Article

Entrepreneurial Strategies to Address Rural–Urban Climate-Induced Vulnerabilities: Assessing Adaptation and Innovation Measures in Dhaka, Bangladesh

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Abstract: Climate change amplifies social, political, economic, infrastructural and environmental challenges in many Global South cities, and perhaps no city is more vulnerable than Bangladesh's capital of Dhaka. Climate-induced rural–urban migration is a profound concern, and Dhaka's political leaders have embraced technology-based innovation as one solution pathway. This article explores the societal impact of Dhaka's innovation environment strategies for climate change adaptation and mitigation. Employing a case study qualitative methodology, our three findings expand knowledge about innovation for urban climate adaptation and mitigation as understood by Dhaka-based entrepreneurs. First, the most effective innovations were not the most technologically advanced, but those with the highest degree of participant ownership. Second, gaps between recipient, corporate and governmental understandings of effective mitigation and adaptation harmed projects were driven by different definitions of risk and competing understandings of vulnerability. Third, even the most technical climate adaptation measures were inherently political in their application. We discuss how to better position urban climate innovation infrastructures in Bangladesh and beyond, including developing a better recognition of innovation lifecycles for urban climate adaptation and widening our definitions of "innovation" to better incorporate more effective and inclusive climate adaptation solutions.

Keywords: climate change; innovation; Bangladesh; adaptation strategies; politicization of technology; Dhaka; urban climate solutions; informal settlements

1. Introduction: Climate Change, Governance and Technology

"When you Mix Technology and Politics, you Get Politics." [1]

Climate change has profound impacts on how and where people live. It increases the magnitude and severity of extreme weather events [2], alters patterns and viability of food production and agriculture [3], and leads to the rise of the sea level and desertification, which create uninhabitable regions, forcing millions to find new homes to mitigate current or future risks [4,5]. These pressures affect the viability and security of food supply [6], the political and economic stability of nations and regions [7] and increasingly the prospects for peace and security [8]. Further, declining agricultural productivity, water and food insecurity and loss of habitation in low-lying, coastal or disaster-prone regions pushes people from rural to urban areas [9,10]. Climate-induced migration is therefore a core urban governance challenge [11] with complex legal [12] and humanitarian implications [13]. The World Bank estimates that 150 million new climate migrants will emerge from sub-Saharan Africa, Asia and Latin America by 2050 [14], spurring polarizing narratives of climate refugees [15].

The majority of those displaced by climate change will likely move from rural to urban areas [16–18]. This will occur in a context wherein sixty percent of the world's population will be urban by 2030, rising to 65% by 2050, as 2.5 billion people will be added to cities, overwhelmingly in the Global South [19]. This transformative demographic shift presents challenges for urban infrastructure, service delivery, and governance [20]. These effects will be amplified by climate change, including more frequent and intense heat waves, rainfall, flooding and sea-level rise [21]. Critically, those most affected by these cumulative stresses will be the poorest and most vulnerable, who have less capacity to adapt to threats, receive fewer services and economic opportunities, and face greater hazard risk exposure [22,23]. Ultimately, "millions of people have moved or are likely to move *towards* and not *away from* environmental risk and hazard by moving from rural areas to rapidly growing urban areas" [24].

As Global South cities face challenges that many lack the requisite capacity to manage [25], climate change and sudden-onset disaster events will act as ecological threat magnifiers to existing social, political, economic, infrastructural and environmental problems [26]. Moreover, the capacity and willingness to engage in urban climate adaptation and mitigation activities is often weak in developing countries [27]. As such, cities in low- and middle-income countries with significant governance, infrastructure and service delivery shortfalls will face some of the most acute climate challenges just as they possess the least adaptive capacity to counter these [28].

Emerging scholarship recognizes that cities are the nexus of both the most severe climate threats and some of the most aggressive climate action, and that radical social and economic shifts are required [29]. In support, a significant literature on urban climate adaptation, mitigation and resilience has emerged over the past two decades [30–35]. One key critique is that in adapting cities to climate change, technical "solutions" are often sought to "fix" what in reality are complex, interlinked social, political, economic and environmental problems [36,37]. Moreover, in framing these as technical problems, policymakers may overlook the broader political economy of urbanization and central challenges related to power, equity and justice [38]. There are louder calls for climate change adaptation to address equity concerns and prioritize the needs of the most vulnerable [39], and some cities have responded with experimental initiatives and governance innovations [40–42]. More broadly, governance experimentation and innovation to combat climate change links with the destructive—and constructive—nature of crises. Here, crises act as opportunities to create new practices, interventions, policies or technologies that can re-evaluate social norms to catalyze positive, just and inclusive social transformations [43,44].

