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The Tourism Adaptation Classification (TAC) framework: An application to New Zealand's Glacier country

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Alongside growing awareness of the significance of environmental change for glacier regions, and their tourism-dependent communities, is the realization of the need to adapt to changing conditions. Such adaptation is necessary for tourism operators, managers, and planners as well as the visitors themselves, and is part of building resilient tourism systems. This paper presents a conceptual framework for understanding the possible stages of adaptation in glacier tourism destinations. The Tourism Adaptation Classification (TAC) framework aligns three stages of adaptation (resilience, transition, and transformation) against adaptation strategies implemented by tourism stakeholders and identifies specific characteristics. Using a desk-based case study approach, the framework is illustrated with reference to Glacier Country in New Zealand's Westland/Tai Poutini National Park in relation to three core dimensions of the tourism system: tourism planning and governance; tourism business and operations; and visitor experience.

KEYWORDS

adaptation, adaptive strategy, Glacier tourism, Glacier country, New Zealand

1. Introduction

More so than at any previous time, tourism in the 21st century can be characterized by disruption, on multiple fronts, and at different scales (Hall et al., 2017; Toffler, 2022). Systems are dynamic and undergo continuous adaptation in response to pressures (Hartman, 2020). Sudden onset natural disasters, international financial crises and global pandemics sit alongside the slow-burning pressures (and evermore apparent) effects of climate change in challenging tourism destinations, communities, operators, and visitors across a variety of tourism contexts (Cheer and Lew, 2017). The tourism settings most vulnerable to perturbation are likely to be those whose natural resources, infrastructure, economy, and people are highly exposed to often rapidly developing or unprecedented scale of change (Hartman, 2020). Few tourism settings illustrate the impacts of environmental change more vividly than glacier destinations (Stewart et al., 2016; Salim et al., 2021a).

Glaciers have been attracting visitors for hundreds of years, and especially since the mid- to late-twentieth century following developments in tourist mobility and a growing public interest in nature-based tourism (Nepal, 2011). Glacier tourism has been described as a subset of nature-based tourism and mountain tourism, where tourists are drawn to destinations to experience glaciers through a variety of ways such as, photography,

education, or physical exertion, which could involve skiing, hiking, or climbing (Furunes and Mykletun, 2012; Welling et al., 2015). In this paper, glacier systems are regarded as the critical foundation in mountain landscapes that attract tourists, including tourism taking place in glaciated valleys, pro-glacial lakes, and mountain ranges. While there is an overall lack of reliable tourism data for mountain destinations worldwide, glacier tourism is regarded as a key sector supporting economies and communities in the mountain zones of Europe, the Americas, Asia, and Oceania (Hay and Elliot, 2008; Romeo et al., 2021), and such areas appear to be even more important to visitors since the COVID pandemic (Romeo et al., 2021). But as this tourism interest peaks, so too has the awareness that the attractions themselves are disappearing—melting away as temperatures rise, and precipitation levels vary season to season (Furunes and Mykletun, 2012; Espiner and Becken, 2014; Welling et al., 2015). Such is the concern among some commentators, that the term last chance tourism (LCT) has been applied to describe the fast-evaporating opportunity for visitors to experience glaciers in some parts of the world (Lemelin et al., 2010; Salim et al., 2022).

The rapidity of environmental change in glacier tourism settings has necessitated the need to adapt. A variety of adaptive responses has been reported and include: changes in visitor access to glaciers and related tourism activities; mitigation of hazards ensuring visitor safety; efforts to alter the visual appearance of the glacier to meet visitor expectations; diversification and substitution of activities; the use of interpretation and education; and changes to planning processes (Lemieux et al., 2018; Salim et al., 2021a,b). While such destination-specific adaptations have been usefully documented, what is lacking is a comprehensive conceptual understanding "in order to tie together the diverse research interests, subjects and methodologies found in the literature" (Welling et al., 2015; p. 652). Furthermore, Salim et al. (2021a; p. 231) have called for the "design [of] a conceptual framework for studying glacier tourism, [to] investigate motivations and behaviors of glacier tourists, and examine the impact of climate change on glacier tourism and the development of climate adaptation strategies."

Against this background, this paper presents a conceptual framework for understanding the possible stages of adaptation in glacier tourism destinations, which we have called the Tourism Adaptation Classification (TAC). The paper begins with a review of the climate change and glacier tourism literature followed by an examination of adaptive strategies adopted in glacier tourism settings. After outlining the key components of the TAC, the utility of the framework is illustrated using a case study of the Glacier Country in New Zealand's Westland/Tai Poutini National Park.

1.1. Climate change and glacier tourism

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) confirms that human-induced climate change has caused widespread disruption to climate systems, adversely impacting bio-physical as well as socio-economic, cultural, and political systems (IPCC, 2022). These climate disruptions have been found to be particularly severe in mountain landscapes and on the cryosphere—places where water freezes into snow or ice (IPCC, 2022). Observations indicate that surface air temperature is rising across the globe and that the rate of increase in mountain ranges throughout Western North America, the European Alps, and High Mountain Asia ($0.3^{\circ}C \pm 0.2^{\circ}C$ per decade) is faster than the global average ($0.2 \pm 0.1^{\circ}C$ per decade) (Hock et al., 2019). Glacier mass balances in mountain regions across the globe are almost universally negative (Hock et al., 2019) and some literature indicates that the rate of retreat has increased over the last decade (Bevington and Menounos, 2022). With regard to the future, glaciers are predicted to lose more than 80% of their current mass by 2,100 and many glaciers are predicted to disappear regardless of efforts to reduce emissions by this time (Hock et al., 2019). These changes in the cryosphere render glacial recession as one of the strongest visual indicators of climate change (Welling et al., 2015). Such observations are stark illustrations of a rapidly changing mountain environment and contribute to a growing concern about the disappearance of iconic natural landmarks and unique features of the landscape (Hugonnet et al., 2021). It is clear that the onset of rapid bio-physical change has far-reaching implications for glacier tourism settings, both directly and indirectly (IPCC, 2022).

One of the most visually apparent 'direct' effects relates to access to the glacier itself. Glacier retreat has made access to, as well as travel on and around glaciers more complex due to changes in glacier forefields and surface morphology (Ritter et al., 2012). For example, Mount Athabasca is an iconic route in the Canadian Rockies that requires travel on the Athabasca Glacier, a glacier that has been severely altered by climate change. It has already receded approximately 1.5 km and lost about half of its thickness (Hugenholtz et al., 2008), prompting predictions that it could be entirely gone by the end of the century (Clarke et al., 2015). Similarly, in the Everest region, glacier retreat, the development of supraglacial ponds, and the emergence and dramatic growth of large glacial lakes have, and are projected to continue to reduce the accessibility of popular trekking and mountaineering routes (Watson and King, 2018).

Another direct effect of glacier recession relates to the increase in glacier-related hazards. Glacial retreat has led to the debuttressing of valley walls, which in turn has contributed to mass movement events (Kos et al., 2016) and catastrophic rockfalls (Ritter et al., 2012). This increases the prevalence of natural hazards in glacier tourism landscapes and threaten tourism/recreation infrastructure (Purdie et al., 2015). For example, the Moosfluh slope, which borders the Aletsch glacier in Switzerland, was moving (for many years) downhill at a rate of approximately 1cm per year (Kos et al., 2016; Grämiger et al., 2017). However, in response to recent glacial retreat the slope has begun to move at approximately 30cm per year, compromising the structure of a nearby cable car and the safety of visitors and workers, resulting in its temporary closure (Kos et al., 2016). Similar observations have been in made in the European Alps. For example, the Pilatte hut, in the Écrins mountain range – a traditional waypoint for hikers and alpinists, has moved in response to glacial debuttressing and resulted in its permanent closure (Duvillard et al., 2018).

