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Green process innovation and sustainable performance: an exploratory study in Bat Trang ceramic craft village

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Abstract: Green process innovation plays a crucial role in enhancing sustainable performance, enabling manufacturers to reduce environmental impacts while gaining a competitive advantage. This study examines green process innovation and sustainable performance among manufacturing establishments in Bat Trang ceramic village. Based on in-depth interviews with ten owners of establishments that have adopted green process innovation, the findings identify five key drivers: 1) market factors; 2) stakeholder pressure; 3) technological factors; 4) collaboration and networking; 5) social, cultural, and ethical considerations. Most establishments are applying cleaner technologies by replacing conventional combustion methods with liquefied petroleum gas and electricity. Respondents also highlighted the positive effects of green process innovation on sustainable performance across three dimensions: economic, environmental, and social. The study offers policy implications aimed at promoting green process innovation to enhance sustainable performance.

Keywords: green innovation; green process innovation; clean technology; sustainability; sustainable performance; economic performance; environmental performance; social performance; craft village; Vietnam.

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1 Introduction

A brown economy, an economy that relies heavily on the exploitation and use of non-renewable natural resources, has caused serious consequences for the environment and negative impacts on human health. As a result, transitioning from a brown economy to a green economy is not only a choice but also a necessity and is becoming a common trend worldwide. Many enterprises have set goals to achieve higher sustainable performance to stand firm in the market at both the national and international levels (Ch'ng et al., 2021), as well as simultaneously address economic, environmental, and social issues.

Green innovation plays a key role in the achievement of sustainable performance (Liu et al., 2024; Suki et al., 2023). Adoption of green innovation is linked to improved environmental performance and financial results (Ha et al., 2024). Additionally, green innovation supports higher corporate social responsibility (CSR) fulfilment, promoting firms' public image (Zhang and Leng, 2025). Among types of green innovation, green process innovation is a strategic factor promoting sustainable development (Sarfraz et al., 2022). The increasing demand for sustainable performance requires enterprises to adopt green processes to minimise negative impacts on the environment (Yousaf, 2021). The implementation of green process innovation reduces resource consumption, minimises waste, and decreases emissions in manufacturing and production processes (Ahmed et al., 2023; Cheng et al., 2023).

In Vietnam, rapid industrialisation has led to significant environmental challenges, particularly in air and water pollution. Discharged wastewater from manufacturing establishments severely degrades aquatic ecosystems (Anh et al., 2023). Air pollution resulting from industrial emissions is negatively affecting air quality and posing threats to human health (Ali et al., 2021). In order to achieve sustainable development goals, green innovation is highly prioritised in the national agenda. According to the 'National Green Growth Strategy for 2021–2030, vision towards 2050' approved by The Prime Minister of Vietnam (2021), the country would focus on applying green technology, management systems and controlling production activities according to good practices to save resources, reduce emissions, and improve the ecological environment. It is expected that through green process innovation, manufacturing establishments and enterprises can gain

long-term competitive advantages, reduce negative impacts on the environment, improve social life, and move the country toward a green and carbon-neutral economy by 2050.

While modern manufacturing establishments in Vietnam are increasingly adopting green innovations to mitigate environmental impacts and improve sustainability, many traditional craft villages remain slow to embrace such advancements. These villages usually rely on conventional, resource-intensive production methods that contribute significantly to environmental degradation and pollution (Dang et al., 2013). Therefore, it is essential to conduct research on green process innovation and sustainable performance in traditional craft villages to facilitate their transition towards environmentally friendly practices and ensure their long-term viability and competitiveness. In particular, Bat Trang ceramic village serves as a typical case study in green process innovation, demonstrating how a traditional craft village once faced with environmental pollution and declining quality of life is constantly striving towards sustainability. Previously, the village struggled due to outdated and environmentally harmful production technologies, negatively impacting its reputation. However, by adopting green process innovation, manufacturing establishments in Bat Trang have achieved positive results in sustainable performance, becoming a promising model for sustainable and environmentally responsible development among craft villages across Vietnam.

Previous studies have predominantly concentrated on measuring and quantifying the relationship between green process innovation and sustainable performance, leaving explorations of the underlying motivations, specific implementation practices, and impact mechanisms relatively under-investigated. Therefore, the objectives of this study are three-fold:

1 to investigate the underlying motivations driving manufacturing establishment owners in Bat Trang village to adopt green process innovation

2 to examine the practices involved in the implementation of green process innovation

3 to assess the outcomes in relation to sustainability performance.

Based on a comprehensive literature review, the natural-resource-based view (NRBV) and stakeholder theory, the authors proposed an analytical framework consisting of three parts: drivers of green process innovation, green process innovation practices, and the impact mechanism of green process innovation on sustainable performance. The framework will be used to analyse data collected from in-depth interviews with owners of manufacturing establishments in Bat Trang ceramic village. This study attempted to find answers to the following research questions:

RQ1 What drives the owners of manufacturing establishments in Bat Trang ceramic village to implement green process innovation?

RQ2 Which green process innovation practices are being implemented in manufacturing establishments in Bat Trang ceramic village?