Yet where these twin narratives of "technical climate solutions" and "innovating in the face of crisis" converge, technological innovation is seen as central to addressing urban climate change, and that a solution's scalability is at least as important as its effectiveness. For this article, we employ Diaconu's definition of innovation as "a process that starts with an idea genesis and continues with its materialization", and following, "technological innovations comprise new or significantly modified technological products and processes, where technological novelty emerges, unlike improvements, from their performance characteristics" [45].

Diverse arenas such as greenhouse gas emissions reduction, urban planning and building design, modalities of governance and others can be filtered through the lens of technological innovation, where the marriage of technology, economic growth and green/sustainability thinking is assumed to yield beneficial and wide-ranging results [46]. Dovetailing with the emergence of the smart and eco-city discourse over the past two decades, there is an increasing alignment between the market and the state to link digital technologies, innovation and sustainable urban development [47] and addressing climate change. While technology can support urban climate resilience—particularly in waste management, energy use and carbon reduction—the discussion of climate adaptation measures often fall into technical potholes in blinkered "technology as solution" thinking [48]. In response, some scholars argue that social innovations, such as changes in practices, knowledge sharing and exchange and "low-or-no-tech innovations" must also be part of the repertoire of adaptive responses to changing urban climate futures [49].

This idea of innovation as re-design or renewal aligns with perspectives on material technologies in Steven Jackson's conception of broken world thinking [50]. Rather than focusing on innovation as

a driver of progress through disruption, novelty and scalability, Jackson's focus is on repair and reuse. In Jackson's "almost always falling apart world" that we live in, understanding and interacting with how things—or systems—break can lead to generative and more productive outcomes. Analogously, instead of prioritizing the "newest and most innovative" solutions (and directing funding streams accordingly), efficiency-based innovations that engage participants in their own design may generate outcomes that are system-building rather than fire-fighting in nature.

Moreover, technology and idea flows also have significant influence on which technologies are employed in the service of development, and their application. While the concept of a globalization of innovation culture and process has existed for at least two decades [51], the cascading effect of innovation flows—and the inference of presumed legitimacy of such ideas—has accelerated. Global innovation hubs such as Silicon Valley increasingly define the frameworks that measure how innovations are "successful", "sustainable", or "pro-poor", affecting the scale, scope, and complexity of technological changes [52]. However, these changes may also accelerate the superficiality of social and cultural participation, and a loss of criticality and reflection [53].

Where technological orthodoxies are applied to urban climate solutions, they can be ineffective or even counter-productive [54], frustrating and puzzling many technology and innovation experts. However, the reason for this is often not a technical failure. Rather, the pursuit of technological solutions in urban climate and sustainability arenas tends to "expand the market for new technology products and services to support 'green growth' with disregard for their wider impacts" and actually "renders the city less resilient in the face of future social and climatic risks" [55]. This intersects with a deeper imbalance in technology design that often pits politics and the market against participation, equity and justice. These and other divisions may limit knowledge, which "shuts down potential solutions, (and) generates a variety of social justice concerns" instead of being able to "illuminate how innovative ways of imagining climate change and the relationship between society and environment can give rise to socially just, effective action" [56].

Several research gaps emerge based upon the above literature. Given the emerging focus on technological and social innovation to address urban climate challenges, we focus on three in an effort to better understand Dhaka's urban innovation environment, and in particular how this environment fulfils the needs of those most vulnerable:

1) Are the most effective innovations for climate adaptation the most technologically advanced ones, and to what extent does participant ownership matter?
2) How do gaps and tensions between entrepreneurial, beneficiary, and governmental understandings of effective mitigation and adaptation influence project selection and design?
3) How important are political considerations in the deployment of technical climate adaptation measures, and do perceptions by entrepreneurs of what is "the most valuable" effectively account for social justice needs to benefit the vulnerable?

This article assesses how political relationships and assumptions about the value of technology influence Dhaka's environment for climate change adaptation and mitigation, based upon fieldwork conducted in 2019 and 2020 [57]. Our focal point is entrepreneurs and innovation actors in Dhaka, gathering and studying their perceptions of the above questions to better understand why certain solutions are prioritized over others, and the possible societal consequences of those choices. Dhaka was selected due to the nature of business and economic development projects in the innovation/tech industry and Bangladesh's connection to climate change consequences. We explore this landscape through pilot research designed to explore the above questions, show representative successes and challenges of nurturing innovation in Dhaka, and illuminate possible new questions and paradoxes of interest for more rigorous forward studies.

Our main findings (presented in the Findings section below) do not intend to be definitive (or definitively answer the above questions), but rather aim to expand our understandings about innovation-climate relationships in Bangladesh and their relationships to society. In our discussion section, we suggest new ways to consider urban climate innovation infrastructures in Dhaka. These include undertaking a more comprehensive mapping of scaling and seeding environments to better

match funding environments with local capacities, developing a better recognition of how political factors influence innovation lifecycles, and widening our definitions of what we consider "innovation" in order to better incorporate more effective and inclusive solutions.