Glacial retreat has also enlarged glacier forefields, which are full of unstable material. As a result, depending on the angle of the

slope, these forefields become a potential zone for rockfall (Ritter et al., 2012). Increased rockfall, associated with climate change and glacier recession, has been observed in New Zealand, Europe, and the high mountain regions of Asia (Hock et al., 2019). For example, between 1900-2012, the total surface area of alpine glaciers in the European Alps decreased by half (Vincent et al., 2017) and accordingly, rockfall increased in both frequency and volume (Geertsema et al., 2006; Ravanel and Deline, 2011; Ravanel et al., 2013; Magnin et al., 2017). As a result of these changes, exposure to rockfall hazards has increased, leaving numerous classic routes in the Alps unclimbable or more hazardous (Magnin et al., 2017; Mourey et al., 2019). At Fox Glacier in New Zealand, Purdie et al. (2014) found that rocks could travel 50 m further onto the glacier as a result of recession between 2008 and 2012, increasing the exposure of visitors to this natural hazard.

In some instances, however, the changing glacier environment can lead to innovative and unexpected tourism opportunities. For example, glacial retreat in Peru's Cordillera Huayhuash has made access to mountain regions both easier and faster, opening new passes and trekking routes, which in turn has increased the number of tourists in the region (Bury, 2008). Similarly, glacier recession at the Tasman Glacier, New Zealand has created a large pro-glacial lake that now offers glacier tours by boat, which allows tourists to get up close to the glacier without having to risk walking on the glacier itself (Purdie et al., 2020).

The indirect consequences of glacier recession relate to the knock-on effects of bio-physical changes including any changes to visitation, visitor experience and behavior (Scott et al., 2008). Of the limited research, findings indicate that a loss of access to glaciers would likely result in reduced visitation. For example, in Jostedalsbreen National Park, Norway the number of participants in glacier tourism activities decreased by 38% between 2003–2009, largely attributed to changes in the morphology of the glaciers and their accessibility (Furunes and Mykletun, 2012). In Vatnajökull National Park, Iceland, nearly a third of visitors stated that they would not be willing to visit the park if they could not get within 150 m of the glacier margin or if they could not stand or touch the glacier (Welling et al., 2020). While there is little scholarly attention on the impact of climate change on tourists' experience of glaciers, there is a comparatively large body of literature on ski tourism (i.e., skiing at a non-glacier specific resort). This research suggests that poor snow conditions associated with climate change will likely result in a decrease in participation in downhill skiing (Steiger et al., 2017). For example, Steiger et al. (2022) found that low snow reliability and poor snow quality in Austria could result in a 64% decrease in visitation.

A small body of literature examines the impact of climate change on the visual aesthetics of the mountain environment. As a consequence of recession, glaciers can become difficult for visitors to see from established viewing points, or hard to differentiate from surrounding rock due to significant debris cover. These changes have the potential to negatively impact on visitation rates. For example, in the Yulong Glacier, Lijing region in China, 19.6% of visitors indicated they would be unwilling to visit the glacier under severely altered environmental conditions. This percentage was higher for visitors to Athabasca Glacier, Canada (23%) (Groulx et al., 2017); Mer de Glace, Mont Blanc Massif, Switzerland (30.2%) (Salim et al., 2021b); and Vatnajökull National Park, Iceland (46%) (Welling et al., 2020). Conversely, some scholars have suggested that vanishing glaciers are actually an important motivation for mountain tourists to visit glacier destinations (Stewart et al., 2016; Salim and Ravanel, 2020), potentially increasing visitation through "last chance tourism" (LCT) (Welling et al., 2015; Lemieux et al., 2018; Groulx et al., 2019).

These observed and predicted changes in the mountain environment will continue to influence the ways in which glaciers are experienced by tourists. Understanding these changes is therefore critical to developing effective adaptation strategies.

1.2. Adaptation strategies

Adaptation is the process of responding to a stimuli or stress, such as climate change, with the goal of preventing loss, spreading or sharing loss, and/or diversifying to moderate harm or taking advantage of emerging opportunities (McDowell et al., 2016). In the climate change literature, adaptation has been classified according to when a stressor occurs (i.e., reactive or anticipatory); the intent of the adaptation (i.e., autonomous or planned); the scope (i.e., spatial or temporal); the form (e.g., technological, behavioral, financial, institutional, regulatory, and informational); the implementation (e.g., hard or soft); and its outcome (e.g., effectiveness, efficiency, equity) (Smit and Wandel, 2006). Pelling (2010) first expressed a spectrum of adaptation, grouping adaptations into three categories: (1) reactive, which are the processes required to continue "business as usual," responding to an immediate state of change; (2) transitional, which are incremental adjustments made to account for future changes of state; and finally (3) transformative, which are the processes that ensure the fundamental changes to a system (Pelling, 2010). The 5th IPCC (2014) Assessment Report expressed adaptation as a priority to cope with the effects of, and the processes involved in adjusting to, the current and future effects of climate change (Meyer et al., 2014). It is not surprising therefore, that in the context of glacier tourism, adaptation has been critical for the survival of glacier destinations over the past few decades (Fischer et al., 2016; Lemieux et al., 2018; Salim et al., 2021a,b; Mayer and Abegg, 2022).

In recent years scholars have identified a range of adaptation strategies used in glacier tourism settings. These have included techniques to preserve the glacier itself, either by slowing glacial retreat or installing equipment to maintain a specific experience. This has included artificial snowmaking (Mayer and Abegg, 2022; Steiger et al., 2022), snow harvesting (Oerlemans et al., 2017), and the use of protective white geotextile blankets during the melting season to increase the glacier's albedo—thereby significantly increasing the amount of solar radiation reflected and slowing ablation (Fischer et al., 2016; Senese et al., 2020; Huss et al., 2021). Another adaptation strategy is the regular maintenance or upgrade of glacier access, predominantly achieved through the installation of infrastructure. For example, in the Mont Blanc region, France over 600 m of ladders have been installed to maintain classic mountaineering routes and access to alpine huts (Mourey and Ravanel, 2017). At both Fox and Franz Josef Glaciers in New

Zealand, visitor access since 2012 has been maintained *via* the use of helicopter shuttles after foot-access to the glaciers became too treacherous (Purdie, 2013; Stewart et al., 2016). Diversification into new activities is another strategy that has been employed by glacier tourism operators, such as the Tasman glacier case earlier described.

Substitution is another adaptation strategy that has been applied in the changing glacier tourism environment. Temporal substitution refers to changing the timing at which an activity takes place, and this change can occur on a wide-ranging time scale, from diurnal to seasonal. For example, alpine mountain guides commonly report shifting the seasonality of their work so they guide more early in the spring when conditions are the best and less in summer when the hazards are elevated (Bourdeau, 2014; Salim et al., 2019; Mourey et al., 2020). Activity substitution refers to changing the originally contracted activity to a different activity. For example, guides will frequently alter the original plan when conditions are adverse, in favor of activities that do not need to be practiced in high mountain environments, such as rock climbing, mountain biking, off piste skiing when conditions allow, water-based glacier tours, and protected climbing routes (Purdie, 2013; Kaenzig et al., 2016; Salim et al., 2019; Mourey et al., 2020). Spatial substitution refers to a change in the location of the contracted itinerary (Purdie, 2013; Salim et al., 2019; Mourey et al., 2020). Most glacier guides state that they need to be increasingly mobile to find good, safe conditions for their clients and some even report abandoning specific routes, which had become too hazardous (Purdie, 2013; Salim et al., 2019; Mourey et al., 2020). For example, the two largest guiding companies in France have stopped guiding the Goûter Couloir up Mont Blanc due to increased rockfall and instead, encourage guests to consider Mt Rosa in Switzerland or Grand Paradiso in Italy (Mourey et al., 2020).