RQ3 How does green process innovation affect sustainable performance from the viewpoints of the owners of manufacturing establishments in Bat Trang ceramic village?

2 Literature review

Previous studies have illustrated the importance of innovation on firm performance. Lestari and Sunyoto (2023) pointed out that internal innovations enabled by organisational capacities could significantly improve firm performance. According to Gaosegelwe and Monametsi (2024), product and process innovation showed stronger effects on firm performance than organisational innovation. Carvache-Franco et al. (2025) focused on tangible innovation actions – such as research and development (R&D) investment, machinery acquisition, and employee training – as key levers that directly enhance a firm's innovative outcomes. In addition, Bui and Krajcsák (2025) found that sustainable innovation exerts an indirect but significant positive effect on financial performance, which fosters firms' recovery from external disruptions.

As a dimension of sustainable innovation, green innovation refers to technological advancements aimed at enhancing environmentally friendly products or processes (Ren and Mia, 2025). Sustainable performance refers to an enterprise's ability to reduce harmful emissions, improve financial performance to maintain a long-term competitive advantage, use resources efficiently, and commit to providing products with better ethics to meet the needs of society (Xie and Zhu, 2020). Green innovation – encompassing green product, process, and technological innovations – consistently improves sustainable performance by increasing resource efficiency, reducing environmental harm, and strengthening corporate reputation and competitiveness (Cheng et al., 2023; Ahmed et al., 2023; Mubeen et al., 2024). However, the extent of impact differs across various types of green innovation. The study of Rahmani et al. (2024) showed that green process innovation showed a stronger effect on environmental performance than green product innovation.

It is reported that green process innovation positively affects sustainable performance, as it reduces resource consumption, minimises waste, and lowers environmental impact (Li et al., 2023). Cheah et al. (2024) showed that initiatives aimed at improving green processes significantly enhance how well firms perform in the social dimension. Rehman et al. (2024) posited that effective knowledge management practices enhance green process innovation, which in turn facilitates the development of environmentally friendly products that secure competitive advantage. Cheng et al. (2023) demonstrated that green process innovation positively influences sustainable performance, and this relationship is significantly moderated by environmental awareness. Specifically, the study found that firms with higher levels of environmental awareness experience a stronger positive effect of green process innovation on sustainability outcomes. This suggests that when stakeholders are more conscious of environmental issues, the implementation of green processes becomes more effective in enhancing sustainable performance. The research of Ji et al. (2024) revealed that green process innovation has a significant positive effect on financial performance, whereas green product innovation did not show a significant effect. Furthermore, the relationship between green process innovation and financial performance is strengthened when firms receive government economic support. Tariq et al. (2023) found that green process innovation reduces a firm's financial risk, and this effect is stronger in highly competitive environments. The study highlighted that green innovation can serve as a strategic tool for financial stability, especially under competitive pressure.

Based on the literature review, it is evident that most previous studies have used quantitative methods to examine the relationship between green process innovation and sustainable performance (Ji et al., 2024; Cheah et al., 2024; Li et al., 2023; Cheng et al., 2023). Quantitative research is a means for testing objective theories by examining the relationship among variables (Creswell, 2009). However, this method is limited in providing insight into the participants' individual motivations or personal experiences (Yilmaz, 2013). Hence, quantitative research can measure and quantify the relationship between variables, but its ability to explain the underlying causes and mechanisms of impact is limited. Furthermore, the majority of existing research has been conducted in industrial or large-scale manufacturing contexts, leaving a notable gap regarding traditional craft villages, particularly in Vietnam, where motivations, practices, and impacts of green process innovation may differ significantly. For this reason, a qualitative approach employing in-depth interviews is essential to capture the nuanced, context-specific drivers, practices, and impact mechanisms of green process innovation on sustainable performance.

3 Theoretical framework

3.1 Relevant theoretical foundation

The NRBV was proposed by Hart (1995) to explain the influence of organisational capabilities on environmental strategies (Mishra and Yadav, 2021). NRBV suggests that enterprises can achieve sustainable competitive advantage when addressing natural environmental issues of enterprises (Hart, 1995). Hart and Dowell (2011) found that the value of natural resources and the ability to increase profits come from reducing pollution. Three specific strategies that enterprises can apply according to NRBV include:

1 pollution prevention

2 product stewardship

3 sustainable development.

In particular, the third strategy not only reduces environmental impacts but also helps enterprises maintain environmental performance in the future. Effective implementation of the above three strategies will create unique values for the enterprise, values that are difficult to replace in conventional ways. In general, the NRBV indicates that environmental strategies and green innovation play an important role in determining sustainable performance (Hart, 1995).

Additionally, Stakeholder Theory posits that organisations must consider and balance the interests of all parties affected by their activities, including shareholders, employees, customers, suppliers, communities, and environmental groups. It emphasises ethical responsibility, long-term value creation, and responsiveness to stakeholder expectations (Freeman, 1984). Adopting green production practices signals to various stakeholder groups that the firm aligns with established norms, thereby fostering greater endorsement, trust, and loyalty, which can ultimately translate into increased sales and other financial advantages (Baah et al., 2021).

