Culture, Community and Policy as Contextual Enablers of Sustainable Tourism Technology: The Case of a Malaysian Heritage Waterfront

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ABSTRACT

Research on sustainable tourism technology focuses mostly on whether tourists accept it. This study asks a different question: what in the destination's culture, community, and policy settings enables or blocks the spread of such technology? It examines the solar-powered river taxi (ePenambang) on the Kuala Terengganu heritage waterfront in Malaysia. A qualitative single case study combining document analysis of national and state policies, media reports from 2017 to 2026, and published studies of the case. Evidence was coded using Scott's three institutional pillars (regulative, normative, and cultural-cognitive) and interpreted through the multi-level perspective on sustainability transitions. Culture is the strongest enabler: the *bot penambang* has run since the 1930s and remains a valued heritage attraction, giving a solar retrofit a legitimacy-ready platform. Community is fragile: the operator base has shrunk to about ten active boats run by an aging workforce on low incomes. Policy is fragmented: national green mobility policies focus on road transport and do not address waterborne tourism transport, while state support has been episodic. Tourists' willingness to use the boat is therefore not the binding constraint. Supply-side capacity is. The study shifts attention from tourist acceptance to the institutional conditions for diffusion and proposes a contextual enablers framework for green retrofits of heritage transport.

Keywords: heritage tourism; sustainable tourism technology; solar boat; institutional theory; multi-level perspective; community participation; tourism policy; Malaysia

INTRODUCTION

Tourism contributes about 8% of global greenhouse gas emissions, and transport is the largest share (Lenzen et al., 2018). Destinations cannot control international flights, but they can control the boats, buses and trishaws that move visitors around once they arrive. Decarbonising this local mobility is one of the few climate actions within a destination's direct reach (Gössling & Higham, 2021; Scott et al., 2016).

Much of the research on green tourism technology asks whether tourists will accept it. Studies apply the Technology Acceptance Model, the Theory of Planned Behaviour and Diffusion of Innovations to measure tourists' intention to use electric vehicles, solar boats and smart services (Davis, 1989; Han, 2021; Rogers, 2003). Such a focus on demand is enlightening but insufficient. A tourist will opt for a solar boat only if it is operational, which depends on the actors who make it operational, the culture that gives it significance, and the policy framework that enables it. Such contextual variables play an important part in determining if the green innovation goes beyond the pilot stage.

Empirical evidence from Malaysia shows the importance of the context of innovation adoption. The bot penambang, a traditional river taxi that plies the Terengganu River, has been operating in Kuala Terengganu,

which is situated on the east coast of Peninsular Malaysia, since the 1930s (Malaysia Aktif, 2026). An innovative solar-powered product, ePenambang, operates in the same waterfront area (Musa et al., 2025; Shahril, 2025). According to survey results, demand is not the constraint: 89.8% of 304 respondents are willing to use the ePenambang, even though only 27.6% were aware of the innovation (Shahril, 2025). In the same survey, the ePenambang's usefulness and ease of use did not significantly affect adoption intention (Musa et al., 2025). Research into another innovation, an electric trishaw called eBECA, found out that commitment to the traditional craft and information accessibility were more critical than the innovation itself (Musa et al., 2026a, 2026b). Nevertheless, the number of traditional craft boats in Kuala Terengganu has decreased from many to ten (Malaysia Aktif, 2026), with operators averaging more than 60 years old and earning approximately RM500-600 per month in 2021 (Bernama, 2021a).

Against this background, the following research question is posed as the main question for consideration in this study: assuming that tourists accept the technology in question, what set of the destination's cultural, social, and political circumstances helps or hinders the diffusion process? Answering the question is significant for both theoretical and practical considerations. First, from the theoretical point of view, it expands the knowledge about tourism technology at the level of its diffusion.