An emphasis on education and interpretation is another adaptation strategy adopted, where the emphasis of visitation shifts from seeing a pristine glacier to helping visitors to understand the consequences of climate change (Carver and Tweed, 2021). For example, at the Athabasca Glacier in the Canadian Rockies, interpretive signs that explicitly attempt to educate visitors about climate change have been installed along the trail leading to the terminus of the glacier (Lemieux et al., 2018). These signs mark the location of glacier extents throughout time, discuss greenhouse gases in the atmosphere, and predict how the landscape may transform in the future (Lemieux et al., 2018).

The positioning of glacier tourism as LCT is a form of adaptive response in both the promotional and marketing sense, as well as from the perspective of the visitor experience (if indeed the loss of the glaciers is a motivator for travel). While there has been some obvious hesitation to label destinations as "last chance," as some believe it puts an expiration date on a destination, destinations such as Athabasca Glacier in Alberta, Canada are embracing the LCT notion, with park managers weighing the "uneasy benefits" (Lemieux et al., 2018; p. 654) and implementing LCT as a marketing tool. This has enabled the destination to create adaptive strategies to manage visitor experiences and expectations, transitioning the destination's tourism products offering educational, interpretive outreach activities (Lemieux et al., 2018). This opens up the possibility that glacier regions have the potential to become ambassadors for climate change action, offering educational opportunities for visitors to act as environmental stewards. While LCT might not be a pre-requisite for ambassadorial activities (see Salim et al., 2022), a destination that is in a state of "last-chance," might accelerate or act as a catalyst for visitors to become environmental stewards.

While all of these adaptation strategies are aimed at coping with environmental change, not all adaptation results in the outcome intended. Maladaptation is an emergent concept that describes "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups" (Barnett and O'Neill, 2010; p. 211). This is evident in artificial snowmaking, where for example, the water required to make snow must be diverted at the expense of aquatic habitat (Schipper, 2020). The use of geotextiles to cover glaciers can also be regarded as maladaptive as the blankets, which are notoriously expensive and labor intensive to install, have been shown to leave materials on the ice. This material can then be transported *via* wind or melt water, accumulating downstream and producing harmful effects on human and non-human (e.g., flora and fauna, aquatic species) communities that rely on glacially derived water resources (Fischer et al., 2016; Huss et al., 2021). LCT could also be considered maladaptive because it only considers a short time scale. LCT will no longer be an effective marketing strategy nor create a draw for tourists when the vulnerable feature being promoted, such as the glacier, is gone (Salim et al., 2022). Further, LCT has been demonstrated to contribute to an increase in greenhouse gas emissions (e.g., D'Souza et al., 2021) because features, such as glaciers, are often in remote destinations with poor public transportation options, and thus requires carbon intensive travel. In practice, this means that some adaptations employed by the glacier tourism industry are not only failing to reduce their vulnerability to climate change, but are also likely contributing to an increase in the amount of harm (to varying degrees) climate change can exert across spatial and temporal scales. In doing this, maladaptive actions can create a positive feedback cycle that necessitates the need for further adaptation in response to increased vulnerability (Barnett and O'Neill, 2010; Magnan et al., 2016; Schipper, 2020).

2. Conceptual framework

Building on work by Welling et al. (2015), Salim et al. (2021a) identified 27 adaptation strategies under seven main themes including changes to access, changes to activities, changes to tourism planning, and educational activities. This work was further distilled by Salim et al. (2022) who examined glacier tourism systems affected by climate change across six major European glaciers, identifying six adaptation strategies related to management, itineraries, infrastructure, destination attractiveness, the safety of visitors, and activities being offered. In the Chinese context, Wang and Zhou (2019) extended Salim et al. (2021a,b,c) work, adding the diversification of products, and adopting multidimensional protective measures in planning, management, and visitor experiences. Climatic changes are also encouraging adaptive strategies accommodating changes in seasonal patterns, the stopping of operations, the inclusion of geotextiles and

increased snowmaking (Mayer et al., 2018). These studies have identified a range of adaptation strategies adopted, but there is a gap in the literature classifying destinations by their stage of change, as adaptive responses vary accordingly. Previous studies have outlined the need for a conceptual framework (Welling et al., 2015; Salim et al., 2021b) to help situate how adaptive responses might change as a destination responds to climate change. This paper draws on the concepts of adaptation and change to create a framework to better understand how destinations adapt over time, which might ultimately assist tourism managers in their decision-making processes as they manage for change.

The Tourism Adaptation Classification (TAC) framework (Figure 1) aligns an interpretation of Pelling's three "visions of adaptation" (resilience, transition, and transformation) against a consolidation of Salim et al. (2021a) adaptation strategies as implemented by tourism stakeholders. Stages of adaptation depict a trajectory from nascent (emerging) to developed resilience at the destination level, namely the reactive, transitional, and transformative stages (also see Espiner et al., 2017). Each adaptive stage is examined in relation to key dimensions of the tourism system which have been distilled from Salim et al. (2021a,b,c) and include: tourism planning and governance; tourism and business operations and the visitor experience.

At a "reactive" stage, resilience is partial, and exposure/vulnerability is acute. The governance and planning dimensions of the tourism system are unlikely to be geared to respond to rapid onset events, and time is needed to alter horizons and adjust strategies. Tourism businesses will attempt to sustain operations with temporary work-arounds necessary to navigate disruption, while visitors are likely to experience unavailable services, closed facilities and reduced satisfaction because of unmet expectations. At a transitional stage, vulnerability is chronic and destination communities, operators, managers, and visitors are becoming more conversant with the changing conditions and potentially accepting that the future may unfold in unfamiliar ways (i.e., no return to normal). Plans and strategies may now reflect this acceptance, and operators are likely to have bedded in systems that allow them to continue delivering glacier tourism services—albeit in ways very different from how things were in the past, requiring the design of alternative visitor experiences. A transformative stage of tourism adaptation is characterized by widespread acceptance of the need to do tourism differently. At a "transformative" stage, vulnerability is reduced by the adoption of actions and strategies that address the root cause(s) of a system's vulnerability such as long-term regenerative tourism planning; substitute tourism products; diversified destination marketing; nimble operators and climate conscious visitors.

The TAC adopts three dimensions through which adaptation might be understood: governance and planning; management and operations; and the visitor experience. Each of these dimensions has a distinct significance in relation to adaptation, reflecting different responses to changing conditions in the tourism setting. Tourism planning and governance encompasses the strategy and oversight dimensions of tourist destinations. In most cases, this includes the perspectives of public and private sector governance structures responsible for strategy and planning functions. In the case of New Zealand, such functions are the responsibility of central and district level government, local iwi,[1] and business associations. Among the central priorities for this part of the tourism system are setting the long-term direction of tourism development, including strategic decisions around visitor access, infrastructure development, and the identification of risk within the environment.