3.2 Green process innovation

3.2.1 Definition and categorisation of green process innovation

Green process innovation refers to the adoption or creation of production techniques that are new to a company and result in reduced environmental impact as compared to existing methods (Wang and Ahmad, 2024). Green process innovation is generally categorised into two types: clean technologies and end-of-pipe technologies (Del Río González, 2005; Rennings et al., 2006; Xie et al., 2015).

Clean technologies involve using environmentally friendly methods to reduce pollution and boost productivity. This includes using energy more efficiently, cutting down on natural resource use, and switching to materials that cause less harm to the environment (Hammar and Löfgren, 2010; Zeng et al., 2010).

End-of-pipe technologies focus on cutting pollution by upgrading equipment and processes that treat waste at the end of production (Horbach and Rennings, 2013). In contrast to clean technologies, manufacturing enterprises applying end-of-pipe technologies passively react to pollution and waste after they have been generated during the production process to comply with environmental requirements (Frondel et al., 2007). According to Hammar and Löfgren (2010), the defining characteristic of end-of-pipe technologies is that they do not alter the production process itself.

3.2.2 Drivers of green process innovation

Tariq et al. (2017) classify the drivers of green process innovation into six categories:

1 market factors

2 stakeholder pressure

3 technological factors

4 collaboration and networking factors

5 organisational-level factors

6 socio-cultural-ethical factors.

Market demand from environmentally conscious consumers and the reputational gains from a green brand image encourage green innovation adoption (Horbach et al., 2012; Kammerer, 2009). Stakeholders such as governments, suppliers, and competitors exert additional pressure, with regulatory incentives facilitating market entry (Demirel and Kesidou, 2011) and competitive dynamics prompting firms to match rivals' green initiatives (Doran and Ryan, 2016). As for technological factors, the successful implementation of green innovation relies significantly on the technological capability of firms, which is defined as the characteristics that enable firms to initiate innovation capabilities to gain competitive advantage (Morgan and Piercy, 1998). Strong networks and external collaborations enhance knowledge transfer and innovation capacity (Cai and Zhou, 2014; Tariq et al., 2017). Organisational scale also matters, as larger firms with more resources are better equipped to implement green practices (Qi et al., 2010). Finally, ethical orientation, national culture, and societal values can shape both consumer acceptance of green products and firms' commitment to green process innovation (Tariq et al., 2017).

3.2.3 Relationships between green process innovation and sustainable performance

Green process innovation is a factor that positively affects sustainable performance (Cheng et al., 2023; Li et al., 2023), helping enterprises achieve economic, environmental, and social benefits simultaneously.

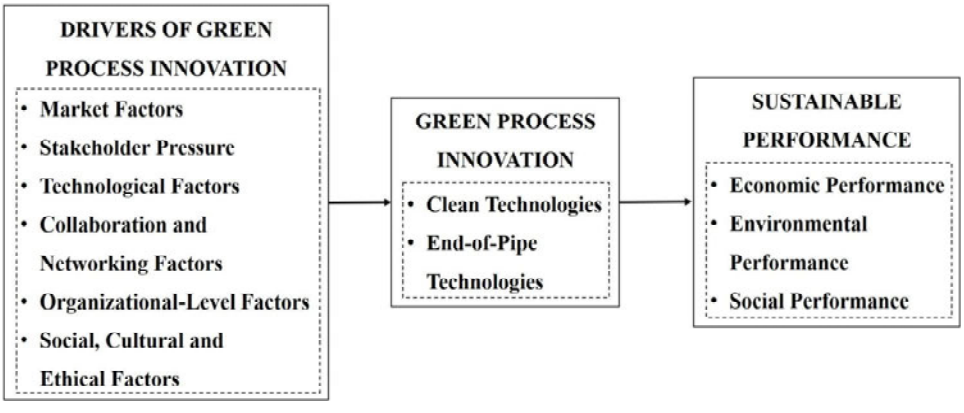
First of all, green process innovation has a positive impact on economic performance. By lowering needless production and operating costs, green process innovation can boost enterprise profits and enhance economic performance (Xie et al., 2019). It was pointed out that enterprises often adopt green process innovation to improve productivity, lower environmental costs, receive more government support, create a 'green' brand image (Wang and Ahmad, 2024), and attract a large number of new customers who are willing to pay more for goods (Piwowar-Sulej, 2022).

Secondly, green process innovation has a positive impact on environmental performance. According to Kivimaa and Kautto (2010) and Cheah et al. (2024), green process innovation improves the efficiency of energy and resource use in the production process, generates values from waste, and reduces emissions related to air, water, and energy. Thus, adopting green process innovation is of great significance for lowering carbon emissions in enterprises (Zameer et al., 2021), and reducing negative impacts on global climate change (Li et al., 2023).

Finally, green process innovation has a positive impact on social performance. According to Galdeano-Gómez et al. (2013), enterprises exhibit social performance through their economic performance, as well as by emphasising human development, generating employment, ensuring equal opportunities, and tackling social and security concerns. It is believed that green process innovation will promote sustainable activities and demonstrate CSR, thereby influencing the perceptions of external stakeholders and contributing to community welfare (Liu et al., 2020).