The study makes three contributions. First, it offers an institutional account of green tourism technology diffusion, using Scott's (2014) three pillars of institutions to organise culture, community and policy as distinct enablers. Second, it applies the multi-level perspective on sustainability transitions (Geels, 2002) to a heritage tourism setting, showing how a niche innovation interacts with an established transport framework. Third, it identifies specific policy gaps, including the absence of waterborne tourism transport from Malaysia's national green mobility policies, and proposes a contextual enablers framework that other heritage destinations can use.

The study proceeds as follows. Section 2 reviews the literature and sets out the analytical framework. Section 3 describes the case and the method. Section 4 presents the findings for each enabler. Section 5 discusses them and presents the framework, and Sections 6 and 7 set out implications, limitations and conclusions.

LITERATURE REVIEW AND ANALYTICAL FRAMEWORK

2.1 From Tourist Acceptance to Contextual Diffusion

Tourism research on green technology has concentrated on the individual adopter. Studies measure how attitudes, norms and perceived benefits shape intention to use eco-friendly services (Han, 2021). Diffusion of Innovations theory adds that perceived attributes such as relative advantage and compatibility drive adoption (Rogers, 2003). For electric boats, visitors have shown willingness to pay a premium, shaped by education and length of stay (Bigerna et al., 2019).

Rogers (2003) also stressed that diffusion happens within a social system, whose norms, opinion leaders, and change agents shape how fast an innovation spreads. This part of the theory has received less attention in tourism. Lesar and Weaver (2022) showed that tourism practitioners abandon sustainability tools for reasons tied to their organisational context. Musa et al. (2024) found that eBECA's integration in Melaka depended on its fit with operators' business continuity, not only on its appeal to tourists. Modelling of sightseeing water transport suggests that new-energy boats diffuse only when the share of green-minded tourists passes a threshold and that improving vessel economics does more than subsidies alone (Xu & Wu, 2026). Supply, in other words, matters as much as demand.

In the study that first studied ePenambang, three contextual factors were proposed alongside user characteristics: cultural attitudes and compatibility, community engagement and government policy and incentives (Shahril, 2025). This study develops that idea through two recognised theoretical lenses.

2.2 Institutional Theory: Three Pillars

Institutions are the rules, norms, and shared beliefs that give social life stability and meaning. Scott (2014) distinguishes three pillars:

1. The regulative pillar consists of formal rules, laws, funding, and sanctions. It shapes behaviour through incentives and coercion.

2. The normative pillar consists of values, roles and expectations within a social group. It shapes behaviour through obligation and professional or community standards.

3. The cultural-cognitive pillar consists of shared meanings and taken-for-granted understandings. It shapes behaviour by defining what seems natural, legitimate and recognisable.

These pillars map closely onto the three contextual factors of interest. Policy operates mainly through the regulative pillar, community through the normative pillar, and culture through the cultural-cognitive pillar (Table 1). The pillars help separate three kinds of support an innovation needs: resources and rules, a community willing to carry it, and a meaning that makes it acceptable.

Table 1. Mapping contextual factors to institutional pillars

Contextual factor	**Institutional pillar (Scott, 2014)**	**How it enables diffusion**	**How it can constrain diffusion**
Policy	Regulative	Funding, subsidies, targets, licensing, infrastructure.	Gaps in scope, short-term or episodic support, unclear responsibility
Community	Normative	Operators and residents who adopt, maintain and promote the innovation.	Ageing or shrinking workforce, low income, weak organisation
Culture	Cultural-cognitive	Heritage makes the innovation legitimate and attractive.	Perception that change threatens authenticity

2.3 Culture and Heritage Meaning

Heritage gives tourist goods meaning that goes beyond practical value. Tourists seek authenticity, which may be assessed either by the origin of the good or by its experience-related aspects (Wang, 1999). Heritage authenticity of sites improves tourists' destination loyalty (Yi et al., 2017). Similarly, place attachment increases tourists' intentions to behave environmentally friendly (Ramkissoon et al., 2013).