2. Case and Methods

2.1. Climate Challenges and the Innovation and Adaptation Environments in Dhaka

Bangladesh is often called the world's most vulnerable country to climate-induced change [58], triggering a significant influx of foreign development aid, domestic adaptation and mitigation measures, and disaster management practices. Bangladesh's "topography and geographical location make it particularly susceptible to extreme weather events including cyclones, floods and storm surges, from biophysical factors (being a flat, low, delta country), and socio-economic factors such as high dependence on agriculture, population density, and poverty" [59].

Traditionally a rural, agrarian society, Bangladesh has limited urban infrastructure. There is no urban development ministry or similar national entity designated to address urban issues such as clean water or waste management, leaving urban policy divided across 26 separate ministries. While urban climate vulnerabilities are a recognized concern, rural climate impacts have more significant short-term risks and are prioritized accordingly. Adaptation measures have improved dramatically along the coastal regions since 2000, but the highly populated Dhaka region remains comparatively ill-prepared for expanded adaptation capacity due to a lack of prioritization, as we will show below.

Lying at the confluence of two of Asia's largest rivers before they empty into the Arabian Sea (the Padma [Ganges] and Bhramaputra), Dhaka is a rapidly growing megacity with 18 million inhabitants that shares urban climate challenges similar to other developing country cities. These include pollution, severe heat, cyclonic storms, overcrowding, flooding, uneven glacial melt, climate variability, rural–urban migration, rainfall increases, and hotter temperatures in a region where large cyclonic storms can generate 8–10 m storm surges, and are getting stronger and more frequent [60,61]. Dhaka's human climate impacts are felt at a large scale. For example, some 200,000 citizens migrate to Dhaka each year from climate-induced triggers, in addition to perhaps an equal number of migrants who come for other reasons, straining Dhaka's limited municipal resources. It also necessitates a "firefighting" as opposed to preventative approach by the city as it hosts a 4.2% annual growth rate, making it one of the world's fastest growing megacities [62].

Climate change-induced migration, while often presumed to be temporary or a last resort [63], is contributing to the rapid growth of the capital Dhaka and other major cities [64,65] and accelerating the country's urbanization [66]. Yet, while rural–urban migration is often seen as a livelihood opportunity [67], migrants from low-lying delta areas arrive in already overcrowded and underserviced cities, and face vulnerable living conditions with limited economic or physical security in flood, hazard or disaster prone informal settlements, often competing with existing residents for increasingly scarce resources [68].

Due partially to the immediacy of climate change as a problem of the present in Bangladesh as opposed to one of the future, the potential environment for climate innovation is rich, with some calling Bangladesh the "climate adaptation capital of the world" [69]. Policymakers in Bangladesh recognize the enormity of the climate challenge, but also the country's comparative lack of infrastructure to support expansive (and expensive) adaptation and mitigation efforts. With climate change as a problem of today, Dhaka policymakers feel significant pressure to find and support the most scalable and wide-ranging innovations possible.

This has led to attempts to circumvent traditional means of urban technological change. For example, the Government of Bangladesh both promotes the concept of "Smart Cities" and seeks ways to leapfrog past the infrastructure typically required to build a traditional smart city, jumping to the "harness benefits" stage. However, given that the innovation atmosphere is climate-oriented, most projects prioritize rural adaptation and mitigation needs over those of urban centers such as Dhaka, which is comparatively under-funded and under-assessed [70]. Examples include the United Nations Development Program's (UNDP) Climate Change Adaptation and Community-Based Adaptation

program for coastal and island communities, and the World Bank's USD 1.2 billion Climate Resilience project prioritizing disaster shelters, food storage facilities for farmers, solar power, and coastal embankments, among other major projects [71].

Moreover, despite a growing public platform in Dhaka that celebrates the launch of viable small-scale (under USD 100,000) pilot urban climate projects, operational urban-centric innovations remain dwarfed by their rural counterparts. Funding and scaling of Dhaka's best indigenous ideas are difficult, as neither national nor international development aid infrastructures are incentivized to support successful ventures. Instead, such initiatives are forced to rely on "the market", which does not fill existing urban needs for various reasons.

Poverty and aid also impact upon adaptation strategies. Individuals or households take different physical, social, economic and political measures to reduce climate risks, using their human, financial and social assets to build individual adaptive practices [72]. In Dhaka, those defined as extremely impoverished (making less than USD 1.25/day) are typically forced into "short-term, individual and ad hoc climate mitigation efforts to save lives or protect property, (where) urban policies and institutions, both formal and informal, place significant limitations on the urban extreme poor in their efforts to extend their individual strategies for long-term resilience" [73]. International development aid figures can also over-state climate adaptation progress. Since 1985, Bangladesh has received USD 60 billion in aid, with the United States, European Union, Norway, Sweden, Denmark and Japan key donors [74]. Of this, approximately USD 10 billion were allocated for disaster and risk management including climate change, but only 10% of the 10 billion was allocated specifically for climate adaptation and mitigation, constituting less than 2% of total foreign aid over the period [75].