Based on NRBV, stakeholder theory and previous studies on green process innovation (Del Río González, 2005; Rennings et al., 2006; Xie et al., 2015; Tariq et al., 2017; Cheng et al., 2023; Li et al., 2023), the authors proposed an analytical framework that consists of three components, as shown in Figure 1.

Figure 1 Analytical framework



Source: Authors

4 Methodology

4.1 Research design

Given the exploratory nature of the research objectives – understanding motivations, implementation practices, and sustainability outcomes of green process innovation – a qualitative approach was deemed appropriate. A qualitative approach was chosen in this research as it allows researchers to explore and understand the meaning individuals or groups ascribe to a social problem (Creswell, 2009). This method enables the researcher to capture rich, contextual insights into the personal experiences, perceptions, and decision-making processes of manufacturing establishment owners in Bat Trang village. In-depth interviews were selected in this research, as it is suitable for research questions that require an in-depth explanation of the research phenomenon (Creswell and Clark, 2017).

Our research focuses on Bat Trang ceramic village to explore green process innovation and sustainable performance. Formed around the 14th–15th centuries, Bat Trang, the oldest ceramic village in Vietnam, is renowned for its high-quality products meeting domestic and international demands. Thanks to its innovative production and the full convergence of strengths characteristic of a traditional craft village, Bat Trang is proudly recognised as a member of the Global Network of Creative Craft Cities by World Craft Council. This asserts Bat Trang as a typical case in preserving traditional values as well as meeting the requirements for sustainable development.

Owners of manufacturing establishments implementing green process innovation in Bat Trang were chosen as the target of this study because they have a long-term understanding of the production process at their establishments. The data in this study were collected through in-depth interviews. According to Malhotra (2009), an in-depth interview is a direct and personal interview in which a single participant is probed by an experienced interviewer to uncover underlying motivations, beliefs, attitudes and feelings on a topic. The data were collected from December 2024 to January 2025.

A sample size of 10 may be adequate for sampling among a homogeneous population (Sandelowski, 1995). According to Hennink and Kaiser (2022), the sample size for saturation ranges between 5 and 24 interviews in qualitative research. In this study, we used a sample size of 10. The selection of ten samples ensured compliance with recognised principles; at the same time, the respondents' answers provided details that allowed the study to have enough data to analyse and draw reasonable conclusions.

4.2 Research instrument

The interview questions used in this study consist of two parts. The first part of the interview consisted of questions about the respondents' information, such as name, job title, workplace, and address. The second part includes five questions focusing on green process innovation and sustainable performance in respondents' manufacturing establishments. These questions are presented in Appendix. Before conducting the interview, the researchers sent a consent form, including information related to the study to each respondent, to ensure that the respondent understand the research objectives, research process, and the use of data from the interview.

4.3 Data analysis

After gathering data in Bat Trang ceramic village, the researchers analysed data by using the content analysis method. This method involves identifying and interpreting meaning within recorded communications by breaking down data into key concepts, then organising them with a framework to describe or explain a phenomenon (Kleinheksel et al., 2020). Data processing and analysis is done manually. This decision was made to recognise the limitations of qualitative data analysis software, which sometimes cannot accurately determine the speech rate of the participants. Therefore, the manual analysis method allows the researchers to exploit deeper meanings of interviews and better understand the experiences of interviewees. Transcription was performed to convert all data from interviews into text form, creating a basis for analysis. The data analysis process involved listening to the interview recordings, transcribing them into documents, and extracting key points. Participants' responses to each question were compared during the analysis, highlighting similarities and differences.

5 Results

5.1 Characteristics of the respondents

All respondents in Bat Trang ceramic village who participated in this study are owners of manufacturing establishments applying green process innovation. Additionally, some respondents serve as technical experts, artisans, or, in one case, as the village chief. To ensure the confidentiality of the identity, the respondents' names were coded as shown in Table 1.

Table 1 Respondent characteristics

No.	*Respondent*	*Professional*
1	Respondent 1	Owner of manufacturing establishment/technical expert
2	Respondent 2	Owner of manufacturing establishment/village chief
3	Respondent 3	Owner of manufacturing establishment
4	Respondent 4	Owner of manufacturing establishment/artisan
5	Respondent 5	Owner of manufacturing establishment
6	Respondent 6	Owner of manufacturing establishment
7	Respondent 7	Owner of manufacturing establishment
8	Respondent 8	Owner of manufacturing establishment
9	Respondent 9	Owner of manufacturing establishment/artisan
10	Respondent 10	Owner of manufacturing establishment

Source: Authors

5.2 Drivers of green process innovation in Bat Trang

5.2.1 Market factors

All respondents confirmed that market factors influenced their decisions to adopt green process innovation in their manufacturing establishments. Respondents 2 and 3 noted that under traditional production processes, product quality was often inconsistent: "There were batches that achieved 70 to 80% of type 1 products, but there were also batches that achieved only 30 to 40% of type 1 products." Consequently, they implemented green process innovation as a means to "upgrade the products" (Respondent 8), "achieve a higher product recovery rate, more type 1 product" (Respondent 6), and "meet the standards and requirements of buyers" (Respondent 3). The desire to build a green brand image also motivated manufacturing establishments in Bat Trang to adopt green process innovation. According to Respondent 1, this approach enables artisans to "differentiate their products from those of other craft villages, promote the green brand image, and contribute to environmental protection and business development."

