gives an overview of all the interviews. It provides information about the identity of the interviewees, their associated opera houses and professional roles. Furthermore, it indicates the

Name	Associated opera house(s)	Role	Performances	Interview duration in hours	Number of investigators
Anna-Katharina Tonauer	Gärtnerplatztheater Munich	Mezzo-Soprano	100	2	1
Dean Power	Bavarian State Opera Munich	Tenor	500	3	1
Christoph Seidl	Gärtnerplatztheater Munich	Bass	300	2	1
Gaël Gandino	Orchestra of the Bavarian State Opera Munich, Mahler Chamber Orchestra, Lucerne Festival	Orchestra Musician	1250	1	1
David Ott	Orchestra of the Bavarian State Opera Munich	Orchestra Musician	750	1	1
Marie-Claude Chapuis	Salzburg Festival, Opera Zurich, Teatro alla Scala Milano	Mezzo-Soprano	1000	1	2
Kristofer Lundin	Salzburg Festival, Opera Zurich, Bavarian State Opera Munich	Tenor	300	1	2
Andreas Winkler	Opera Zurich	Tenor	1000	1	2
Jennifer O'Loughlin	Gärtnerplatztheater Munich, Volksoper Wien	Soprano	600	1.25	1
Christoph Filler	Gärtnerplatztheater Munich	Tenor	300	1	2
Sum			6100	14,25	

Table 1.
 Overview of conducted interviews.

number of live performances that interviewees were involved in, the duration of the interviews and the number of investigators conducting them.

In total, eight interviews with opera singers and two interviews with opera orchestra musicians were conducted in two data-collection stages. In the first stage, three interviews with opera singers and two interviews with orchestra musicians were carried out by a single investigator in Munich in June 2018. After the first data-collection stage, the interview protocol was slightly revised, as the initial findings from the interviews with the orchestra musicians indicated that the unit of analysis should focus on opera singers. The second stage, including five interviews with opera singers, took place in Cambridge in July 2018 *via* Skype or phone.

We are keen to declare detailed timelines in this chapter; The data and findings were used for teaching purposes in between. However, we would also argue that the phenomena under study have not changed since 2018. We would argue that the structural characteristics of emotions have remained consistent over the past decades and likely longer.

4.3 Interview content

A research protocol was used in the interviews to ensure repeatability, validity and reliability, and to mitigate biases. The protocol, outlined in **Figure 4**, consists of 15

Human Displays of Emotion in Frontline Service Encounters:

<u>Interview Protocol</u>	
1.	Would you mind introducing yourself briefly and how many performances have you sung so far?
2.	What was the last new production you were working on?
3.	Can you explain the process of how you try to understand the emotional states of the characters you play/sing?
4.	What factors do influence you positively or negatively on your performance and how do they influence you?
5.	How does the organisation of an opera house influence you on your role as artists/ on your performance?
6.	How does the audience influence you during a performance?
7.	How could the emotion joy/delight be presented/displayed by your playing/singing?
8.	How could the emotion sadness be presented/displayed by your playing/singing?
9.	How could the emotion trust be presented/displayed by your playing/singing?
10.	How could the emotion disgust be presented/displayed by your playing/singing?
11.	How could the emotion fear be presented/displayed by your playing/singing?
12.	How could the emotion anger be presented/displayed by your playing/singing?
13.	How could the emotion surprise be presented/displayed by your playing/singing?
14.	How could the emotion anticipation be presented/displayed by your playing/singing?
15.	Are there any other ways how you might display emotions?

Figure 4.
Interview protocol.

questions. Question 1 is meant to gather information about the interviewee. Question 2 leads to the core of the interview. Questions 3–6 investigate the preparation process of emotion elicitation, and internal and external factors influencing the performance or the role of the artist. Questions 7–14 focus on how each of Plutchik's eight emotions [63] is displayed by the interviewed singers.

4.4 Questioning process

The use of semi-structured interviews allowed us to ask follow-up questions when ambiguous answers were given or new topics emerged. This instrument was used often, and follow-up questions provided further insights and new findings.

Questions 7 to 14, which focus on specific emotions from Plutchik's conceptualization, rarely led to enlightening insights when the question was asked, as noted in the protocol (see **Figure 4**). When the formulation of questions 7–14 proved unsuccessful in an interview, a different formulation was used. The revised version of the question reads as follows: "What would the audience see if you genuinely felt the emotion xyz and you were displaying it authentically?" This version led, in many cases, to rich and detailed cues. One possible explanation is that artists might not accept the idea that emotions are displayed on purpose or faked. At some point during the interview, each artist mentioned that their displayed emotions resulted from a genuine feeling experienced during the performance. Hence, the revised question avoided giving the interviewee the impression that we were insinuating that emotions were staged.

During the first interview, the interviewee mentioned that, through their reactions, other artists on stage prove or disprove the authenticity and effectiveness of displayed emotions from other persons. The issue of the impact that other people on stage may have on displayed emotions was embedded in the interview process in all subsequent interviews. The question is not mentioned in the research protocol because it was asked only when it seemed to lead to promising findings. Usually, this question was asked in the second half of the interview (questions 7–14).

4.5 Triangulation of data through observation

The triangulation process carried out by attending live opera performances was divided into two stages, which consisted of three and four opera visits, respectively. The objective was to validate the interview findings. Concepts and cues for displaying emotions, mentioned in interviews, were compared in a structured manner with observations made by the investigator during live performances. These observations were written down for the second comparison following the data-gathering process. Research, preparation and conversations with artists were carried out before attending the performance. The preparation process elicited a deeper understanding of characters' emotional states, allowing the author to evaluate the emotional state of the role.