The second system dimension that informs the TAC relates to the operational elements of tourism at the destination. This encompasses commercial tourism businesses, as well as public sector agencies who have operational responsibilities in relation to public access and recreation provision. Primary considerations within this sphere include day-to-day business operations, destination image, and managing risk for visitors. Specific adaptations in response to climate change (or other disruptive conditions) are implemented through tourism and business operations. The third and final dimension, visitor experience, recognizes that the people visiting the attraction also respond and adapt to changing conditions. Tourist motivation, emotions and feelings expressed toward climate-impacted destinations, the activities that are available or have since been altered due to negative climate effects, and the behavior of visitors toward destinations that may be in a state of crisis due to change. This dimension proposes that visitor adaptation to change is complex, evolving from responses that may reflect dissatisfaction regarding unexpected or dynamic conditions, through to greater levels of acceptance of what the destination can offer, and even to the extent of engaging in ambassadorial activities.

Climate change is a continuous, dynamic phenomenon that requires constant adjustment to predicted and unexpected change in an ever-evolving socio-ecological system. The TAC framework acknowledges this by situating the tourism system within a wider global context—one heavily influenced by a range of diverse economic, political, environmental, social, and cultural drivers, all of which influence the effectiveness of an adaptation strategy and impact the core dimensions of the framework, facilitating or constraining movement across the adaptation stages. Furthermore, the TAC allows for the possibility that the adaptive stages may be experienced differentially across the three dimensions of the tourism system. For example, visitors and operators may be in a reactive phase, while the actions of policy makers may be transitional in nature. Additionally, it is unlikely that the dimensions will shift in unison over time, or in a manner that is linear. Instead, the pathway through the adaptive stages is likely to haphazard, fluctuating and intermittent, as illustrated by the variable shading and feedback loops on the TAC framework.

3. Applying the TAC: A case study of Westland/Tai Poutini National Park

In this section, the TAC framework is illustrated via reference to Glacier Country in New Zealand's Westland/Tai Poutini National Park (Figure 2) in relation to three core dimensions of the tourism system. While this is a largely conceptual paper, it

1 An iwi, or Māori tribe, is one of the largest kinship groupings and is generally made up of several hapū that are all descended from a common ancestor (Statistics New Zealand, 2023).

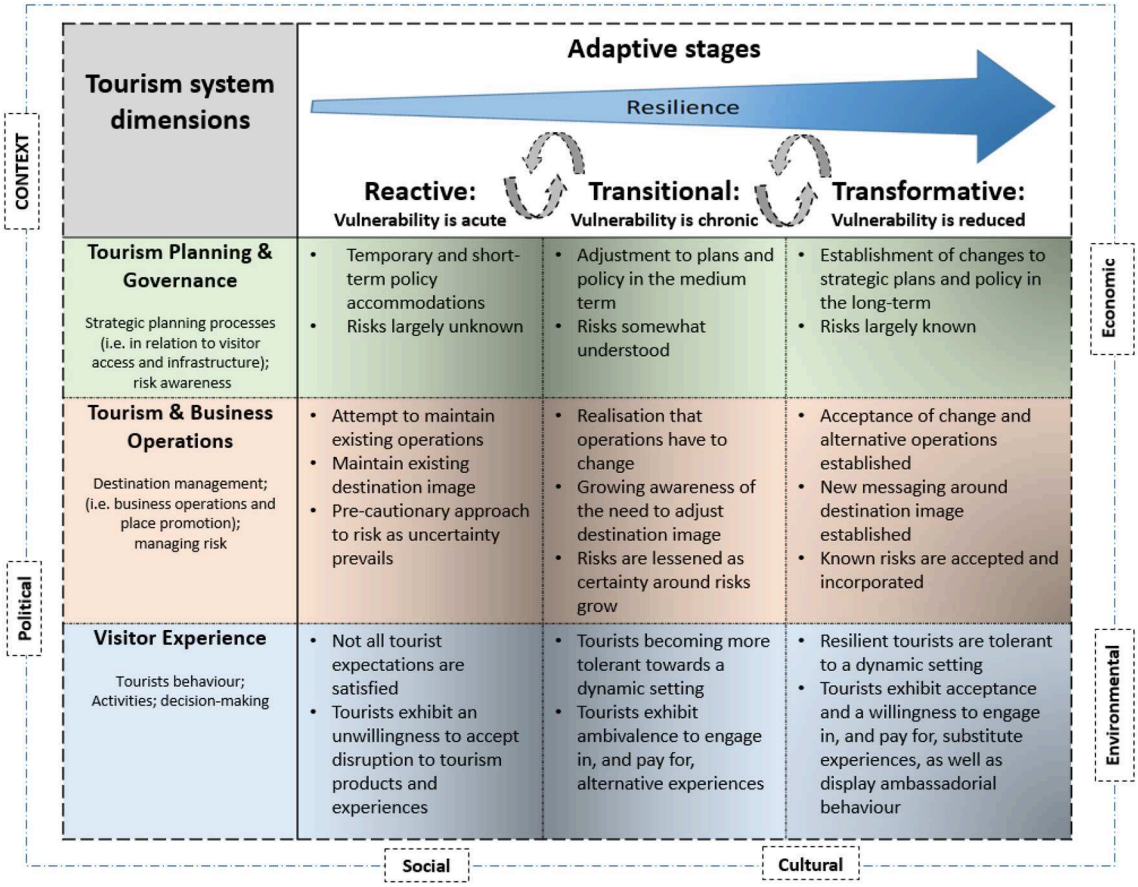

FIGURE 1
Tourism adaptation classification (TAC) framework (after Pelling, 2010; Salim et al., 2021a).

is important to point out that evidence collected as part of case study has been a desk-based exercise, reviewing scholarly literature on the subject of glacier tourism in Glacier Country. No new empirical work was undertaken to support the application of the classification framework to the Westland/Tai Poutini National Park.

In "Glacier Country," the Te Moeka o Tuawe/Fox and Kā Roimata o Hine Hukatere/Franz Josef glaciers are regarded as the cornerstone tourism attractions on the West Coast of New Zealand's South Island/Te Waipounamu. This natural resource tourism-dependent region has a long history of environmental and economic vulnerability, coupled with a community character that has successfully navigated decades of disruption (Espiner and Becken, 2014). We characterize adaptive responses to change in Glacier Country as existing on a continuum from "reactive" to "transformative" as outlined by the TAC framework.

Glacier Country has been an important dimension of the West Coast economy for well over 100 years, with the glaciers described as the 'engine room' of the tourism industry in this remote region (Espiner and Becken, 2014). Prior to the COVID-19 pandemic, the glacier region attracted approximately 700,000 visitors annually (Wilson et al., 2012), and recent reports suggest that tourism on the West Coast generally is quickly returning to pre-pandemic levels (Bywater, 2022). The central attraction for visitors to Westland/Tai Poutini National Park are two relatively accessible glaciers that descend steeply from the peaks and neves of the Southern Alps to the bush-clad valleys just above sea-level on the West Coast. The accessibility of these two glacier attractions has led to the development of a range of outdoor recreation opportunities and nature-based tourism services at the glaciers, most notably, high quality walking tracks to glacier viewpoints; extensive car parks and associated visitor amenities; and a thriving glacier guiding, heli-hiking and scenic flight industry.