Moreover, these climate programs tend to focus exclusively upon rural areas, such as low-lying delta islands and vulnerable farmland. Concrete figures are difficult to ascertain, but it is likely that less than 1% of foreign development aid to Bangladesh goes towards urban climate assistance. As one example, the 2011–2019 United States Agency for International Development (USAID) Bangladesh Country Development Cooperation Strategy sees improving responsiveness to climate change as one of four key pillars of its development support, "to improve Bangladesh's ability to respond to climate change and to mitigate the effects of climate change on the country's most vulnerable populations" [76]. USAID aimed to achieve these goals by funding rural conservation and biodiversity, rural electrification, Geographic Information Systems (GIS) for forest conservation, and clean energy for agriculture. Of USAID's USD 1 billion in funding to Bangladesh for the period, no funds were earmarked for urban climate adaptation or mitigation projects. This allocation breakdown is common. Of the few international development agencies with urban climate adaptation portfolios, most employ traditional development approaches such as municipal capacity building, microcredit, skills training, technical financing, and access to health services [77].

This lack of international focus on urban climate issues created a window of opportunity for domestic ideas. In Dhaka, narratives of domestic vulnerability and passive incapacity are often rejected in favor of the promotion of indigenous resilience, creativity and innovation to solve Dhaka's growing climate change-based pressures [78]. Domestic Non-Governmental Organisations (NGOs) and institutes including BRAC, Social and Economic Enhancement Programme (SEEP), Bangladesh Climate Innovation Centre and the International Centre for Climate Change and Development (ICCCAD) are pioneers in this space, hosting regular contests designed to promote local urban climate solutions, often with the help of seed donors such as the World Bank or UNDP. Merging local innovation actors with foreign funding streams has become a popular way, both in Bangladesh and in many other developing countries, to attempt to bring local ownership into sustainable development mechanisms of all types [79,80].

Likewise, the innovation environment has changed rapidly. The biggest problem for Dhaka entrepreneurs five years ago was a lack of funding and infrastructure to support good ideas [81]. In 2011, there were only four incubators/accelerators in the country, and none focused on development. Today, dozens of accelerators dot the development space alone, including standalone ventures by various government agencies and ministries. International venture capitalists such as Sequoia Capital are active, competing alongside international development funders such as UNDP, World Bank,

European Union (EU), and NGOs. Most offer services including capacity building, piloting, funding rounds, connection with venture capitalists, and other guidance patterned on Silicon Valley models.

This landscape informed our three main fieldwork agenda points. First, what is the human impact of this rapid proliferation of interest in climate innovation in Dhaka for the most vulnerable affected communities: destitute migrants from rural areas, and those already living in impoverished parts of the city, where new migrants further pressure scarce resources? Moreover, are there particular types of innovations or technologies that seem to be more effective than others in this space, and why might that be so?

Second, it is well recognized that governments, businesses and individuals typically have very different understandings of societal risk when formulating effective climate adaptation and mitigation strategies [82–84], but how do these differences of risk influence policymaking in Dhaka? Particularly given competing understandings of which communities are the "most vulnerable", and even which communities are more worthy of attention?

Third, climate adaptation measures are generally conceived of as technical problems with technical solutions—allocating scarce resources (and generating new ones) more efficiently and providing tools for a constructive transition into a climate-resilient future. Gaps in such deliveries are often blamed on "innovation bottlenecks"—bureaucratic or technical roadblocks that stop "great ideas" from being implemented. But what is the impact of such bottlenecks in practice, and how might they influence projects designed to support the most vulnerable communities?

2.2. Methods

Our method [85] is a case study qualitative methodology. A qualitative case study opens new avenues of testable support when employed in a pilot format such as here, helping to decipher links between technology, climate change and political processes [86]. It is considered to be a balanced and agency-positive method to engage with and interview individuals in vulnerable communities, but also for research about vulnerable communities [87]. We employed Donini's "perspectives" approach [88], which stresses longer open-ended interviews to better tease out engagement with political processes and better frame citizen interactions with political entities. We designed our questions to extract knowledge and existing assumptions about technology, climate adaptation and mitigation, and the effectiveness of innovation structures in Dhaka. It is designed to help the researcher engage in deeper discussion and reduce reliance upon pre-scripted assumptions. This approach does not utilize coding, clustering/visualization techniques, or testable research questions. Its value (similar to that of grounded theory methodologies) lies in using generative questions to pursue potentially unexpected responses to better understand what local communities find most valuable, in their own words.