For both triangulation processes, the author chose the Bavarian State Opera in Munich and pieces by Richard Wagner. This opera house, its ensemble and guest singers are considered world-leading by critics. Richard Wagner's pieces were also chosen because of the broad range and intensity of the main characters' emotional states. The combination of extremely skilled singers and emotional depth of the pieces seemed promising for the triangulation process.

The first triangulation stage took place after three interviews with singers and two interviews with orchestra musicians had been conducted at the end of June 2018.

The investigator attended 11.5 hours of live performance, including two opera performances and one final rehearsal. Twelve different main characters were observed on stage, each with different and changing emotional states during the opera. Richard Wagner's *Parsifal* was attended at a live performance and a final rehearsal, while the *Flying Dutchman* was attended at a live performance. One of the interviewed singers performed at these three opera events. For time and organizational reasons, no other performance featuring interviewed singers was attended.

The second triangulation stage was carried out after interviews had been completed at the end of July 2018. The author attended Richard Wagner's *Ring of the Nibelung*, which consists of four operas and lasts 15 hours. On this occasion, 20 main characters with different emotional states were observed.

After each performance, the investigator compared, in a structured manner, findings from the interviews with observations from the live performance. Upon completing the data analysis and refining the framework, a second comparison was performed. All concepts used in the final framework (see Section 5) were observed during live performances and confirmed by this triangulation process. The influence that other people on stage had on displayed emotions was also confirmed; therefore, the validity of the data was enhanced. External and internal influences on singers, and the preparation process of emotional display, could not be assessed through this form of triangulation.

5. Data analysis and findings

Section 5 discusses data analysis and findings. The data-analysis process was divided into three stages and overlapped the data-collection stage, as described in Section 3. This section also shows key findings in a resulting framework.

5.1 Data analysis

Figure 5 provides a chronological overview of the process of data analysis and shows its connection with the interviewing and triangulation stages.

The first stage of data analysis was carried out after the first interview stage and prior to the first triangulation stage. The transcribed qualitative data were systematically analyzed. First, the data were coded by the author following Strauss and Corbin's procedure [100], which includes open, axial, and selective coding. After coding, within-case analysis was conducted following Eisenhardt's procedure [97] to understand each case in greater depth.

The first data-analysis results showed that conducting interviews with opera singers is an effective strategy to understand how emotions are displayed and to identify factors that influence artists' performance. Contrary interviews with orchestra musicians yielded negligible results for this study.

The second stage of analysis occurred after eight interviews with singers and before the second triangulation stage. It involved transcribing interviews, data coding according to Strauss and Corbin [100] and within-case analysis following Eisenhardt [97]. Cross-case analysis using pairs of cases was partly carried out at this stage.

The third data-analysis stage followed the second triangulation stage, including comprehensive cross-case analysis using pairs of cases. This led to a deeper understanding of the data and showed that no contradictory findings regarding influences

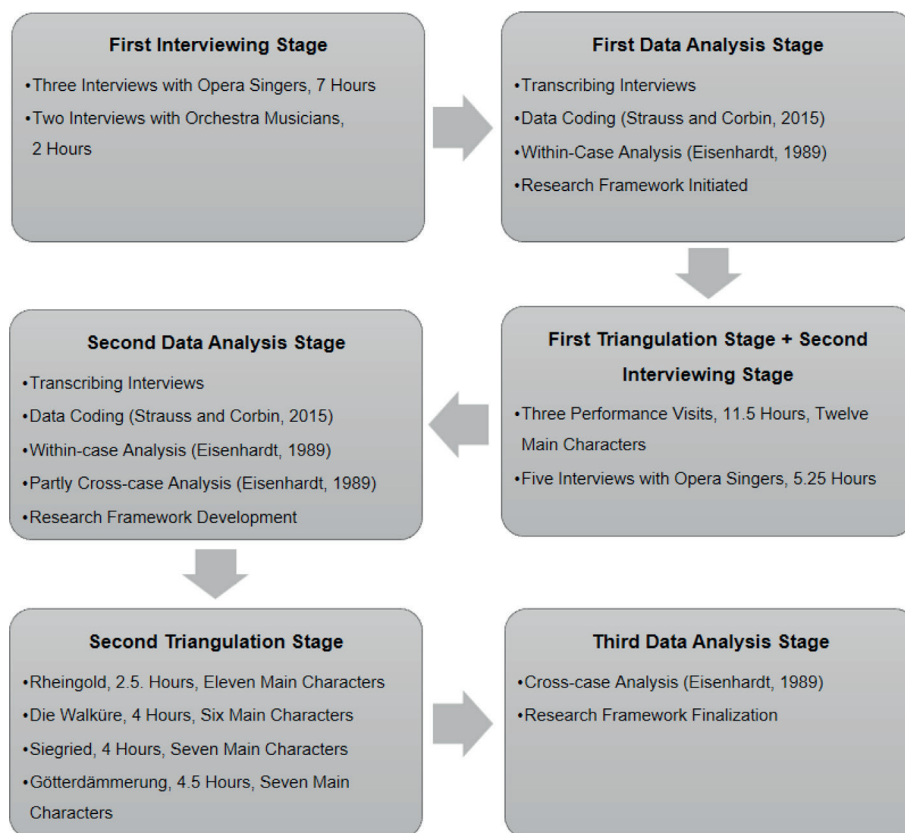


Figure 5.
Overview of data analysis.

on singers and cues for emotional elicitation occurred in any of the compared pairs. At this stage, the research framework was finalized.