Meeting the tourism demand to experience the glaciers has not been without its challenges over the years, with maintaining visitor access among the primary challenges (McCormack, 1999). In recent decades in particular, Franz and Fox Glaciers have undergone dramatic morphological changes largely due to changing environmental conditions in the catchment (see Figure 3). Warmer temperatures, and reduced snowfall at higher altitudes have resulted in significant recession and down-wasting at both glacier sites (Purdie et al., 2014). Mills (2012) reported a 500m retreat at Franz Josef over the previous 4 years—the most rapid retreat ever recorded at this site. Climate change projections for the glacier region suggest further increases in mean temperature over coming decades, with wetter autumns

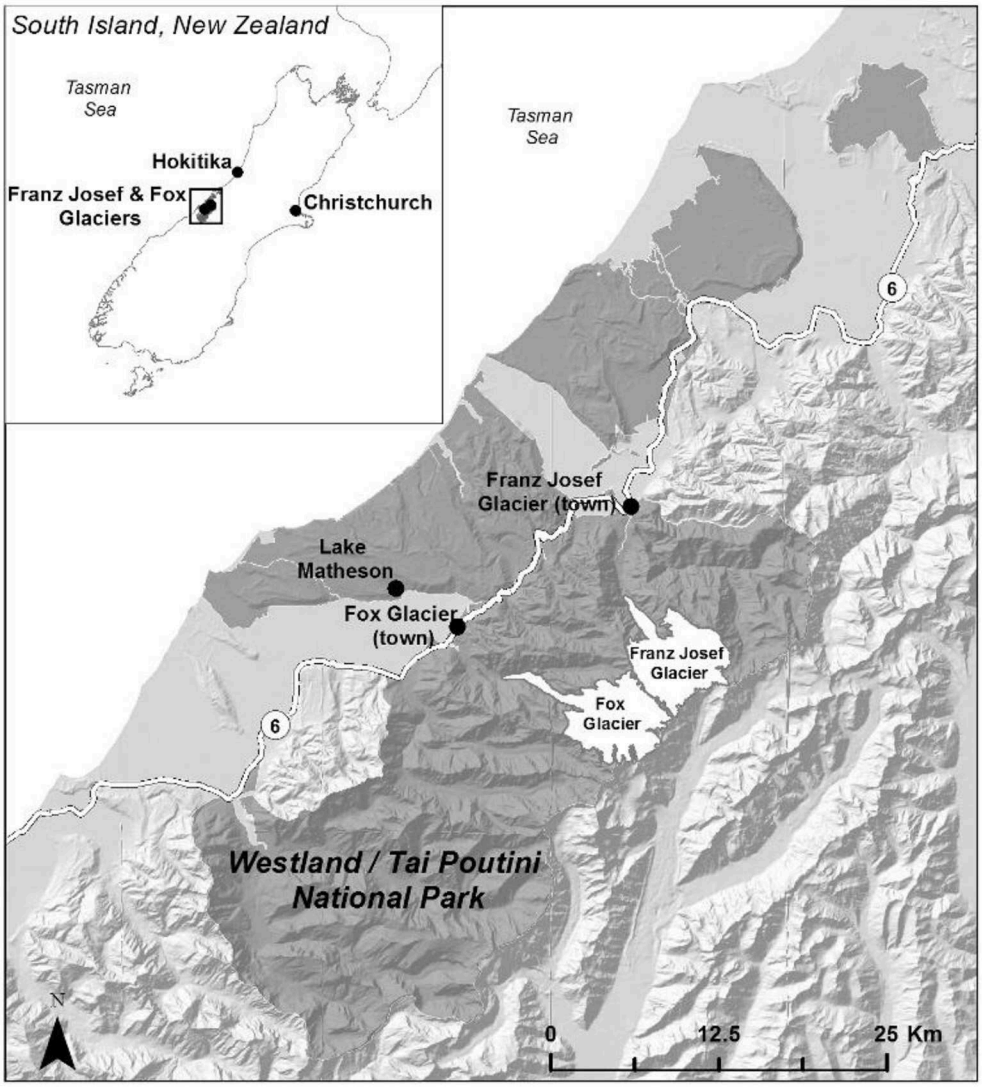

FIGURE 2
Location of Westland/Tai Poutini National Park and Te Moeka o Tuawe/Fox and Kā Roimata o Hine Hukatere/Franz Josef Glaciers (Stewart et al., 2016; p. 381).

and winters (Ministry for the Environment, 2018). The impacts of anticipated environmental change on the Westland glaciers will be profound, where higher snowlines are expected to drive mass-balance losses that will inevitably reduce the glaciated area (Lorrey et al., 2022) and increase hazards (Purdie et al., 2018). Future climate modeling scenarios indicate that by 2099, these glaciers will lose their long, steep and narrow tongues and be reduced to small glaciers at high elevations (Anderson et al., 2021).

Recent and anticipated environmental change at Fox and Franz Josef Glaciers is putting immense pressure on those responsible for maintaining public access and delivering tourism services at these attractions. Using the TAC framework, several adaptive responses to these changes can be observed in the Glacier Country region (see Glac_TAC, Figure 4). Here we interpret these responses as corresponding to the three adaptation stages: reactive, transitional, or transformational. Illustrations of these stages are provided through governance, operational and visitor experience dimensions.

3.1. Reactive Stage (1900–2014)

For the vast majority of its history as a tourism destination, adaptive responses to changing conditions in Glacier Country can be characterized as reactive. Reactive responses to these evolving conditions have included attempts to maintain glacier access infrastructure (e.g., tracks and roads), canceled operations (e.g., guided walks), unmet expectations among visitors, and revealed planning tools to be insufficiently nimble. As Espiner and Becken (2014) noted, visitor services at the glacier have constantly evolved to address the advancing and retreating glaciers. They detected a robust resilience among the local tourism industry forged in part by strong self-efficacy and an embedded social practice of innovation. In their attempts to maintain existing tourism operations circa 1900, for instance, workers at Franz Josef constructed a complex cantilevered bridge structure high on the rock walls leading to the glacier, only to see it destroyed 10 years later by rapid glacier advance