5.2.2 Stakeholder pressure

With around 1,000 charcoal-fired kilns, Bat Trang consumed approximately 70,000 tons of charcoal and 100,000 tons of materials annually for ceramic production, releasing an estimated 130 tons of dust, 225 tons of soil, materials, and charcoal residues, along with 6,800 tons of ash. The air was further polluted by roughly 2,000 tons of toxic gases – including CO, CO_2, SO_2, and H_2S – negatively affecting residents' quality of life and health (Respondent 7). To address these concerns, manufacturing establishments in Bat Trang were encouraged to change their ceramic production processes in order to "protect their health and life, protect employees from occupational diseases" (Respondent 5).

Political stakeholders also exerted pressure on local manufacturers to adopt green process innovation. Respondents emphasised the necessity of process innovation through environmentally friendly technologies to comply with state environmental protection regulations. For instance, the Vietnamese Law on Environmental Protection stipulates that "Manufacturing establishments and households in a craft village must seek and implement environmental protection measures as regulated by law." For establishments engaged in export activities, "International practical requirements on reducing emissions into the environment is the reason for establishments to convert their processes towards greening" (Respondents 4 and 5). Furthermore, the Government's pledge to reduce emissions at the 2021 United Nations Climate Change Conference has reinforced the need for ceramic manufacturers to invest in emissions treatment and carbon reduction measures.

5.2.3 Technological factors

The technological capacity of manufacturing establishments in Bat Trang is reflected in their ability to research, develop, and apply environmentally friendly technologies to production processes. Although Bat Trang received technological support from Taiwan, Korea, Japan, and Germany, these technologies often proved unsuitable for actual operational needs. Consequently, in the late 1990s, Bat Trang artisans – such as Respondent 1 – sought to develop more appropriate technological solutions. Leveraging strong absorptive capacity, Respondent 1 combined the expertise of veteran ceramic

craftsmen with personal knowledge and experience to create valuable technologies for the community. In contrast, other respondents placed greater emphasis on ease of use and simplicity when selecting technologies for process innovation. This highlights differing perspectives on technology adoption among respondents. Moreover, within the craft village context, technological spillovers in Bat Trang have played a significant role in influencing the decision of manufacturing establishments to green their production processes.

5.2.4 Collaboration and networking factors

Since 2002, the People's Committee of Bat Trang Commune and the Ceramic Association have actively connected and mobilised manufacturing establishments to innovate their production processes in line with the National Energy Efficiency Programme. Between 2006 and 2011, the project 'Promoting Energy Conservation in Small and Medium-Sized Enterprises' – initiated by the Ministry of Science and Technology in collaboration with the United Nations Development Programme and the Global Environment Facility – was implemented in Bat Trang ceramic village. The project provided loan support and facilitated the sharing of technical knowledge. Through this initiative, the modern ceramic firing technology developed by Respondent 1 was more widely transferred to other manufacturing establishments in the village (Respondents 2, 3, 6, and 7). Successful establishments involved in the project subsequently encouraged and connected with others to adopt similar innovations. As Respondent 2 recalled: "Initially, many households felt hesitant, but then it spread – from 5 households, to 7, then to 10. They saw the clear effectiveness and proactively switched to modern technology."

5.2.5 Cultural, social and ethical factors

Respondents 2 and 4 emphasised that "Green process innovation is an inevitable development of society; we must be in harmony with it and go with the flow." They associated societal progress with the rapid advancement of technology across all industries, including ceramics. Respondent 3 added: "I innovate so that our children and grandchildren know how to appreciate, love, and respect their parents' profession. From there, I have the next generation to pass on." Preserving and developing the village, therefore, is not only about meeting the needs of the present generation but also about safeguarding its cultural and economic legacy for future generations.

5.3 Green process innovation practices

The ceramic production process in Bat Trang goes through 7 steps, including "raw material preparation; product shaping; drying; repairing; decorating, painting; glazing; and firing" (Respondent 4). However, people at Bat Trang village are now aware that the main cause of pollution was the ceramic-firing step with traditional kilns using firewood and charcoal. As a result, since the 2000s, Bat Trang artisans have proactively applied cleaner technologies by converting traditional manual kilns to liquefied petroleum gas (LPG) and electric kilns. All respondents proudly said, "Up to now, Bat Trang no longer has a traditional charcoal kiln".

The LPG kiln is a shuttle kiln system that operates intermittently according to the principle of reversing the flame. The main fuel used is LPG. While LPG is still a fossil fuel, it generates less pollution than traditional charcoal kilns. Some manufacturing establishments in Bat Trang continued to innovate the process by applying electric kilns. Out of a total of 10 respondents participating in the interview, Respondents 4 and 6 have used electric kilns for their establishments. These kilns will heat up due to thermal radiation. There is no flame in the kilns, so no emissions are generated during the ceramic firing process.