The key findings from this study can be divided into four categories and will be described and critically evaluated:

1. Cues for emotional display
2. Internal and external influences on singers
3. Influence of preparation process on emotional display
4. Influence of other artists being on stage on emotional display

5.1.1 Cues for emotional display

This study investigated how eight different emotions conceptualized by Plutchik [63] may be displayed by opera singers on stage: joy, sadness, trust, disgust, fear, anger, surprise and anticipation. **Table 2** shows a detailed split of the number of concepts analyzed from interviews for displaying emotions.

Emotion	Number of different concepts	Mentioned concept one time	Mentioned concept two times	Mentioned concept three times	Mentioned concept four times	Number of different concepts used in framework
Joy	16	6	9	1	0	12
Sadness	14	6	3	3	2	10
Trust	7	7	0	0	0	6
Disgust	7	3	4	0	0	7
Fear	7	1	1	3	2	6
Anger	12	4	6	2	0	8
Surprise	8	5	2	1	0	7
Anticipation	3	0	2	1	0	3
Sum	74	32	27	11	4	59

Table 2.
Concepts in the final framework.

In the interviews, 74 distinct concepts were mentioned: for example, “looking down” was mentioned four times regarding how artists could display “sadness”. Thus, “looking down” was counted four times within the total number of 135 concepts. Some concepts are similar; for example, “shoulders dropped” or “hanging body” describe similar physical manifestations of “sadness”.

Table 2 also shows that the data gathered from the interviews provides most concepts for “joy”. The emotion “sadness” was described using 14 concepts. The high number of concepts and the multiple mentions of several of them suggest that the results for “joy” and “sadness” are most valid in this study for displaying particular emotions. A high degree of validity can also be claimed for “anger” (12 concepts), “fear” (5), “trust” (7), and “anticipation” (3).

In addition, the richness of findings varied across cases. One participant contributed 6 of the overall 135 concepts, whereas 2 participants introduced 29 and 31 concepts, respectively.

5.1.2 Internal and external influences on singers

Analysis of the internal and external influences on singers produced the following results. Regarding internal influences, the concept of “technical problems” was mentioned by four interviewees, while the second most popular concept was “life experience”, mentioned three times, followed by “stage experience”, mentioned twice. Regarding external influences, the two most important concepts were “colleagues” and “whole team works towards the same objective”, with five and three mentions, respectively.

5.1.3 Influence of preparation process on emotional display

This can be described as the conscious-preparation-unconscious-playing process: preparation is a conscious approach, whereas playing on stage is unconscious.

Preparation for the emotional display with libretto, score or background reading was cited by interviewees five, six and seven times, respectively. Following this stage of gaining an understanding of the content, the singers do mental work. All eight interviewees stated that they transfer the content and its associated emotions to their personal life experiences and the emotions felt during these experiences.

5.1.4 Influence of other artists being on stage on emotional display

All eight interviewees emphasized the crucial influence that other artists on stage have on their emotional display. Other solo singers, opera choirs, and extras prove or disprove displayed emotions. Two singers specifically stated that “One person on stage can destroy everything”, and three singers said that “A king cannot be played, it is played by the others”. Hence, other service participants have a significant influence on emotional display.

5.2 Summary of data analysis

The data analysis was carried out in three stages that overlapped with data gathering, and two stages of data triangulation were conducted. The overlapping process of data gathering, analysis and triangulation proved successful because emerging topics and ideas could be included in the study. Additionally, this iterative process ensured an in-depth understanding of the research study and enabled a solid, grounded theory approach with high validity. In general, the validity was evaluated by considering the number of mentions and the triangulation process of the data, where applicable.

The framework, shown in **Figure 6**, consists of four main sections. Central to this framework are *cues for emotional display*, which can be used to detect a person's emotional state or to consciously display an emotional state, whether the person displaying it feels so or not. The latter is strongly influenced by the authentic display of emotions. The *preparation process of emotional display* highly influences the authenticity of displayed emotions. Singers tend to consciously tap into felt emotions and then display them unconsciously, which tends to increase the authenticity of the emotion. The credibility of emotions displayed on stage is influenced by not only how artists display them but also the *influence of other artists on stage*. With their reactions, other artists either prove or disprove the displayed emotion. According to the singers interviewed, this has a huge impact on the credibility of the emotions. Additionally, there are *internal and external influences on singers*, which affect the role of the singer. These influences can strengthen or weaken singers' emotional display.

The data used in the final framework is characterized by a high degree of validity for the four emotions of “joy”, “sadness”, “fear” and “anger”. The information about displaying “disgust” and “surprise” can be considered highly valid, while the validity of “anticipation” and “trust” may be evaluated as medium-high. The influence of other artists being on stage and of the preparation process on emotional display also has very high validity. Both influences, or parts of the influence, were mentioned by all interviewees, who emphasized the importance of these two influences. Regarding internal influences on singers, “life experience” and “technical problems” had high validity. The same characterization applied to “colleagues” and “same objective of the whole team in an opera house”. Overall, the validity of the framework may be evaluated as high.