Cultural aspects of heritage transportation vehicle retrofit can work in both directions. If the retrofitting process maintains the shape of the beca, its route, and a human driver, it gains legitimacy within the tradition and thus acceptance. The reasoning behind this is eBECA: attachment to the traditional beca was the only significant predictor of adoption intention for the electric version of the transport (Musa et al., 2026a).

2.4 Community Participation and The Operator Base

Community participation is an old concept in sustainable tourism; yet, it faces structural barriers in developing nations, including a lack of resources, knowledge, and bargaining power among local communities (Tosun, 2000). Community-based tourism emphasises that local people should be allowed to participate in decision-making processes and benefit from them (Okazaki, 2008). With regard to innovation in the transport system, the key community actors include the operators. Boatmen and trishaw drivers invest their own money and provide the service; they represent the face of the culture, and their willingness determines their ability to offer the service.

2.5 Policy and Sustainable Tourism Governance

Governance of sustainable tourism involves multiple levels of government, the private sector and communities (Bramwell & Lane, 2011). Policy can enable innovation through funding, regulation and information, often

described as carrots, sticks and sermons (Bemelmans-Videc et al., 1998). Hall (2011) argues that most sustainable tourism policy produces only first- or second-order change, adjusting instruments and settings, rather than third-order change in goals. Policy can therefore support green tourism technology in name while leaving the conditions for its diffusion unchanged.

2.6 The Multi-Level Perspective

The multi-level perspective (MLP) explains sustainability transitions as interactions between three levels (Geels, 2002). **Niches** are protected spaces where radical innovations emerge. **Frameworks** are the established rules, technologies, practices, and actors that dominate a sector. The **landscape** is the wider context of slow-changing trends and shocks, such as climate commitments or pandemics. A transition occurs when niche innovations gain momentum, the framework is under pressure, and landscape changes open a window.

In this case, ePenambang is a niche innovation. The framework is the traditional river taxi system: diesel or petrol boats, ageing owner-operators, fixed routes and fares, and a shrinking local customer base. The landscape includes Malaysia's climate commitments, national energy and tourism policies, and shocks such as COVID-19. The three institutional pillars operate across these levels. Together, the two lenses form the analytical framework used in Section 4.

METHODOLOGY

3.1 Research Design

The study uses a qualitative single case study design. A single case is appropriate when the case is revealing, that is, when it offers access to a phenomenon that has been little studied (Yin, 2018). ePenambang is one of the few solar retrofits of a heritage passenger craft in Southeast Asia studied from the demand side, making it a suitable case for examining the supply-side and institutional conditions that demand studies often overlook.

3.2 Case Setting

Kuala Terengganu is the capital of Terengganu State. Its waterfront along the Terengganu River estuary includes Pasar Payang (the central market), the Kuala Terengganu Drawbridge and the Crystal Mosque. The *bot penambang* crosses roughly 750 metres between Seberang Takir and the Pasar Payang jetty in about ten minutes, carrying up to ten passengers (Malaysia Aktif, 2026). It once served commuters and visitors. Since new road bridges opened across the river, local residents increasingly drive, and the service now relies mainly on tourists (Bernama, 2021a).

3.3 Data Sources

The study draws on three types of evidence, summarised in Table 2.

1. Policy documents. National policies relevant to sustainable tourism and green mobility, and state-level announcements on green technology and heritage transport.

2. Media reports. Malaysian news reports on the *bot penambang* and related initiatives from 2017 to 2026, which give a record of state interventions and operators' circumstances.