5.4 Impact of green process innovation on sustainable performance

5.4.1 Economic performance

Time efficiency is one of the most significant advantages of clean technologies compared to traditional methods. According to Respondent 9, using an LPG kiln reduces "firing time by about 20%." Other respondents reported similar benefits: "Gas kilns help reduce product firing time to 8 hours" (Respondent 1); "firing time is reduced to 12 hours" (Respondent 8); "Wood kilns take 3–5 days to burn, while gas kilns only take 2 days" (Respondent 4); and "it takes about ten hours to make a batch, whereas previously, using a charcoal kiln, it took about 3–4 days" (Respondent 10). Likewise, Respondent 5 noted that the firing process now "only takes about ten hours." In addition, when fired using LPG or electricity, ceramics can be produced at any time of the day, regardless of weather conditions. These kilns have also enabled a "quantity increase of 3–4 times" (Respondent 1), allowing producers to meet market demand, particularly large orders from foreign companies.

Green process innovation enables manufacturing establishments to enhance product quality and reduce defects. According to Respondent 2, the proportion of products meeting quality standards reaches 95%–99%, which is 30–50% higher than with charcoal-fired technology: "For example, in a production batch of 1,000 products, only 1–2 are lost due to cracking, handling, or collision. The remaining products have uniform enamel color and quality." Respondents 3 and 7 reported that since adopting LPG kilns, "the rate of products reaching the standard is up to more than 90%," whereas "a batch from wood-fired kilns only reaches one-third" (Respondent 4). Respondent 6 highlighted that "the advantage of gas kilns is that they produce beautiful and high-quality products." Similarly, Respondent 9 agreed: "Since using gas kilns, the products have been more beautiful and stable. Before, I could lose about 40%–50% of a batch; now it is only 10%." This improvement is largely due to modern kilns' ability to regulate and maintain precise temperatures: "If you set it to 1,200 degrees, it will be 1,200 degrees; if you set it to 1,300 degrees, it will be 1,300 degrees –unlike traditional kilns, which could not measure" (Respondent 2).

The improved product quality has attracted an increase in domestic and international customers every year, contributing to building a green brand image for manufacturing establishments and Bat Trang village. Respondent 2 explained, "When we switched to LPG kilns, the quality of the products improved, and the products became more beautiful. At that time, foreign customers liked it very much. Even though the selling price was increased by 10%, they liked environmentally friendly products, so they thought the price was worth it". Respondent 1 said, "The brand image is enhanced when customers know that we have applied a green process to produce environmentally friendly products".

Respondent 4 gave a similar answer, "the number of customers increases a lot and the competitiveness is also higher".

LPG and electric kilns are considered greener alternatives, which changes manufacturing establishments' revenue and profit significantly. "Modern technology helps to improve product quality significantly, which increases profits" (Respondent 2). Overall, "revenue and profit are 2–3 times higher than traditional technology" (Respondents 1 and 7). Five respondents, however, argued that revenue and profit growth also depend on many other factors. "The profit is better than when using charcoal kilns, but it still has to meet conditions such as knowing how to advertise, sell products, and have many orders" (Respondent 3) and "relies on market factors and business strategy" (Respondent 4).

Although bringing many benefits to manufacturing establishments, clean technologies require high investment costs. The cost of an LPG kiln is more than eight times higher than a charcoal kiln, while an electric kiln has a similar price but requires establishments to meet the 3-phase power source. To invest in a modern kiln, manufacturing establishments must spend from VND 200 million to over VND 1 billion. However, the investment costs for these kilns can be depreciated during use (Respondent 5). Furthermore, in the long-term, LPG and electric kilns can lower production expenses for Bat Trang villagers. Compared to traditional methods, less polluted and energy-saving technologies enable manufacturing establishments to "save up to 40% on fuel costs, contributing to a reduction of up to 30% in production costs each year" (Respondent 1). For example, the cost of producing a vase when using an LPG kiln will be 20% cheaper, or producing a set of tableware will be 60% cheaper than using a charcoal kiln. This cost reduction potential has brought significant economic benefits, helping establishments reinvest and develop production activities.

5.4.2 Environmental performance

Green process innovation has marked an important step forward in addressing environmental pollution in Bat Trang ceramic village. Data from the study indicate that all respondents agreed that switching to LPG and electric kilns has brought substantial environmental improvements. Clean technologies not only reduce the release of toxic emissions but also improve air quality, creating a cleaner and greener living and working environment. Respondent 3 noted with satisfaction that "the environment has become cleaner, the amount of toxic emissions has decreased, and there is no longer the unpleasant smell of burning charcoal like before."