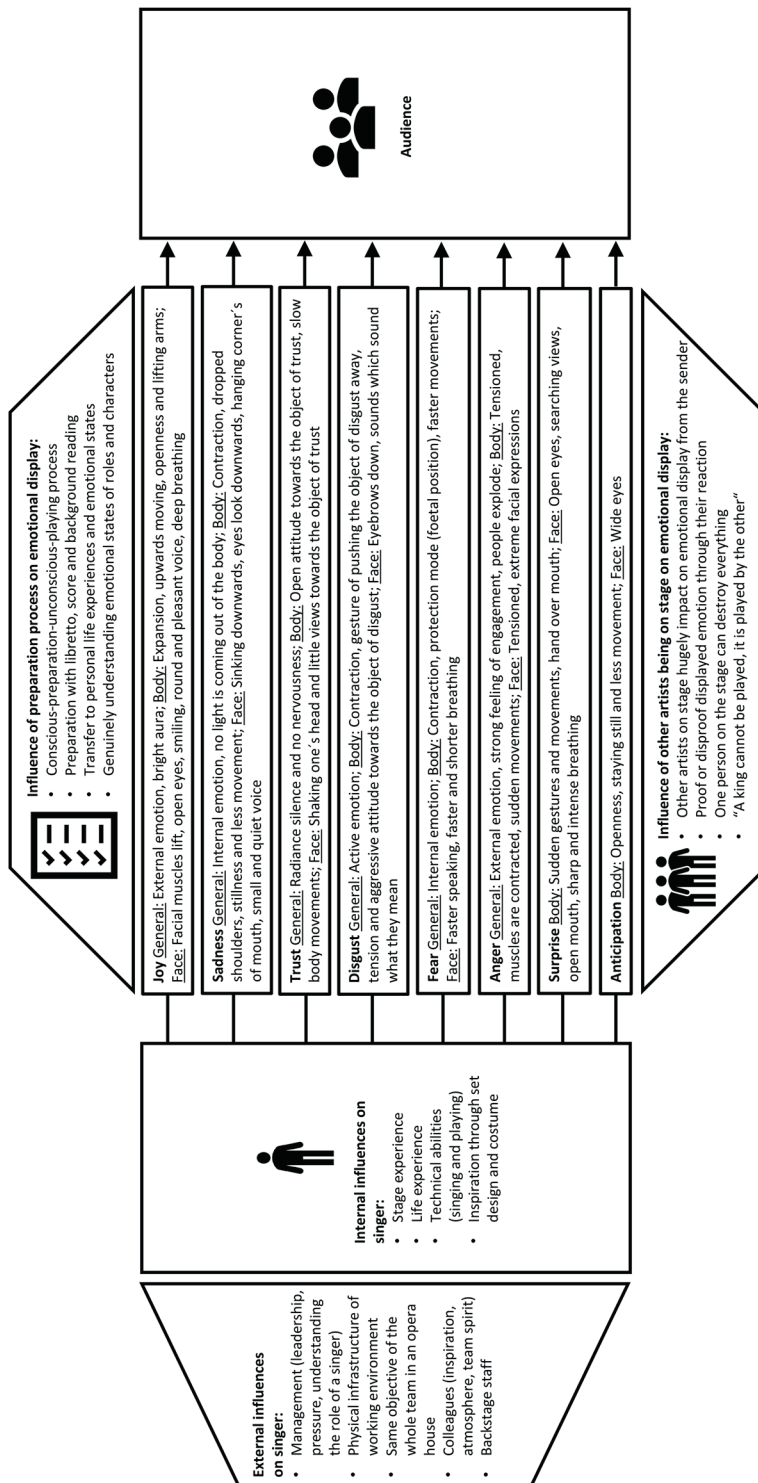


Figure 6. Research framework.

5.3 The research framework

The qualitative data analyzed were summarized in a research framework developed during the data-gathering, data coding, data-analysis (within-case and cross-case) and triangulation process. Data coding provided concepts and relations between concepts, which were systematically organized, structured and generalized where necessary. Four key criteria were considered to establish whether a particular concept should be included in the framework: the number of times a concept or related concept was mentioned, the results of the triangulation process, the results from cross-case analysis, and the investigator's judgment. **Figure 6** shows the final research framework.

6. Discussion

This study contributes to the current scholarly debate on managing and designing customer experience, which is considered crucial for companies, since it critically impacts their financial success [1, 2, 6, 10]. In particular, the portfolio of diagnostic cues helps to better design the relational context in terms of intangible service elements such as personal interaction between employees and customers [39, 40, 43, 50, 51]. Literature has argued that displaying emotions in a service encounter represents a dilemma, since it should be spontaneous, authentic and effective [42, 79, 80]. The research framework developed in this study contributes to solving this dilemma by increasing the authenticity of displaying emotions through its novel information about the conscious-preparation-unconscious-playing process. In addition, this research enables a better working environment design to accomplish emotional labour. This work could influence the selection process of new employees through findings about internal influences on service-deliverers. By providing a portfolio of diagnostic cues, the framework could lead to more sophisticated research on emotions in service encounters. In future, emotional states of the unit of analysis could be observed without being measured by questionnaires answered by respondents. Furthermore, this study advances current knowledge about emotions in opera [93].

6.1 Training frontline employees

Du et al. [87], Mattila and Enz [76] and Menon and Dubé [26] suggest that frontline employees should receive effective emotional training and that a portfolio of diagnostic cues should be developed to understand how customers typically display emotions, but none provide details about the training content. The findings from this study are the first attempt to fill this gap. The framework shows how people can display eight different emotions. These cues can be used in training frontline employees in service operations either to display a particular emotion during the "moment of truth" or to detect customers' emotional states. Detecting emotional cues and properly assessing customer emotional states is the first step to customizing service delivery. Furthermore, it can potentially counteract unwanted emotional states in customers. In services, mitigating negative emotions or reinforcing positive emotions, irrespective of the cause of emotional change, has a positive impact on customer satisfaction [11, 24, 26, 27]. According to the concept of emotional contagion [81, 84], displaying a particular emotion leads to a corresponding emotional change in the receiver. For example, emotions displayed by the sales clerk influence customer emotions during the service encounter. It is likely that the customer "catches" the

triggered emotions [26, 84]. Hence, the framework can help to train frontline employees to send desirable emotional cues or avoid sending cues that may lead to negative emotions through emotional contagion.