Table 2. Documentary evidence analysed

Code	Document	Level	Year	Relevance
D1	National Tourism Policy 2020–2030 (MOTAC)	National	2020	Sustainability and governance strategies for tourism
D2	Low Carbon Mobility Blueprint 2021–2030 (KASA/MGTC)	National	2021	Green mobility priorities and scope
D3	National Energy Transition Roadmap (Ministry of Economy)	National	2023	Green mobility as one of six energy transition levers

Code	Document	Level	Year	Relevance
D4	Terengganu Green Technology Master Plan 2030, announcement (TRDI, 2025)	State	2025	State renewable energy priorities
D5	State upgrade of *bot penambang* fleet (TRDI, 2017)	State	2017	Direct investment in heritage boats
D6	Operators' circumstances (Bernama, 2021a)	Local	2021	Income, costs, fleet decline
D7	Monthly aid to beca riders and boat operators (Bernama, 2021b)	State	2021	Income support
D8	VR boat experience and solar beca plans (Utusan Malaysia, 2021)	State	2021	Technology-led revitalisation
D9	Current state of the service (Malaysia Aktif, 2026)	Local	2026	Fleet size, route, tourist reliance
D10	Shahril (2025); Musa et al. (2024, 2025, 2026a, 2026b)	Research	2024–2026	Tourist demand, operator fit, information effects

3.4 Analysis

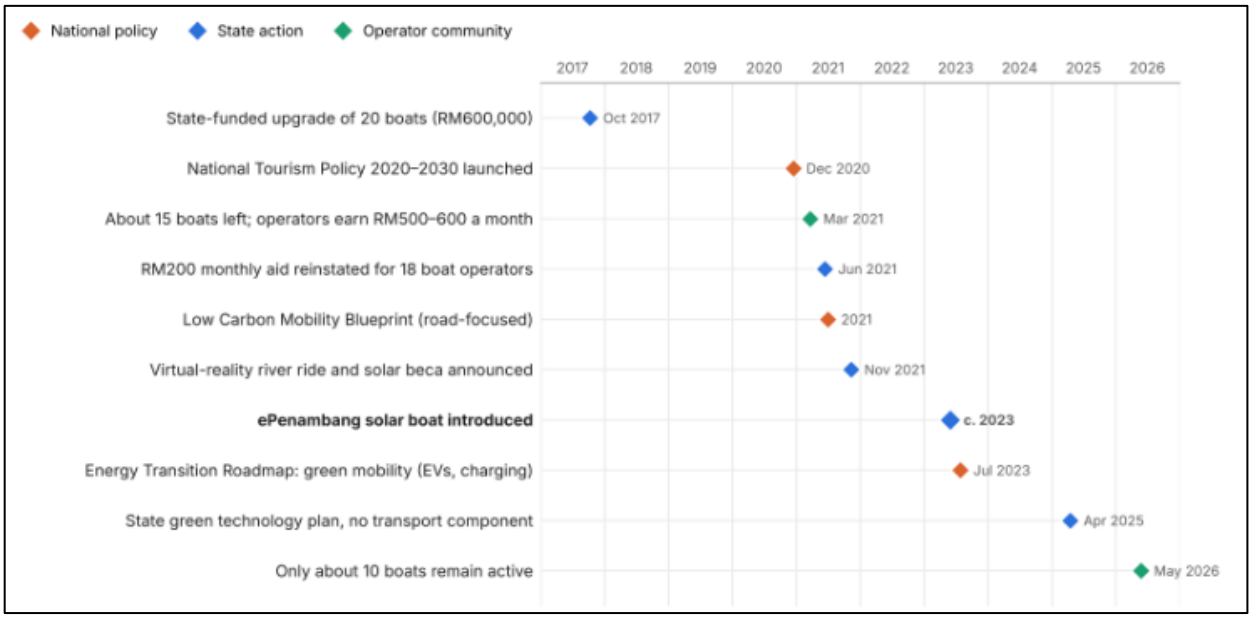
Documents were analysed using qualitative document analysis, which involves finding, selecting, appraising and synthesising the content of documents (Bowen, 2009). Coding proceeded in two rounds. In the first round, evidence was coded deductively to Scott's (2014) three pillars: regulative (policy), normative (community), and cultural-cognitive (culture). Within each pillar, each piece of evidence was marked as an enabler or a constraint. In the second round, evidence was placed on the three levels of the multi-level perspective (niche, framework and landscape) to trace how the enablers interact (Geels, 2002).