Ceramic manufacturers that have adopted modern kilns have reduced energy consumption and minimised the environmental pollution caused by traditional manual kilns. Estimates suggest that within seven years of implementing the clean firing technology project, "Bat Trang ceramic village had reduced 93,161 tons of CO_2, saved about 3,000 tons of oil equivalent, and cut emissions by over 12,000 tons of CO_2 per year" (Respondent 1). Supporting these findings, research by Hotza and Maia (2015) shows that LPG kilns produce significantly lower emissions than coal or wood kilns. Compared to coal, LPG reduces CO_2 by 32.92%, CH_4 by 90%, and N_2O by 93.32%. In comparison to wood firing, LPG reduces CO_2 by 32.85%, CH_4 by 96.66%, and N_2O by 97.5%. These results demonstrate that LPG kilns not only substantially reduce CO_2 emissions but also markedly suppress other greenhouse gases, making them far more environmentally friendly than traditional fuels. Collectively, these figures highlight the

significant positive impact of green process innovation on the environmental performance of Bat Trang ceramic manufacturing establishments.

The application of LPG and electric kilns also helps to significantly save raw materials and reduce waste. Before adopting green process innovation, manufacturing establishments consumed a large amount of input materials, leading to large losses and wastage. However, with LPG and electric kilns, "These days, each batch of kilns only wastes 1–2 products" (Respondent 2). Additionally, to complete a batch of firing, a gas kiln only consumes about 30–50 kg of gas, while a traditional kiln requires 500–700 kg of firewood or 300–500 kg of charcoal. Consequently, "the consumption of raw materials has decreased significantly, saving 30%–35% compared to before implementing the innovation" (Respondent 1). This respondent also stated that, "On average, 41 LPG kilns have helped save 4,000–5,000 tons of oil annually".

5.4.3 Social performance

Manufacturing establishments' green process innovation efforts ensure the health and safety of employees and the community. "Thanks to the simplicity and convenience of technology, employees reduce labor intensity because LPG or electric kiln operators only need to adjust the temperature control system, remote heat control, and do not need to spend much time adjusting the flame directly" (Respondents 8 and 9). "Employees also avoid occupational diseases such as respiratory or eye diseases" (Respondents 3 and 5), saving health costs. LPG and electric kilns' reduction of polluting emissions has contributed to building a safer and healthier working environment as well as a green craft village environment.

Thanks to green process innovation, manufacturing establishments in Bat Trang village can create jobs and improve the quality of life of local people (Respondent 1). The high production volumes of ceramic products after implementing innovation require establishments to have enough labour to meet market demand. Therefore, the job problem for thousands of local employees has been solved. According to respondent 2, from the economic performance, establishments have a policy of increasing wages by at least 10% per year to attract and retain employees. Specifically, green process innovation has improved employee and household incomes. "In the past, an employee's salary was about 5 million VND, but now it ranges from 7 to 8 million VND" (Respondent 7). Additionally, when implementing LPG and electric kilns, "employees have the opportunity to be trained and developed" (Respondent 5), thereby improving their skills.

Manufacturing establishments' efforts in green process innovation to protect the environment have been recognised by the local authority and community. Many individuals and establishments have received certificates from prestigious organisations for applying clean technologies in the production process. Bat Trang village is also recognised by the government as a model for developing craft villages associated with environmental protection, becoming an example for other craft villages nationwide. This recognition indirectly promotes the craft village image to other stakeholders such as consumers, investors, suppliers, and the community.

The success of green process innovation is an opportunity for manufacturing establishments to share information with the community, contributing to raising awareness of sustainable development for society. The craft village environment associated with tourism has created conditions for Bat Trang villagers to openly introduce and promote their products produced using environmentally friendly processes to

customers. They consider it a responsibility to society, a way to educate about sustainable development and guide the community to shift to a sustainable lifestyle.

6 Discussion

This exploratory study identified five key drivers motivating ceramic manufacturing establishments in Bat Trang village to adopt green innovation, specifically green process innovation: market factors, stakeholder pressure, technological factors, collaboration and networking, and cultural, social, and ethical considerations. These results align with the findings of Tariq et al. (2017), Kobarg et al. (2020), Rui and Lu (2021) and Xie et al. (2024). Notably, organisational-level factors were not cited by respondents as influencing their decision to adopt green process innovation. This contrasts with Qi et al. (2010) and Baeshen et al. (2021), who argued that firm size significantly affects environmentally friendly practices. Evidence from Bat Trang indicates that small manufacturers are actively engaging in green process innovation. This may be explained by the unique characteristics of Vietnam's craft villages, where most businesses are micro or family-owned and deeply rooted in community values. Furthermore, Vietnam's national strategy for a green and sustainable economy has fostered a supportive policy environment that encourages even the smallest enterprises to innovate. Fostering green transformation among micro, small, and medium-sized enterprises is critical for long-term competitiveness and market access. In this context, household manufacturers are not constrained by their size; rather, they are driven by the need to remain competitive, respond to evolving market demands, and uphold social values such as community responsibility and intergenerational well-being.

A second notable finding is that manufacturing establishments in Bat Trang primarily adopt clean technologies while largely neglecting end-of-pipe technologies. The "newness" and "greenness" of production processes have gradually increased through continuous technological improvements, transitioning from kilns using polluting fuels like firewood and charcoal to those powered by cleaner energy sources such as LPG and electricity. However, end-of-pipe technologies have not been implemented. Given that most ceramic production in Bat Trang is household-based, financial capacity is limited, and the adoption of end-of-pipe technologies requires substantial investment in machinery and equipment. Respondent 7 also noted that "this process entails the need to expand production space," yet Bat Trang currently faces a shortage of available land for such expansion. Therefore, to fully green their production processes, manufacturing establishments in Bat Trang would require support from government and local authorities in integrating both end-of-pipe and clean technologies.