20 semi-structured interviews of 15 open-ended questions (plus follow-up interviews) were conducted in August–September 2019 and February 2020. Our focal point was private enterprise organizations and innovation entrepreneurs in particular, including technology startup Chief Executive Officers (CEOs) and industry professionals, tech/innovation experts, and heads of incubators/accelerators. Anonymity was granted for those who wished. Particular focus was placed on individuals who could speak for the concerns of a larger community (e.g., heads of incubators and accelerators). This community was selected to provide a window into how entrepreneurs in Dhaka perceive urban climate adaptation and innovation, and how they act upon and within it. A snowball sampling technique was employed to find relevant participants. We also triangulated findings to avoid projecting bias to one set of actors. Specifically, we pursued data triangulation in our interviews so that sets of responses to key questions converged across our interviewees and led to consolidated findings within our sample. Moreover, we further triangulated findings across different groups of actors, also interviewing government officials, funders, climate/urban experts, and development aid planners/designers who engage with Dhaka's technology innovation environment, in addition to a secondary literature analysis.

Interviews were set through a first approach over email with 15 Dhaka-based participants, then facilitated by a local research assistant familiar with the topics, totaling 24 interviews. The sample is

75% male due to similar gender dynamics of local technology/innovation actors and ownership across Dhaka. Most respondents were between 25 and 50 years of age. We achieved partial saturation, as interviews began to overlap on generalities of the Dhaka tech innovation landscape, but each interviewee had unique experiences navigating themselves/their companies through it. Interviews were conducted in English. Alternative explanations for findings were also considered and are discussed below in turn.

As a robustness mechanism, this study adhered to the consolidated criteria for reporting qualitative research (COREQ) [89]. The theoretical framework and design fit COREQ requirements for transparency and replicability. See Appendix A for 32 point criteria and study framework details.

3. Results

Intuitively, respondents had a wide variety of experiences and opinions for why Dhaka's climate innovation landscape was imbalanced and which improvements could make it more efficient and beneficial for migrants in informal settlements. Still, respondents coalesced around three main challenges: over-funding, poor pilot design, and a lack of political interest in urban development.

First, with over one dozen well-funded agencies soliciting climate innovation startups, there was a general consensus amongst interviewees of a shortage of fundable ideas, an over-capacity of funding, and an over-enthusiasm for the ideas that are pitched. Most entrepreneurs leveraged this crowded space, following funder guidelines to focus pitches on how their "urban development" products will provide strong returns. The idea shortage was so acute that some entrepreneurs sought parallel seed funding, shopping the same pitch to a series of donors and securing funding from up to ten funders for the same pilot idea [90]. These "professional pitch entrepreneurs" reduced Dhaka's overall return on investment and diversity of opportunity for urban climate innovation. As one accelerator head said, many of these serial pitchers simply "want (the award) to enrich their CV to impress an employer or foreign university, or even to get some pocket money. In most cases they have no interest in actually making their product" [91].

For example, the blood donation startup app BloodMan allowed citizens to click a button on their smartphone to have a registered professional come to take a free blood donation to help reduce the chronic blood shortage in Dhaka hospitals. It was funded with USD 10,000 in seed money and piloted despite the fact that the founders had no tech expertise for building an app, no marketing plan for how to let potential donors know about the app, and no refrigeration unit or other suitable storage mechanism for the donated blood itself [92]. No product was ever developed with the funding, but the founders continued to successfully pitch the same product in other seed events. As one incubator head lamented, even after twelve years in business, "our biggest issue is still how to get over the naivety of innovators on understanding informal urban cultures, (as they repeatedly) pitch and get funding for unrealistic ideas that they haven't even piloted" [93].

Second, promising ideas that worked in similar cities elsewhere failed in Dhaka due to a poor understanding of local communities. Our interviewees discussed numerous initiatives that failed because their products, even if more efficient than existing alternatives, were not coupled with an instructional period or a long enough pilot period to be accepted culturally [94]. Then, during the 3–6 month assessment period, they were deemed failures and shuttered. In Dhaka's large informal communities, adaptation strategies are "impact minimization" in nature (such as placing water barriers at door frames and raising furniture on bricks) as opposed to long-term preparedness measures (such as moving to higher ground or into a two-story house) [95]. Poverty in Dhaka's slums is so severe that many ideas failed simply because people find it impossible to plan for even a short-term future [96]. Shock events wiped out meagre savings and/or adaptation measures, making medium- to long-term planning impossible (e.g., planning for the next flood season) as more immediate needs took precedence, primarily food security and housing instability.