Credibility was supported by triangulating across document types so that each finding rests on more than one source where possible and by keeping an audit trail linking each claim to its documentary code.

FINDINGS

The evidence points to one central finding. Culture strongly enables the diffusion of ePenambang, but a weakening community base and fragmented policy limit it. Figure 1 shows the sequence of interventions and changes on the waterfront between 2017 and 2026, and Table 3 summarises the enablers and constraints under each pillar.

Figure 1: Timeline of policy, state action and community change, 2017–2026



4.1 Culture: A Strong Enabler (Cultural-Cognitive Pillar)

The Penambang vessel has operated along the Terengganu River since the 1930s and has become an identifiable element of the riverfront's identity (Malaysia Aktif, 2026). The journey involves passing three major attractions in the city: Pasar Payang, Kuala Terengganu Drawbridge, and Crystal Mosque. Currently, the boat's main clientele is tourists seeking a classic experience on the riverfront (D9). The government has always considered the vessels a tourist attraction along with transportation, improving their aesthetics in 2017 (TRDI, 2017).

This interpretation can serve as a legitimate justification for using solar retrofits. Since ePenambang retains the traditional shape and route while merely changing the energy source, visitors can easily identify the rickshaw as the bot penambang. Evidence confirms demand-side alignment with the interpretation. People were more than willing to make use of ePenambang (89.8%) even though they had very little awareness of it (27.6%) (Shahril, 2025). Acceptance belief measures such as perceived usefulness and ease of use do not explain the intention to use ePenambang (Musa et al., 2025). In contrast, attachment to traditional beca has been the best predictor of intention to use the electric version of the traditional rickshaw in Melaka (Musa et al., 2026a).

There are no indications of cultural resistance against the solar retrofit. No study to date has tested whether tourists or local people believe the solar retrofit innovation is authentic.

4.2 Community: A Fragile Base (Normative Pillar)

The boat operator group forms the weakest link of the industry. In March 2021, about fifteen boatmen were operating, with an average age above 60 years (Bernama, 2021a). Their monthly incomes were estimated at RM500 to RM600, with daily fuel expenses of RM20 and total maintenance expenditure of over RM14,000 over a period of five years. On low-activity days, some boat operators recorded no income at all. By May 2026, only ten boats remained operating, compared to dozens seen before.

The community possesses its distinctive strengths. The operators are part of the organisation named Persatuan Bot Penambang Seberang Takir, and they share their daily income equally amongst all vessels, which is based on trust (Bernama, 2021a). Such solidarity operates as a normative resource and illustrates how the community can organize itself and provide services even under difficult circumstances.

Nevertheless, the same evidence shows weaknesses similar to those discussed by Tosun (2000) regarding community participation in developing countries. Operators have limited capital, are older, and lack the means for youth to enter this profession. The introduction of solar retrofit does not solve these problems and may even worsen them, since operators will have to hire technicians to maintain the batteries. Without proper means of living, there may not be enough operators for green boats.

4.3 Policy: Present but Fragmented (Regulatory Pillar)

Policy support for the waterfront exists at both national and state levels, but it is fragmented in three ways.

Malaysia's main green mobility measures do not include water-based tourism transport. In particular, the Low Carbon Mobility Blueprint 2021–2030 focuses on road transport and electric vehicles, as well as their charging points (MGTC, 2023). Similarly, the National Energy Transition Roadmap identifies green mobility as one of six levers, but its goals focus on electric cars, charging points, and public transport (Ministry of Economy, 2023). The Green Technology Master Plan 2030 of Terengganu highlights renewable energy production such as floating solar power and green hydrogen; however, it includes no transport-related elements (TRDI, 2025). Sustainable and responsible tourism is one of six strategic pillars of the National Tourism Policy 2020-2030 (MOTAC, 2020). Still, it does not link this to green tourism transport.