From the respondents' perspective, green process innovation significantly enhances sustainable performance. It improves economic outcomes by increasing product quality, revenue, and profit, thereby contributing to local economic development. The replacement of outdated combustion methods with cleaner technologies has also reduced pollution, resulting in a greener craft village environment. Furthermore, social performance has improved through the creation of safer, healthier working conditions for employees (Cheah et al., 2024) and the reinforcement of positive community values.

7 Conclusions

7.1 Theoretical implications

By analysing the data collected from ten manufacturing establishments in Bat Trang ceramic village, this article presents some theoretical advancements. Firstly, given the scarcity of research on green process innovation and sustainability in Vietnam, this study addresses a critical knowledge gap by providing evidence from manufacturing establishments in Bat Trang ceramic village. While prior studies have largely examined these topics in developed economies, our findings extend the literature to the unique socio-economic and cultural context of Vietnam, thereby enriching the global discourse on green process innovation in emerging markets. Second, this research advances theory by integrating the NRBV and stakeholder theory into a unified analytical framework. This approach enables a more holistic understanding of the drivers, practices, and impacts of green process innovation. Our integrated framework captures both the multi-dimensional antecedents (including market, stakeholder, technology, collaboration, and socio-cultural factors) and the pathways through which green process innovation enhances economic, environmental, and social performance. Finally, these theoretical insights provide a robust foundation for future research on green innovation and sustainability in developing economies. Scholars can build on our framework to examine other sectors or geographical contexts, explore longitudinal effects of green process innovation, or investigate additional moderating and mediating factors influencing the innovation–performance nexus.

7.2 Practical implications

This study offers several implications for policymakers and manufacturing establishments in Bat Trang ceramic village to promote green process innovation to enhance sustainable performance. First of all, raising awareness of green production is essential for innovation in traditional craft villages like Bat Trang ceramic village. Governments and environmental organisations should promote green innovation and provide information on pressing environmental issues and benefits that manufacturing establishments can achieve, such as sustainable performance. Secondly, it is suggested that the government should provide a financial incentive policy mechanism related to investment, interest rates, and taxes. This drives manufacturing establishments to boldly invest in green process innovation and modernise the craft village. Thirdly, limitations in infrastructure and production conditions pose significant challenges for manufacturing establishments in Bat Trang aiming to expand their production scale. Therefore, governments and local authorities should promptly enhance infrastructure planning, implement supportive policies and mechanisms, prioritise land allocation, and facilitate long-term land lease agreements to assist these manufacturers. Fourthly, governments should encourage the integration of renewable energy and end-of-pipe technologies in manufacturing establishments. Specifically, Bat Trang villagers need to pay more attention to renewable energy or biofuels for firing ceramics, thereby creating a greener production process. Finally, fostering collaborations with experts, private organisations, investment funds, credit institutions, and international organisations is also important to promote green process innovation in manufacturing establishments to achieve economic prosperity, social equity, and environmental quality.

7.3 Limitations and future research

Despite achieving certain results, this study also has limitations. Due to limited resources and time, the sample size is small. The authors recommend expanding the sample size, including manufacturing establishments not implementing green innovation. Therefore, we may explore the barriers preventing non-adopters from adopting green innovation and obtain more comprehensive conclusions in future studies. Additionally, this study was conducted using qualitative methods, so it has not quantified the impact level of factors affecting green process innovation, or green process innovation on sustainable performance. In the future, a research model should be conducted to quantify the impact level between factors. Finally, the research scope was restricted to Bat Trang ceramic village, Vietnam, so the results may not be representative. In the future, studies regarding green process innovation and sustainable performance should be expanded in scope to other craft villages in Vietnam to improve the generalisability of insights.

Declarations

The authors would like to acknowledge the use of advanced artificial intelligence language tool (OpenAI's ChatGPT) in refining the clarity, coherence, and academic tone of the manuscript.

All authors declare that they have no conflicts of interest.

All participants involved in this study provided informed consent prior to their participation. They were fully informed about the purpose, procedures and the treatment of data. Participation was entirely voluntary, and participants had the right to withdraw from the study at any time without any consequences. Confidentiality and anonymity of participant information were strictly maintained throughout the research process.

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Appendix

Interview questions in Bat Trang ceramic village

Question 1	Is your establishment currently implementing any innovations aimed at making the ceramic production process greener?
Question 2	What motivates your manufacturing establishment to pursue green innovations in the production process?
Question 3	Which is the most important reason driving your manufacturing establishment to innovate towards green process? Why?
Question 4	The ceramic production process in Bat Trang involves multiple distinct stages. At which specific stages has your establishment implemented green process innovations, and could you describe these innovations in detail?
Question 5	What specific benefits has your establishment gained from adopting green process innovations, particularly in terms of economic, environmental, and social aspects?