Relatedly, there are some 4000 slums in Dhaka, but several respondents expressed concern that the majority of pro-poor urban climate innovations are piloted in just one, the large Korail slum, which lies within walking distance from most international NGOs, Embassy and tech headquarters offices in Dhaka. Due largely to proximity, Korail's 100,000 residents are the preferred testing ground

for new projects, which may not only skew results because of Korail's particular demographic characteristics, but may also suppress uptake simply because residents are inundated with so many competing pilot products [97]. This prioritization comes at the expense of not only other informal settlements but also peri-urban residents who are often in just as much need but have even fewer resources available [98]. Several interviewees expressed frustration at the inability or incapacity of innovation structures to support a sort of "holistic learning" that could account for these societal particularities, particularly when pitching foreign funders, given the additional time and resources needed to properly integrate such into project design and rollout [99]. As one urban climate innovation head mentioned, "You can't just give a poor resident a new technology—even if it's better—and assume that they will accept it into their life practices. It takes longer than pilot studies allow for, and I've seen many, many promising projects cut right at the point of uptake" [100].

Third, nearly all entrepreneur interviewees expressed difficulties with navigating local political environments, and most considered themselves ill-equipped to do so. Most entrepreneurs attempted to circumvent cumbersome political roadblocks, for example by crowdsourcing funding on Facebook instead of partnering with a slow-moving government entity [101]. As a result, even entrepreneurs working specifically on social innovations for urban climate adaptation rarely visit relevant government departments for advice or guidance [102]. This can result in poor planning and design and the creation of products that do not fill needs gaps. Similar to many rapidly growing developing cities, local politicians often see foreign development funding as a profit source for facilitating pass-through services. This can take the form of new taxes, the establishment and prioritization of NGOs run by politicians or their family members as "preferred" local partners, and other rent-seeking behaviors [103].

Failing to account for local political factors (i.e., a trash pickup model that ignores the local trash mafia) is typically a recipe for failure, for reasons that have little to do with the quality of the innovation. One accelerator head gave the example of a public bus tracking app that would tell people when public busses were arriving and how full they were, a sorely needed innovation for a city without any online public transportation infrastructure or countdown timers at bus stops [104]. The pilot worked perfectly but was scrapped after one week after the bus drivers destroyed all of the tracking monitors on the busses because they also monitored the number of illegal passengers that they were pocketing fares from. Without bus driver support, the project was sunk. As one incubator head explained, "the pilot stage is where most promising ideas fail, once younger innovators realize they can't get anywhere without political connections. Older entrepreneurs know not to even start without it. (the political component) comes first, not last" [105].

Further, urban issues remain a low political priority. A consortium of NGOs and politicians drafted an Urban Sector Policy in 2011 to reduce inefficiencies and prioritize urban needs—it has been tabled for eight years [106]. Likewise, there remains no Urban Development Minister, and while the government drafted a Dhaka Master Plan for the coming 5- and 10-year periods, it has no climate change component, no funding for climate-based resilience or adaptation measures, and slum dwellers are specifically excluded as citizens of the city [107]. An insular community for innovators is also reciprocated by innovators themselves. As one example, the Dhaka-based International Centre for Climate Change and Development (ICCCAD) is one of Bangladesh's premier institutes for urban climate adaptation and mitigation research. However, ICCCAD's senior research coordinator Sarder Shafiqul Alam noted that to his knowledge not one entrepreneur had ever come to their office to seek out knowledge on informal urban communities or their expertise on what these communities needed most [108].

To offer more concrete representations of these challenges, we present below two cases of urban climate innovation in Dhaka that we considered to be representative of the Dhaka innovation environment as a whole, cases that embodied the promise of local innovation strategies to address climate issues, but also how bureaucratic, financial, and political structures can diminish the potential for workable innovations to succeed. The first case typifies one set of "success" narratives that we heard, businesses that succeeded in the climate innovation space through Dhaka's government-market compatibilities, and were promoted as such, albeit carrying an unclear benefit to climate mitigation and adaptation. The second, and more common narrative, details an example of a "failure"

that was impactful in practice, but due to those same government-market dynamics was shuttered. The examples also illustrate the consequences of a failure to calculate and disaggregate risk across the city, and in particular to new migrants and existing vulnerable residents, as what is effective mitigation for one group is rarely effective for all.

1) Turning Buzzwords into Successful Sustainability: The EcoPack Case

EcoPack is a paper cup company founded in Dhaka in 2014, producing 60 million paper cups per year for the Dhaka market. Originally, EcoPack was sustainable in name only. The founder used terms including "eco", "sustainable", "biodegradable" and "recyclable" in his branding, but nothing in the production process actually distinguished their product as more ecologically friendly than their competitors. EcoPack's founder was interested in sustainability concepts but did not really know what they meant or entailed other than that people bought more cups when they had those words on them.