6.2 Solving the dilemma between authenticity and the effectiveness of emotional display

Moreover, the theory on the preparation process' influence on emotional display provides service companies with guidance on how emotions can be displayed authentically. This is crucial because it can potentially solve the dilemma of authenticity and effectiveness [42, 79, 80]. The first step is a conscious preparation process to thoroughly understand each possible emerging emotion in the "moment of truth" and to transfer this to personal experiences and emotional states. The second step, which takes place before the emotional display, taps into the feeling and helps to display authentic emotions.

6.3 Enhancing work environment and recruitment of emotional labour staff

Mattila and Enz [76] highlight that the work environment must be adjusted to foster positive affect on employees. This study offers service companies necessary insights for creating an environment suitable to perform emotional labour. Internal and external influences on singers were collected and systematized, and requirements for the work environment can be derived from these findings, mostly from external influences. Regarding internal influences, the importance of life experience for emotional labour is yet to be discussed in management literature. This new finding may affect the selection process of employees, since life experience positively affects individuals' ability to display emotions.

6.4 New measurements for assessing emotional states

In this research, we set out how emotional states can be measured through observation using the portfolio of diagnostic cues. This knowledge can significantly advance research on the importance of emotional displays by employees in service encounters. Measuring the impact of employee behavior, Tsai [85] and Pugh [84] use the rudimentary measures by Rafaeli and Sutton: greeting, smiling, eye contact and thanking [94, 95]. Using the portfolio of diagnostic cues in future research will allow scholars and companies to better assess emotions displayed by employees and enable them to explore their impact.

This research also contributes to current scholarship on emotions in opera, which remains a relatively niche field of study. Balteş and Miu [93] stated that scholars do not possess a deep scientific understanding of the process of emotional display and elicitation in operas. The resulting framework is the first attempt to systematically provide information on emotional displays. The framework can be used in future research to investigate more thoroughly and systematically the impact of stage performance on customer emotions.

7. Conclusions and future research

Emotions occurring in service interactions seem to strongly influence perceived quality and customer satisfaction. Therefore, managing and designing emotions

better during the “moment of truth” is beneficial for companies. This study explored how direct service-deliverers can authentically display emotions and better assess emotional states through diagnostic cues. Additionally, this work investigates internal and external factors influencing the emotional labour of service-deliverers. Finally, this section describes the impact of findings on industry and academia and discusses how future research may build on this study.

The thesis presents a comprehensive framework for emotional design in opera, based on data gathered from interviews with renowned experts in the field and validated through observation. The framework provides a wealth of diagnostic cues for the emotions conceptualized by Plutchik [63], incorporating internal and external influences on service-deliverers. It also represents the first attempt to solve the dilemma of authenticity and effectiveness in emotional display.

From an industry perspective, this work provides crucial information about emotional displays, elicitation and their influence on internal and external factors. This can help managers to build a better service environment emphasizing the importance of emotions. The portfolio of diagnostic cues for emotions helps to detect customers' emotional state or to give guidance on how certain emotions can be displayed. Assessing customers' emotional states is a necessary first step to customizing services according to customers' emotional states. Customers can “catch” emotions displayed by employees through emotional contagion. Hence, the sender of cues can either intentionally send desired cues or avoid sending undesired cues. Employees should be trained to control or send emotions, and the portfolio of diagnostic cues provides a scientific foundation for this. This work also helps to solve the dilemma of authenticity and effectiveness in emotional display thanks to the development of the conscious-preparation-unconscious-playing process, a tool that enables the display of emotions perceived to be authentic by the receiver. This work also demonstrates that the authenticity and effectiveness of displayed emotions are influenced by others on stage. Transferred to service encounters, this means that the reaction of indirect serving employees on direct serving employees influences customers' perceptions of emotions displayed by direct service employees.

7.1 Implications for academia

From an academic perspective, the main contribution of this work lies in the possibility to generate new and more sophisticated research designs on emotions in service management and service operations using the framework developed. The portfolio of diagnostic cues allows scholars to assess emotions displayed by service actors, providing the opportunity to study the impact of emotions displayed by employees on customer emotions triggered during service encounters. Studies built on this portfolio may offer new and important information for managing and designing emotions, enhancing customer experience.

7.2 Future research

This study has several limitations that should be addressed in future research. First, interviewing more singers and others involved in opera, such as conductors, set designers, costume designers and stage directors, may enhance the findings' generalizability. Second, conducting interviews with artists working in different contexts may also enhance generalizability. Future research fields could be ballet, modern dance, spoken theater or stand-up comedy. Studying ballet or modern dance

may shed light on body language, whereas investigating spoken theater or stand-up comedy may lead to further insights into voice, language and facial expressions. Third, the validity of the research framework may be enhanced through additional triangulation. This study focused exclusively on sending and displaying emotions. While the data was triangulated through observation by the author, the effectiveness of the cues may be further evaluated with the help of studies using the audience as the unit of analysis. This can be done in a laboratory setting, with video excerpts or during live performances. Moreover, action research or accompanying the whole rehearsal process of a new opera production may provide new, rich and enlightening information about the display of emotions, its process and requirements for artists.


This work represents a first attempt to provide scholarship on the service industry and management with a comprehensive framework on emotional design. We hope it will encourage scholars in the fields of service management and opera to collaborate and pursue further research on emotional cues and on the internal and external factors that influence service-deliverers and their emotional displays.