State interventions have been practical but temporary. In 2017, the state government invested RM600,000 to improve 20 boats at RM30,000 per boat, focusing on safety, lighting, and aesthetics (TRDI, 2017). In 2021, the RM200-per-month subsidy was renewed for 18 boat operators and 57 beca riders after the previous programme expired (Bernama, 2021b). That year witnessed another intervention through the installation of virtual reality in

boats and solar panels for becas among five beca operators (Utusan Malaysia, 2021). Each intervention addressed a different problem: appearance, earnings, or innovation.

Responsibility for the boats is spread across tourism, culture and technology portfolios at state level, while national green mobility policy sits with energy and environment agencies. No single body is responsible for the green transition of heritage transport.

Table 3. Enablers and constraints by institutional pillar

Pillar	Enablers	Constraints	Net effect
Culture (cultural-cognitive)	Heritage meaning since the 1930s; route past key landmarks; retrofit keeps form and route; high tourist willingness	The authenticity of the retrofit has not yet been tested with tourists or residents.	Strong enabler
Community (normative)	Operators' association; shared-earnings practice; collective resilience	About ten active boats; ageing operators; low and unstable income; new technical skills needed.	Fragile; binding constraint
Policy (regulatory)	Sustainable tourism strategy in NTP 2020–2030; state upgrade (2017), aid (2021), VR and solar beca (2021)	The national green mobility policy omits waterborne tourism transport; support is episodic; unclear ownership	Present but fragmented

Interactions Across Levels

Considering a multi-level approach, ePenambang may be seen as an innovation niche within an eroding regime.

Favourable context includes recognition and commitment in Malaysia to energy transition and low-carbon transportation and tourism policies that prioritise sustainability as a key strategy. There are many challenges for the regime (traditional river taxis), such as pressure from road bridges, a drop in passengers, and the impact of COVID-19 (Bernama, 2021a).

Nonetheless, the window of opportunity created by such pressures does not seem to be taken advantage of, since there is a misalignment between the three levels. The cultural level favours the innovation, but the community of implementation is weakening, and the policy is unable to provide a protected space needed for niches to develop. According to Geels (2002), in this situation the niche does not have enough resources and actors to break through the regime. The danger here is that the regime erodes and the niche erodes with it; thus, the heritage service and its sustainable innovation disappear.

DISCUSSION

The immediate conclusion from the above results is that tourist acceptability in research on the diffusion of green tourism technology was not the main factor limiting the diffusion of ePenambang. Tourists are willing participants, and the craft's heritage value supports their interest. The limitations that affect diffusion relate to the community's ability to provide services and the policy framework to maintain them. This is consistent with literature from other regions on sightseeing water transportation, where diffusion depends on economic viability, incentives, and tourists' preferences (Xu & Wu, 2026; Bigerna et al., 2019). Additionally, it supports Rogers's (2003) theory that a social system affects diffusion; in heritage tourism, the social system consists of a vulnerable group of operators who keep the tradition alive.

Another implication of the above discussion is that none of the three enablers are substitutes for each other. Cultural enablers cannot substitute a weak community base, and funding cannot substitute for a weak labour force. According to Scott (2014), institutions are more stable when the three pillars complement each other and least stable when the pillars are different. In the case of the Kuala Terengganu waterfront, the three pillars differ: culture stresses the importance of the boats, while the rules and resources to operate them are weak.

This finding has a counterintuitive consequence. Strong cultural support may hide the problem. Because tourists and the state value the boats as heritage, interventions have focused on their appearance (TRDI, 2017) and on new experiences around them (Utusan Malaysia, 2021). These are cultural interventions. The more fundamental needs, a livelihood that attracts new operators and a fleet renewal plan, have received less attention.

The third implication concerns the type of policy change. In Hall's (2011) terms, the interventions so far are first-order changes (adjusting the level of aid or upgrade funding) and second-order changes (adding new instruments such as VR experiences or solar becas). No third-order change has occurred, which would redefine heritage transport as part of the destination's low-carbon mobility system. National policies reinforce this pattern by treating green mobility as a matter of road vehicles and charging points. As long as small passenger boats sit outside that definition, they will not benefit from the larger funding streams attached to the energy transition.