After attending a meeting for sustainable startups in Dhaka in 2015, EcoPack's founder learned that he could get funding to scale his business, but only if he could show that his product did indeed offer a significant improvement in sustainability. He turned to Better Stories, a local sustainable development incubator, and the World Bank to learn how to adapt his company. Better Stories navigated him through turning his idea first into a product, then through a comprehensive training course to better understand what a product needed to be to truly be "eco-friendly". EcoPack developed innovative new material alternatives, production alternatives, and worker safety measures across their production chain. After the pilot, the company focused on urban areas exclusively, reducing waste, and making the waste that was created more biodegradable. They also changed their inks, paper, and production facilities (among others) to actually be what they promised in order to secure additional investment and partnered with officials for government contracts for their first major clients.

Over the course of 18 months, the product was designed to be substantially more eco-friendly, and was rewarded with urban innovation contracts designed for firms that could find sustainable climate-positive solutions to Dhaka's significant and rapidly growing waste management concerns. With a quarter million climate migrants moving to Dhaka each year, municipal officials joined with innovation actors and international donors to promote initiatives such as EcoPack through waste reduction and recycling campaigns as a way to reduce climate change-induced urban pressures [109]. As a marriage of business interests/profitability, foreign funder priorities, and showing local government actors that they had something to gain through the relationship, EcoPack eventually became the legitimate eco-friendly and sustainable alternative that it initially claimed to be in 2014.

Despite the public acclaim, it is unclear how EcoPack's success makes a material difference to Dhaka's climate mitigation and adaptation efforts. While their market-friendly innovations have made their sector slightly more sustainable, there is little evidence that such initiatives—even collectively—move the needle in a city that does not significantly promote recycling or have an infrastructure to support such. Namely, only 37% of Dhaka's trash is collected and only 15% recycled, mostly manually in the landfills themselves [110]. While certainly a market friendly innovation, it does not address or contribute to any of Dhaka's most pressing inequities in climate adaptation and urban sustainability. Of course, no firm can make a major contribution alone, but the municipal and market promotion of EcoPack as a firm that *is* impactful illustrates how skewed priorities on the promotion of urban climate mitigation innovations can lead to inefficiency and a misunderstanding of impact.

2) Low-Tech, High Impact, No Interest? The Saap-Sidi Game

Saap-Sidi (trans: Snake-Ladder) is a variant of the children's board game Chutes and Ladders/Snakes and Ladders, designed in 2016 by the Indian NGO Mahila Housing Sewa Trust (MHT) under a USAID grant "to improve the habitat conditions of poor women in the informal sector—to impart messages on climate change, its adverse effects, and building climate resilience" [111]. The game has the same basic layout and play as a chutes and ladders game, with the exception that ladder/snake squares each contain the brief description of a livelihood improvement activity that

one living in an informal settlement typically makes, along with its consequence at the top of the ladder (e.g., invest together in a water supply → family sick less often) or detrimental activity at a snake and bottom consequence (e.g., water enters home during monsoon → greater chance of illness from bacteria). The game is tailored to each informal settlement and designed to pinpoint the most impactful yet least undertaken activities that are feasible for players to incorporate into their lives without significant cost [112].

In 2017, MHT launched Saap-Sidi in several informal settlements across Dhaka, in partnership with ICCCAD. The results were dramatic. ICCCAD's Urban Climate department said it was their most effective project in the last five years [113]. Saap-Sidi worked because it leveraged community interests in game-playing and engagement to change behaviors through cause and consequence repetition, in a way that no project before could manage. In these same settlements, projects that were more technology oriented (e.g., Global Positioning System (GPS) tracking mechanisms for hazard mapping, renewable energy modules for micro-electricity) were considered too complicated, too time-consuming, or too unreliable to be useful, despite their technological superiority. Saap-Sidi also had the advantage of being up to 95% cheaper than tech-focused projects, with a similar or better impact.

However, ICCCAD was forced to close down the Saap-Sidi teaching module despite its success due to a lack of funding [114]. Donors favored more technologically advanced forms of knowledge generation, ones they believed to be more scalable across Dhaka's informal settlements. Modules such as Saap-Sidi, which require human training and teaching presence, were viewed as less efficient than smartphone-based or mobile-based counterparts. Private funders were also uninterested. There was no established means to profit from Saap-Sidi or way to refine the product in order to scrape user data and ostensibly make a free rollout an attractive investment. Last, there was no reliable way for government officials to benefit. In fact, Saap-Sidi could be considered threatening to municipal officials, as it exposed problems over which residents had no recourse. While technology solutions tend to promise "new, never before tried" things that leapfrog "business as usual", Saap-Sidi could lead players to question power and rights imbalances and inequalities in existing municipal structures, particularly when the services they lack (and decisions they must make for their health) are not problems across the street where municipal resource allocations are greater.