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References

- [1] Pullman ME, Gross MA. Ability of experience design elements to elicit emotions and loyalty behaviors. *Decision Sciences*. 2004;**35**:551-578
- [2] Zomerdijk LG, Voss CA. Service Design for Experience-Centric Services. 2010;**13**:67-82
- [3] Oliver RL. Measurement and evaluation of satisfaction processes in retail settings. *Journal of Retailing*. 1981;**57**:25-48
- [4] Zeithaml VA, Berry LL, Parasuraman A. Communication and control processes in the delivery of service quality. *Journal of Marketing*. 1988;**52**:35
- [5] Homburg C, Koschate N, Hoyer WD. The role of cognition and affect in the formation of customer satisfaction: A dynamic perspective. *Journal of Marketing*. 2006;**70**:21-31
- [6] Ladhari R. Service quality, emotional satisfaction, and behavioural intentions: A study in the hotel industry. *Managing Service Quality: An International Journal*. 2009;**19**:308-331
- [7] Liljander V, Strandvik T. Emotions in service satisfaction. *International Journal of Service Industry Management*. 1997;**8**:148-169
- [8] Mano H, Oliver RL. Assessing the dimensionality and structure of the consumption experience: Evaluation, feeling, and satisfaction. *Journal of Consumer Research*. 1993;**20**:451-466
- [9] Oliver RL. *Satisfaction: A Behavioral Perspective on the Consumer*. 2nd ed. Armonk, NY: ME Sharpe; 2010
- [10] Wirtz J, Bateson JEG. Consumer satisfaction with services. *Journal of Business Research*. 1999;**44**:55-66
- [11] Bigné E, Mattila AS, Andreu L. The impact of experiential consumption cognitions and emotions on behavioral intentions. *Journal of Services Marketing*. 2008;**22**:303-315
- [12] Gibson H. Towards an understanding of "why sport tourists do what they do.". *Sport in Society*. 2005;**8**:198-217
- [13] Gupta S, McLaughlin E, Gomez M. Guest satisfaction and restaurant performance. *Cornell Hotel and Restaurant Administration Quarterly*. 2007;**48**:284-298
- [14] Ladhari R, Souiden N, Dufour B. The role of emotions in utilitarian service settings: The effects of emotional satisfaction on product perception and behavioral intentions. *Journal of Retailing and Consumer Services*. 2017;**34**:10-18
- [15] Pine J, Gilmore J. Welcome to the experience economy. *Harvard Business Review*. 1998;**July–August**:96-105
- [16] Teixeira J, Patrício L, Nunes NJ, Nóbrega L, Fisk RP, Constantine L. Customer experience modeling: From customer experience to service design. *Journal of Service Management*. 2012;**23**:362-376
- [17] DeWitt T, Brady MK. Rethinking service recovery strategies: The effect of rapport on consumer responses to service failure. *Journal of Service Research*. 2003;**6**:193-207
- [18] Keaveney SM. Customer switching behavior in service industries: An

exploratory study. *Journal of Marketing*. 1995;**59**:71

[19] Smith AK, Bolton RN. An experimental investigation of customer reactions to service failure and recovery encounters: Paradox or peril? *Journal of Service Research*. 1998;**1**:65-81

[20] Reichheld F, Sasser E. Zero defections: Quality comes to services. *Harvard Business Review*. 1990;**September–October**:105-111

[21] Zeithaml VA. Service quality, profitability, and the economic worth of customers: What we know and what we need to learn. *Journal of the Academy of Marketing Science*. 2000;**28**:67-85

[22] Anderson EW, Fornell C, Mazvancheryl SK. Customer satisfaction and shareholder value. *Journal of Marketing*. 2004;**68**:172-185

[23] Gruca TS, Rego LL. Customer satisfaction, cash flow, and shareholder value. *Journal of Marketing*. 2004;**68**:172-185

[24] Arnould EJ, Price LL. River magic: Extraordinary experience and the extended service encounter. *Journal of Consumer Research*. 1993;**20**:24. DOI: 10.1086/209331

[25] Fiore AM, Kim J. An integrative framework capturing experiential and utilitarian shopping experience. *International Journal of Retail and Distribution Management*. 2007;**35**:421-442

[26] Menon K, Dubé L. Ensuring greater satisfaction by engineering salesperson response to customer emotions. *Journal of Retailing*. 2000;**76**:285-307

[27] Ng S, Russell-Bennett R. The role of affect in consumer evaluation of

health care services. *Health Marketing Quarterly*. 2015;**32**:31-47

[28] Westbrook RA. Product/consumption-based affective responses and Postpurchase processes. *Journal of Marketing Research*. 1987;**24**:258

[29] Westbrook RA, Oliver RL. The dimensionality of consumption emotion patterns and consumer satisfaction. *Journal of Consumer Research*. 1991;**18**:84

[30] Carbone LP, Haeckel SH. Engineering customer experiences. *Marketing Management*. 1994;**3**:8-19

[31] Holbrook MB, Hirschman EC. The experiential aspects of consumption: Consumer fantasies, feelings, and fun. *Journal of Consumer Research*. 1982;**9**:132

[32] Meyer C, Schwager A. Understanding customer experience. *Harvard Business Review*. 2007;**February**:117-126

[33] Prahalad CK, Ramaswamy V. Co-creating unique value with customers. *Strategy and Leadership*. 2004;**32**:4-9

[34] Voss C, Roth AV, Chase RB. Experience, service operations strategy, and services as destinations: Foundations and exploratory investigation. *Production and Operations Management*. 2008;**17**:247-266

[35] Chase RB. The customer contact approach to services: Theoretical bases and practical extensions. *Operations Research*. 1981;**29**:698-706

[36] Roth AV, Menor LJ. Insights into service operations management: A research agenda. *Production and Operations Management*. 2009;**12**:145-164