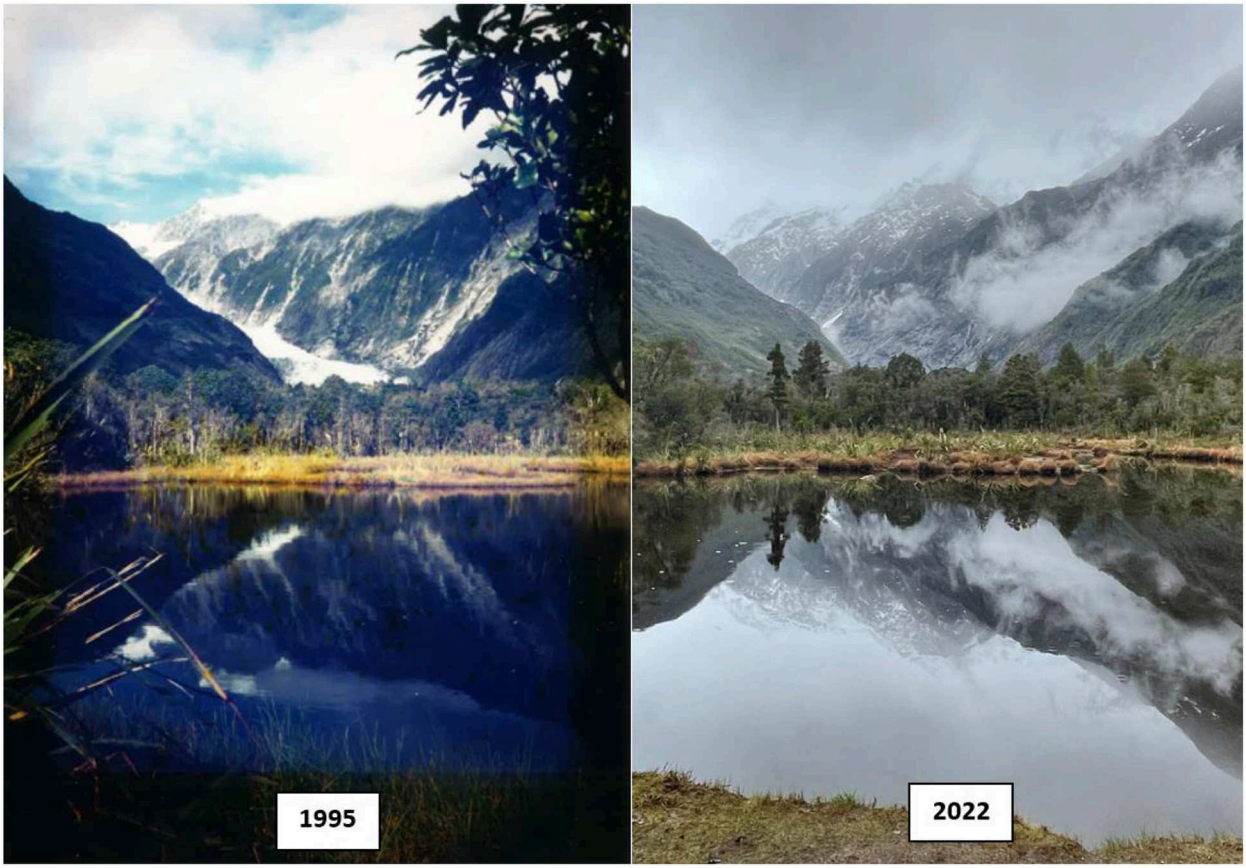

FIGURE 3
Images of Franz Josef Glacier taken from the same vantage point, Peters Pool a small kettle lake, in 1995 (Photo: E. J. Stewart) and in 2022 (Photo: S. Espiner) illustrating significant glacial recession.

(McCormack, 1999). Similarly, when a lake formed in front of the glacier during the1930's guides had to use row boats to ferry tourists to the glacier terminal (McCormack, 1999). These are two historical examples where tourism businesses and public authorities took quick action to meet visitor demand through maintaining access and services in the face of difficult environmental conditions.

In more contemporary times, as environmental changes at the glaciers have become more obvious and persistent, park management plans have been revised and policies augmented so that public access and tourism businesses can be sustained. One example of this is the Westland/Tai Poutini National Park Management Plan (DOC, 2001), which was formally amended in 2014 to allow for many more aircraft landings on the glacier after guided foot access was rendered unsafe following collapse of the lower reaches of Franz Josef Glacier. At the time, tourism businesses operating in the area had concessions to guide 400 clients per day onto the glacier—all of whom became reliant on helicopter access once conditions made it unsafe to use the traditional foot access route. The amendment to the Plan was necessary because the existing Plan (prepared in 2001) did not allow for a large number of landings on the glaciers. As the amendment to the Plan notes: "When the plan was approved in 2001 the dramatic rate of glacier retreat and consequent problems of access to/or onto the glaciers was not anticipated" (DOC, 2014; p. 6).

Another example of changing operational policies at the Glaciers relates to the maintenance of public access routes on the valley floor. In the past, DOC policy did not allow large earthworks machinery in the river bed (preferring a less environmentally invasive approach). Rapidly changing conditions (as a result of more water in the river and large flood events) has meant that this policy was set aside for a period while attempts were made to maintain visitor access to areas close to the Franz Josef Glacier terminus. Efforts to maintain foot access proximate to the glacier were abandoned altogether in 2014 and the visitor walking track at Franz Josef was severely truncated—now offering only a distant view of the higher reaches of the glacier from a vantage point above the river. While some visitors were no doubt disappointed public access to the terminus of the glaciers was diminished because of changing conditions, other visitors adapted by accessing the glacier by air, or hopping between the two Glaciers to maximize their chances of access (Wilson et al., 2012). A visitor survey undertaken in the summer of 2013/2014 ($n = 500$) confirmed that not all visitor expectations had been satisfied, including the visual appearance of the glacier with approximately half of the respondents reporting that the glacier was not as big as expected (50.1%) and that the ice didn't look as they expected (52.6%) (Wilson et al., 2012).

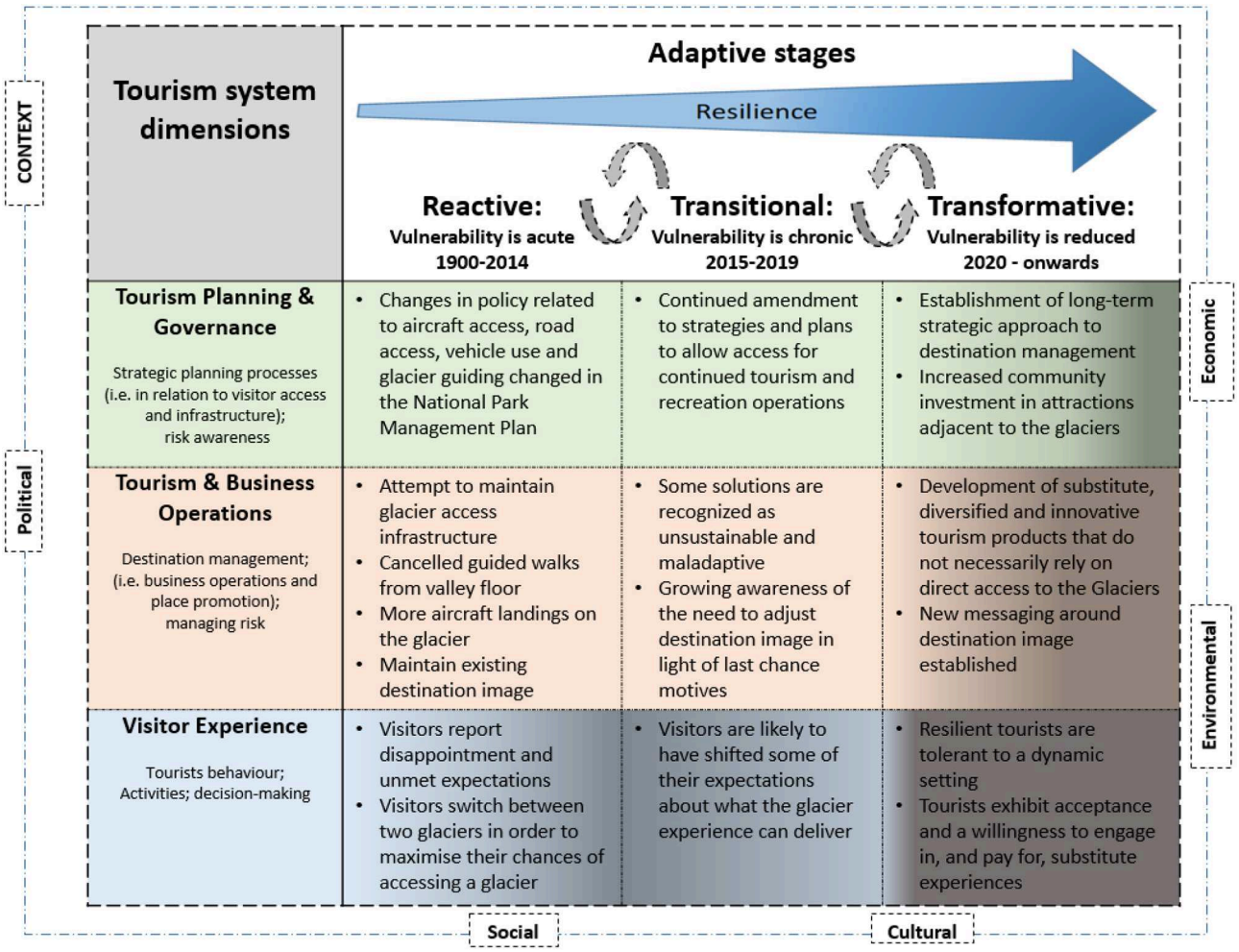

FIGURE 4
Adaptation Classification (TAC) framework applied to the Glacier Country (Glac_TAC).