Figure 2 brings the findings together in a framework for green retrofits of heritage transport. It places the innovation at the niche level and shows the three pillars as conditions that must be present together for it to grow into a renewed framework.



Figure 2 · Contextual Enablers Framework

The status of each pillar reflects the evidence in Table 3 for Kuala Terengganu. All three must be in place for the niche to renew the heritage framework.

The framework makes three claims that future research can test:

1. Culture provides legitimacy. Retrofits that keep the form, route and human operator of a heritage craft gain acceptance from tourists and residents more easily than new vehicles.

2. Community provides capacity. Diffusion depends on a viable operator base. Where operators are ageing, poorly paid or few, cultural legitimacy alone will not lead to diffusion.

3. Policy provides continuity. Diffusion requires sustained support that treats heritage transport as part of the low-carbon mobility system, not as a one-off tourism project.

The framework also implies a priority order. In Kuala Terengganu, legitimacy is already in place. The most effective next steps strengthen capacity and continuity.

IMLICATIONS

The study identifies three theoretical contributions. First, the study shifts existing research on sustainable tourism technology adoption from a personal adoption paradigm to an institutional diffusion paradigm. While demand-

based theories analyse the possibility of tourists adopting the innovation, they do not consider the availability of the innovation. The approach combines diffusion of innovations and institutional theories.

Second, the study shows how Scott's (2014) three pillars of tourism innovation may be operationalized through the connection between policy, community, and culture and regulative, normative, and cultural-cognitive institutions. This gives scholars a methodical way to analyse context, rather than treating it as a residual concept.

Third, it applies the MLP approach to a heritage tourism environment and identifies an interesting configuration: niche innovation emerging within an eroding framework. In most MLP approaches, niches are pitted against established frameworks; here, the niche depends on the framework's continuity, since the green boat shares both the operators and the heritage significance of the traditional one.

Table 4 sets out recommendations for each pillar and the actors responsible.

Table 4. Recommendations by pillar

Pillar	Recommendation	Lead actors
Policy	Include waterborne tourism transport explicitly in national and state low-carbon mobility plans, making small passenger boats eligible for energy transition funding.	Ministry of Economy, KASA/NRES, MGTC, Terengganu state government
	Replace one-off grants with a multi-year fleet renewal programme that converts remaining boats to solar-electric power, with maintenance support.	Terengganu state government; local authority
	Assign one coordinating body for heritage transport across tourism, culture and technology portfolios.	Terengganu state government
Community	Link income support to a succession scheme that trains younger operators, including in solar and battery maintenance.	State government; operators' association; TVET institutions
	Involve the operators' association in designing, branding and pricing the solar service.	Operators' association; tourism secretariat
Culture	Market ePenambang as the heritage *bot penambang*, powered by the sun, rather than as a new technology.	State tourism agency operators
	Raise awareness through digital channels before and during visits, given low awareness among potential users.	State tourism agency

CONCLUSION

The study has limitations as well. It uses only secondary sources and does not include any interviews. Thus, it does not include the views of operators, officials, and local residents. Media may focus on newsworthy stories rather than everyday actions. The study is also limited to one case and cannot be generalised. Future research needs to include interviews with operators and officials and surveys of the local population on their views of the authenticity of the retrofitting process, as well as a comparative study of heritage water transport retrofits in Malaysia and Southeast Asia.

One main finding of the paper is that the diffusion of sustainable technology in the heritage waterfront is more closely tied to institutions than to tourists. Kuala Terengganu has both the asset and willing tourists. The realisation of this asset is contingent upon the existence of a community of operators able to make a living using the green boats and the presence of a policy framework that considers the significance of these vessels for the low-carbon destination future. This means that the combination of culture, community, and policy is the condition for implementing heritage innovation.

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