- [37] Solomon MR, Suprenant C. A role theory perspective on dyadic interactions: The service encounter. *Journal of Marketing*. 1985;**49**:99-111
- [38] Shostack L. *The Service Encounter: Managing Employee/Customer Interaction in Service Businesses*, The Advances in Retailing Series. Lexington, Mass: Lexington Books; 1985
- [39] Cook LS, Bowen DE, Chase RB, Dasu S, Stewart DM, Tansik DA. Human issues in service design. *Journal of Operations Management*. 2002;**20**:159-174
- [40] Bitner MJ. Evaluating service encounters: The effects of physical surroundings and employee responses. *Journal of Marketing*. 1990;**54**(2):69-82
- [41] Glushko RJ, Tabas L. Designing service systems by bridging the “front stage” and “back stage.” *Information Systems and e-Business Management*. 2009;**7**:407-427
- [42] Price LL, Arnould EJ, Deibler SL. Consumers’ emotional responses to service encounters: The influence of the service provider. *International Journal of Service Industry Management*. 1995;**6**:34-63
- [43] Gupta S, Vajic M. The contextual and dialectical nature of experiences. In: *New Service Development: Creating Memorable Experiences*. United States: SAGE Publications, Inc.; 2000. pp. 33-51
- [44] Baker J, Cameron M. The effects of the service environment on affect and consumer perception of waiting time: An integrative review and research propositions. *Journal of the Academy of Marketing Science*. 1996;**24**:338-349
- [45] Mehrabian A, Russell JA. *An Approach to Environmental Psychology*. Cambridge: MIT Press; 1974
- [46] Strati A. *Organization and Aesthetics*. SAGE, London: Thousand Oaks; 1999
- [47] Dasu S, Chase RB. Designing the soft side of customer service. *MIT Sloan Management Review*. 2010;**Fall**:32-39
- [48] Cronin JJ, Brady MK, Hult GTM. Assessing the effects of quality, value, and customer satisfaction on consumer behavioral intentions in service environments. *Journal of Retailing*. 2000;**76**:193-218
- [49] Vargo SL, Lusch RF. Evolving to a new dominant logic for marketing. *Journal of Marketing*. 2004;**68**:1-17
- [50] Forlizzi J, Ford S. *The Building Blocks of Experience: An Early Framework for Interaction Designers*. ACM Press; 2000. pp. 419-423. DOI: 10.1145/347642.34780
- [51] Patrício L, Fisk RP, Falcão e Cunha J, Constantine L. Multilevel service design: From customer value constellation to service experience blueprinting. *Journal of Service Research*. 2011;**14**:180-200
- [52] Groth M, Hennig-Thurau T, Walsh G. Customer reactions to emotional labor: The roles of employee acting strategies and customer detection accuracy. *Academy of Management Journal*. 2009;**52**:958-974
- [53] Johnson M, Zinkhan GM. Emotional responses to a professional service encounter. *Journal of Services Marketing*. 1991;**5**:5-16
- [54] Tranfield D, Denyer D, Smart P. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*. 2003;**14**(3):207-222

- [55] Jalali S, Wohlin C. Systematic literature studies: Database searches vs. backward snowballing. In: International Conference on Empirical Software Engineering and Measurement, ESEM'12, 19-20 September 2012. Lund, Sweden: ACM Press; 2012. p. 29
- [56] Izard CE. Basic emotions, natural kinds, emotion schemas, and a new paradigm. *Perspectives on Psychological Science*. 2007;**2**:260-280
- [57] McColl-Kennedy JR, Smith AK. Customer emotions in service failure and recovery encounters. *Research on Emotion in Organizations*. 2006;**45**:237-268
- [58] Scherer KR. What are emotions? And how can they be measured? *Social Science Information*. 2005;**44**:695-729
- [59] Bagozzi RP, Gopinath M, Nyer PU. The role of emotions in marketing. *Journal of the Academy of Marketing Science*. 1999;**27**:184-206
- [60] Oatley K. *Best Laid Schemes: The Psychology of Emotions, Studies in Emotion and Social Interaction*. Cambridge, New York, Paris: Cambridge University Press; Editions de la Maison des science de l'homme; 1992
- [61] Lazarus RS. *Emotion and Adaptation*. 1st ed. New York: Oxford University Press; 1994
- [62] Erevelles S. The role of affect in marketing. *Journal of Business Research*. 1998;**42**:199-215
- [63] Plutchik R. A psychoevolutionary theory of emotions. *Social Science Information*. 1982;**21**:529-553
- [64] Ekman P, Friesen WV. Universals and cultural differences in the judgments of facial expressions of emotion. *Journal of Personality and Social Psychology*. 1987;**712**-717
- [65] Izard CE. *Human Emotions*. New York: Springer Science + Media; 1977
- [66] Watson D, Anna L, Tellegen A. Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*. 1988;**8**
- [67] Richins ML. Measuring emotions in the consumption experience. *Journal of Consumer Research*. 1997;**24**:127-146
- [68] Plutchik R. The nature of emotions: Human emotions have deep evolutionary roots, a fact that may explain their complexity and provide tools for clinical practice. *American Scientist*. 2001;**89**:344-350
- [69] Gorn GJ, Goldberg ME, Basu K. Mood, awareness, and product evaluation. *Journal of Consumer Psychology*. 1993;**2**:237-256
- [70] Chitturi R, Raghunathan R, Mahajan V. Form versus function: How the intensities of specific emotions evoked in functional versus hedonic trade-offs mediate product preferences. *Journal of Marketing Research*. 2007;**44**:702-714
- [71] Jani D, Han H. Influence of environmental stimuli on hotel customer emotional loyalty response: Testing the moderating effect of the big five personality factors. *International Journal of Hospitality Management*. 2015;**44**:48-57
- [72] Kim S, Park G, Lee Y, Choi S. Customer emotions and their triggers in luxury retail: Understanding the effects of customer emotions before and after entering a luxury shop. *Journal of Business Research*. 2016;**69**:5809-5818