While reactive responses are legitimate and logical adaptations, they are typically short-term and temporary workarounds undertaken in the face of complexity, and as such, poorly understood situations. Reactive adaptations documented at the glaciers might have been sufficient in the past but they are not sustainable. It is with this realization, that we observe a shift to a transitional stage in adaptation response in this setting, circa 2015.

3.2. Transitional stage (2015–2019)

It is our contention, that Glacier Country is currently characterized by such a transitional phase, at least concerning the dimensions related to business operations and visitor experience. The transition phase at the glaciers is characterized by an acknowledgment that the disrupted conditions are unlikely to be temporary, although the strategies for future success may not yet be in place. In this phase of adaptation, estimated as starting around 2015, those in planning and governance roles have attempted to amend strategies and plans to allow for the continued tourism and recreation operations. However, some of these "solutions" are recognized as unsustainable and maladaptive most notably in the cases of Fox and Franz Josef Glaciers, the park management's temporary increase in number of aircraft landings to accommodate the lost opportunity of foot access for commercially guided visitors (Espiner et al., 2015). Anecdotal evidence suggests that the helicopter experience is now a highlight of the visit for many tourists. Despite the price of the guided experience increasing ~4-fold as a result of the new access arrangements, demand for glacier guiding remained strong during this time period (until the pandemic). This indicates that in the transitional adaptation phase, visitors are likely to have shifted some of their expectations about what the glacier experience can deliver (e.g., limited access, increased cost, reduced certainty). In the case of Fox Glacier, the visitor access road and car park were closed since February 2019, following several significant flood and rockfall events which had made the road uneconomic to reinstate and maintain (see Figure 5). As a DOC manager noted "you are not managing for some sort of consistent state, you actually have to manage for change" (Wilson et al., 2012; p. 29).

The realization, and acceptance of LCT at the destination level, might also be indicative the transitional adaptation phase, where

FIGURE 5
The access road to Fox Glacier was closed indefinitely following storm damage in February 2019 (Photo: S. Espiner).

some tourism operators might leverage the loss to motivate visitors. The 2014 visitor survey did highlight that the chance "to see a natural feature that may disappear in the future" ($x = 6.01$) was an important reason to visit the region. However, these somewhat macabre motives, might actually offer educational opportunities for visitors to act as environmental stewards and aid in awareness and conservation, as has been the case in at the Chacaltaya and Athabasca glaciers (Kaenzig et al., 2016; Lemieux et al., 2018).

Also, in this transitional phase, tourism businesses and other operations are beginning to envision tourism products and recreation opportunities beyond those developed for a previous era. For example, in response to the changed access at the glaciers, the International Visitor Levy (IVL) (established in 2019) funded by a $35 NZD levy imposed on most international visitors to New Zealand, was used to invest in projects that protect the natural environment and support local communities (Ministry of Business Innovation Employment, 2022a). So far, there have been seven IVL-funded projects in Glacier Country, including Te Kopikopiko o Te Waka (translated as 'the capsized canoe'), a new visitor viewpoint near Fox Glacier, developed as a partnership between Ngāti Māhaki and the Department of Conservation with the support of the community (Development West Coast, 2022).

> "We were confronted with what could have been a disaster for local tourism. DOC, Te Runanga o Makaawhio and the community came together to find solutions to sustain tourism and build the Glacier Country's economic resilience in a changing climate. We worked collaboratively to develop a range of alternative attractions to continue to draw visitors to this area. That done we then successfully secured $3.9 million from the IVL [...] to enable the work to be done" (DOC South Westland Operations Manager Wayne Costello, cited in Development West Coast, 2022).

The new installation, offering a long-distance perspective on the glacier, alongside the stories of Te Runanga o Makaawhio, is a direct result of efforts to re-frame the visitor experience after the loss of road access to Fox Glacier in 2019. These projects, which challenge dominant cultural discourses and traditional visitor expectations of what it means to visit a glacial site, are in alignment with the move from transitional to transformational adaptations. This example illustrates that the planning and governance dimension of the tourism system might actually be advancing into the realm of transformational adaptation ahead of the other dimensions related to business operations and visitor experience. As Figure 4 illustrates (note variable shading) not all dimensions of the tourism system may move through the three adaptive stages simultaneously.

3.3. Transformative stage (2020–onwards)

Evidence of Glacier Country arriving at the threshold of a more transformative adaptive stage would include: strategies and plans that anticipate and embrace the possibility of rapid change; the development of substitute and innovative tourism products that do not necessarily rely on direct access to the Glaciers (e.g., development of new mountain bike trails); and diversified and/or substituted visitor experiences cognizant of the changing

environment. Given the geographically peripheral character of Glacier Country, and the looming reality of a lower-carbon future, transformative adaptation might also be observed among businesses developing new technologies or narratives around their products. As yet, there is little evidence of this in Glacier Country. Moreover, in the public domain, current national park planning and strategy processes at the Glaciers, while comprehensive and participatory, are highly labor-intensive and lack the agility required to respond to rapidly developing environmental, socio-cultural and economic phenomena. A tourism destination at a more transformative stage of adaptation would have developed planning models that allowed for various scenarios and built in processes that allow agile responses to inevitable change.

In Glacier Country, there are signs that transformative adaptation may be emerging in subtle ways, such as the park management agency's decision not to reinstate the access road to Fox Glacier, and increased public, iwi, and community investment in visitor attractions adjacent to the glaciers. Furthermore, in 2020 $3.9 million was allocated from the IVL fund to develop a long-term strategic approach to destination management in Westland (Ministry of Business Innovation Employment, 2021). A key focus of this strategic work in Glacier Country is maintaining access to the glacier valleys. In order to progress this aim, DOC is working alongside local iwi, the wider community and multiple national stakeholders (councils, local business and non-government agencies). Such long-term, collaborative and inclusive destination planning may be an important feature that will allow for transformative adaption at the governance level.

4. Discussion

The literature reviewed previously indicates that adaptation strategies currently tend to focus on the immediate need, a finding supported by IPCC (2022), who report that "most adaptation responses to natural hazards in mountain regions are *reactive* [emphasis added] to specific climate stimuli or post-disaster recovery" (IPCC, 2022; p. 2288). This reactive approach appears to be informed by impact-driven vulnerability, where vulnerability is understood to be the direct result of climate change to an exposed individual, community, or population (O'Brien, 2012). However, the effects of climate change on a system vary, largely due to a mosaic of unequally distributed non-climatic factors, such as access to finanical resources, social networks, and information (Smit and Wandel, 2006). By continuing to frame adaptation as impacts-driven, the underlying social conditions that produce vulnerabilty are obscured (Ford et al., 2018) and reactive adaptations become only temporary solutions. In turn, this prevents a system from being able to address the root causes of vulnerabilty and thwarts the progression to transitional and transformational adaptation strategies.

In the context of glacier tourism, this tendency to adopt reactive approaches has, in some instances, resulted in the implementation of maladaptive strategies. For example, artificial snowmaking is a reactive adaptation used to extend the glacier ski tourism season, reduce ablation, and essentially maintain "business as usual" operations for as long as possible. This "temporary work around" with an overt bio-physical emphasis ignores the complex socio-ecological impacts of artificial snowmaking and, rather than reducing the system's root causes of vulnerability, may actually amplify them. For example, the energy required to make snow directly contributes to a global increase in greenhouse gas emissions—A driver of glacier ski resorts vulnerability. Further, the water required to make snow must be diverted at the expense of aquatic habitat as well as the exacerbation of water scarcity conflicts. The consequences of reactive turned maladaptive trajectories for the glacier tourism sector extend beyond a lack of reduction in vulnerability to climate change to the creation, persistence, or enhancement of vulnerability arising from a lack of consideration for underlying dynamics (Barnett and O'Neill, 2010; Magnan et al., 2016; Schipper, 2020).

Transformational adaptive strategies understand vulnerability as a pre-existing condition of an individual, community, or society (Ribot, 2010). Applying this conceptualization to adaptation, can reveal how socio-economic, cultural and political characteristics interact over time and space to produce varied experiences of environmental change and inform deep adaptation that can restructure socio-political and economic regimes (Pelling, 2010). Thus, transformational approaches juxtapose reactive approaches as they adopt actions and strategies that address the root cause(s) of a system's vulnerability. However, very few transformational adaptations (such as the long-term planning approaches adopted for the previous site of the Chacaltaya glacier see Kaenzig et al. (2016) were identified in the literature. This finding reflects a tendency for reactive approaches to climate change adaptation and suggests that the sector has not sufficiently adapted to the challenges (and potential opportunities) that climate change presents. By contrast, our analysis of glacier tourism at New Zealand's Glacier Country, indicates that this destination may have already emerged from the reactive stage, and is currently in a transitional phase of adaptation, with some signs that the destination may be on a transformative trajectory. Given this adaptive trajectory, there may be aspects of the New Zealand case that are instructive for other glacier settings.

There are several features of the New Zealand example that may have contributed to adaptation shift we propose here. Many of the actors (those in governance, management and operators, and perhaps the early visiting public as well) in the West Coast Glaciers setting have excelled in the reactive adaptation stage. Key among facilitators of this response were a strong pioneer spirit among members of the community (Espiner and Becken, 2014) and socio-political conditions that permitted entrepreneurial and *ad hoc* solutions to environmental challenges. As the governance and management of parks and protected areas became more formal and visitor numbers grew, a longer term perspective has started to dominate, rendering reactive responses inadequate and unacceptable for well-established tourism destinations. Increasing public and political awareness of the current and impending climate crisis—and especially within the government sector—has compelled those responsible for governance and management of Glacier Country to pay close attention to anticipated climate scenarios, including loss of access, increased infrastructure maintenance costs and health and safety challenges. These conditions have a foundation for transformational adaptation.

The progression of Glacier Country from a reactive to a transitional adaptation phase and beyond has been facilitated by the Central Government's policy of targeted funding for tourism destinations, such as the IVL funds mentioned previously that

created the new visitor viewpoint near Fox Glacier, as well as laying the foundation for long-term strategic tourism planning across the region. A further example is the Tourism Infrastructure Fund (TIF). Established in 2017, the TIF acknowledges the critical role of tourism in supporting regional economies yet recognizes the challenges faced by communities with high numbers of visitors but small ratepayer bases (Ministry of Business Innovation Employment, 2022b). Since establishment, the fund has allocated approximately $100 million NZD across 273 projects to improve the quality of tourism infrastructure and facilities in New Zealand's regions. The West Coast (including Glacier Country) has been a primary beneficiary of this initiative, receiving nearly $6 million NZD in project funding over 5 years. These resources have allowed Glacier Country and neighboring destinations to improve the resilience of their tourism infrastructure to cope with anticipated increases in visitor numbers and environmental change.

Adaptation in the Glacier County context is also facilitated by a well-established conservation management strategy and national park planning process embedded in New Zealand statute. While these laws (and resulting policy documents) contain some rigid and bureaucratic processes, they are at least comprehensive and inclusive attempts to engage with partners, stakeholders and the wider community to achieve valued conservation and other outcomes from public lands and waters. National Park Management Plans, for instance, have a 10-year perspective—although many of New Zealand's national parks have plans that are well past their review date. While the 10-year frame provides for a degree of certainty and continuity in how each park will be managed for the next decade or so, a lot can change with the park context within that time—environmentally, socially and economically. In recognition of the potential for change, the park management planning process does allow for amendments to the plan in particular circumstances.

It is our contention that the underlying socio-political context in New Zealand has enabled the Glacier Country, under challenging circumstances, to move beyond the short-term and *ad hoc* reactions to environmental change, to offer, at least, the hope of transformational adaptation. Developing such adaptation actions is not without its challenges, as it demands strategies, often built on imperfect information with high levels of uncertainty, that can navigate present and future needs, local and global impacts (Barnett and O'Neill, 2010). However, under enabling conditions, transformation does seem possible, facilitating the development of robust adaptive responses in the glacier tourism sector that contribute to meaningful change for the visitors, operators and the environment itself. However, the concept of maladaptation reminds us that not all adaptation is ultimately beneficial. Despite the best intentions of their initiators, determined to sustain existing tourism businesses and community livelihoods, some adaptation strategies can actually contribute to, and perpetuate vulnerabilities to climate change (Barnett and O'Neill, 2010). The TAC framework underscores the importance of understanding these unintended consequences and non-linear interactions.

5. Conclusion

Disruption has become synonymous with the first quarter of this century, and as such, the requirement to adapt to any number of intersecting pressures has become critical. In nature-based tourism settings, those with the greatest adaptive capacity are likely to be the most resilient, and therefore the most sustainable over time. Given the rate of change experienced in climate-sensitive glacier settings, the most resilient destinations will be those who are proactive and able to move beyond reactive adaptation modes toward transformative adaptation strategies. It is important to acknowledge, however, that, in some contexts, destinations will not have the resources to shift past a mostly reactive phase. In wealthy western democratic contexts, such as the case study highlighted in this paper, there may be public and private resources to invest in new technologies that buffer against some aspects of environmental change. Such societies also operate relatively open and transparent governance systems that allow for community engagement in planning and policy-making—circumstances not necessarily applicable in all contexts.

The TAC framework is an attempt to conceptualize adaptation and resilience within the glacier tourism destination context, by depicting that adaptation can take a variety of forms, and can exist at every level of a destination's development. Through exploring the impact of distinct stages of adaption on key dimensions of the tourism system, the framework allows scholars to map the trajectory of change. The framework highlights that resilience grows as destinations move through the stages of adaptation, making it especially relevant for those responsible for governance, planning and business sustainability in vulnerable natural resource-dependent tourism settings. Future researchers might choose to confirm the veracity of the proposed TAC framework in a range of glacier tourism, and other tourism contexts. There is considerable scholarly and applied value in documenting evidence of adaptation in each of the three core tourism system dimensions identified here. Those responsible for tourism planning and governance; tourism businesses and operations personnel; and the people visiting glacier attractions, are critical lenses through which adaption to environmental change can be better understood.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

SS initiated the research and she was supported by ES with conceptual development of the model, alongside SE who also added the case study application. KH contributed to the literature review. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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