- [73] Koenig-Lewis N, Palmer A. Journal of Services Marketing. 2014;**28**:437-451
- [74] Claeys C, Roozen I. The impact of the emotional and functional component of the customer experience on the company-customer relationship in hedonic and utilitarian service. *Contexts*. 2014;**58**:26
- [75] Ladhari R, Rigaux-Bricmont B. Determinants of patient satisfaction with public hospital services. *Health Marketing Quarterly*. 2013;**30**:299-318
- [76] Mattila AS, Enz CA. The role of emotions in service encounters. *Journal of Service Research*. 2002;**4**:268-277
- [77] Wong A. The role of emotional satisfaction in service encounters. *Managing Service Quality: An International Journal*. 2004;**14**:365-376
- [78] Rust RT, Oliver RL. Should we delight the customer? *Journal of the Academy of Marketing Science*. 2000;**28**:86-94
- [79] Hochschild AR. *The Managed Heart: Commercialization of Human Feeling*. 20th anniversary ed. Berkeley, California: University of California Press; 2003
- [80] Rafaeli A, Sutton RI. Expression of emotion as part of the work role. *The Academy of Management Review*. 1987;**12**:23-37
- [81] Hatfield E, Cacioppo JT, Rapson RL. *Emotional Contagion*. University Cambridge Press; 1993. DOI: 10.1111/1467-8721.ep10770953
- [82] Barsade SG. The ripple effect: Emotional contagion and its influence on group behavior. *Administrative Science Quarterly*. 2002;**47**:644
- [83] McColl-Kennedy JR, Anderson RD. Subordinate–manager gender combination and perceived leadership style influence on emotions, self-esteem and organizational commitment. *Journal of Business Research*. 2005;**58**:115-125
- [84] Pugh SD. Service with a smile: Emotional contagion in the service encounter. *Academy of Management Journal*. 2001;**44**:1018-1027
- [85] Tsai W-C. Determinants and consequences of employee displayed positive emotions. *Journal of Management*. 2001;**27**:497-512
- [86] Luong A. Affective service display and customer mood. *Journal of Service Research*. 2005;**8**:117-130
- [87] Du J, Fan X, Feng T. Multiple emotional contagions in service encounters. *Journal of the Academy of Marketing Science*. 2011;**39**:449-466
- [88] Brown AS, Novak JL. *Assessing the Intrinsic Impacts of a Live Performance*. WolfBrown; 2007
- [89] O'Neill S, Edelman J, Sloboda J. Opera and Emotion: The Cultural Value of Attendance for the Highly Engaged. 2016;**13**:27
- [90] Operavision. *Opera, the Art of Emotions* [WWW Document]. Brussels: OperaVision; 2017. Available from: <https://operavision.eu/de/bibliothek/geschichten/opera-art-emotions> [Accessed: July 3, 2018]
- [91] Balteş FR, Avram J, Miclea M, Miu AC. Emotions induced by operatic music: Psychophysiological effects of music, plot, and acting. *Brain and Cognition*. 2011;**76**:146-157
- [92] Felsner M. *Operatica: Annäherungen an die Welt der Oper*. Würzburg: Königshausen & Neumann; 2008

[93] Balteş FR, Miu AC. Emotions during live music performance: Links with individual differences in empathy, visual imagery, and mood. *Psychomusicology: Music, Mind, and Brain*. 2014;24:58-65

[94] Rafaeli A. When clerks meet customers: A test of variables related to emotional expressions on the job. *Journal of Applied Psychology*. 1989;74:385-393

[95] Rafaeli A, Sutton RI. Busy stores and demanding customers: How do they affect the display of positive emotion? *The Academy of Management Journal*. 1990;33:623-637

[96] Edmondson AC, Mcmanus SE. Methodological fit in management field research. *Academy of Management Review*. 2007;32:1246-1264

[97] Eisenhardt KM. Building theories from case study research. *The Academy of Management Review*. 1989;14:532-550

[98] Yin RK. *Case Study Research: Design and Methods*. 5th ed. Los Angeles: SAGE; 2014

[99] Dawes Farquhar J, Deigh L. *Living dangerously: Generalizing in case study research*. 2016

[100] Corbin JM, Strauss AL. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. 4th ed. Los Angeles: SAGE; 2015

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Globalization, climate change, and digitalization are fundamentally changing the business environment. Companies face growing challenges that require new approaches to internationalization, sustainable development, and innovation. This publication provides a comprehensive overview of the current trends and strategies that are shaping the future of business in the 21st century. In the first section of the book, the authors examine internationalization in the current business environment – from the influence of top management on the performance of Indian companies to the dynamics of global labor mobility and its impact on trade and investment. The second section is dedicated to sustainable business practices. Readers will find an analysis of innovative solutions in road freight transport, a discussion of the possibilities for sustainable business in the European petrochemical industry, as well as an examination of circular fashion and the recycling of 3D printing waste. The third section focuses on innovative business approaches. The chapters present creative approaches to international research in an Islamic context and provide a framework for exploring human emotions in musical performances as a source of new insights for design and research. The publication combines theoretical insights with practical examples from diverse cultural and regional settings. It is intended for academics, researchers, students, and practitioners seeking a deeper understanding of current trends and future perspectives in business.

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