Taken together, these brief examples hint at how market-oriented forces in Dhaka's innovation environment for climate resilience can skew priorities. A skewed environment can still deliver efficiencies and improvements, as the EcoPack example shows, but it can also make it even harder to deliver the most important, most impactful projects to the most vulnerable. Notably, it is examples such as EcoPack and similar that are those commonly promoted in Dhaka, helping to define for the public (and innovators) what "success" is and which priorities matter. Projects such as Saap-Sidi are rarely given such public prioritization. Both examples show gaps in understanding what "optimal adaptation" strategies mean, why these gaps exist, and why these gaps are likely to continue to exist.

4. Discussion of Findings

Respondents working across various aspects and positions in the urban innovation for climate adaptation and mitigation space in Dhaka expressed several common insights, presented here as three discussion points. These data points are not designed to argue for definitive answers to our guiding questions, but intend to show common perceptions of Dhaka's innovation entrepreneurs on issues of urban climate adaptation and mitigation, their roles and contributions within this sphere, and the overall complexity of the endeavor. We then give possible pathways to future research, relating our findings to existing knowledge and knowledge gaps.

First, the most effective innovations for climate adaptation for vulnerable populations in Dhaka were not necessarily the most high-tech but shared a high degree of participant ownership. A fundamental question that successful projects asked in the design stage was: what do our target communities *really* need, and how do we know that we have the right answer? Startups and innovation actors that asked this question tended to also ensure that recipients had an actionable say in project design and implementation. This was a difficult step for many firms as few wished to

relinquish control over their cornerstone designs if their visions for what is most needed did not align with target communities.

We see these consequences in the Saap-Sadi example. A more impactful approach may simply be to design old ideas in new ways rather than seeking new tech solutions. However, without an approach to "profitable scaling", or "leapfrogging" existing inefficiencies, this rapid proliferation of interest in climate innovation in Dhaka through technology first and foremost may be counterproductive for the poorest. This is not to say that high-tech solutions are not valuable; indeed, many can be essential, but when choosing which communities to help and how, our interviewees generally experienced that particular types of innovations or technologies will be more effective than others. This supports previous findings that awareness of local context—and mandating local buy-in for project design—is essential [115,116]. As such, climate adaptation measures that accounted for and included the experiences, needs and knowledge of marginalized groups, while simultaneously recognizing and contending with the inherently political nature of urban climate resilience transitions, tended to be the most impactful and the most durable, again in support of previous findings [117,118].

Relatedly, seeding and capacity building can reach a point of diminishing returns. In Dhaka, our interviewees agreed that the urban innovation environment went from one of significant need to over-saturation in five years. Most startups have not scaled, and frustrated investors have cut funding pools as a consequence. The funding environment also remains imbalanced. Urban climate innovations that prioritize middle and upper classes (typically for scalability and profit reasons) receive much more support than comparable innovations that target the poorest. Funders fear that this will prompt a new cyclical downturn due to continued dissatisfaction of the quality of innovations in their narrow band of interest, again straining Dhaka's innovation environment. An alternative model for urban climate innovation could instead focus more directly on the "social" element of "social innovation" and elevate uptake and impact to first order targets.

Second, gaps between recipient, corporate and governmental understandings of effective climate mitigation and "beneficial" adaptation were driven by different definitions of risk and competing understandings of who are the "most vulnerable". Many of Dhaka's most successful urban climate innovation applications were similar to our first highlighted case. Some adapted and transformed a rudimentary understanding of climate buzzwords to develop impactful urban climate innovations by incentivizing sustainability at multiple stages of the innovation lifecycle, as EcoPack did. Others leveraged low-tech innovation ideas by listening to the needs of the poorest and responding to what they see as most useful, as Saap-Sidi did. Saap-Sidi style approaches had several common factors: they focused more on impact than on initial return on investment; they had longer pilot timeframes than are typically designed; and they aimed to supplement, not supplant, local municipal initiatives and authorities.

Climate adaptation measures in Dhaka were generally conceived as a technical problem with a technical solution: how do we allocate scarce resources (and generate new ones) to impacted communities in the most efficient manner possible, while also providing resilience tools to enable a constructive transition into a climate-impacted future. Gaps in such deliveries are blamed on "innovation bottlenecks", bureaucratic, technical, or other roadblocks that presumably stop "great ideas" from being implemented. However, given that all climate adaptation measures are also inherently political in their selection, design, and approval, a Dhaka without such bottlenecks may not necessarily be more responsive or beneficial for its most vulnerable communities.

Defining a "successful" urban climate innovation in Dhaka is grounded at least as much in astute understandings of the local political environment as the quality of the innovation itself. Entrepreneurs are encouraged to "disrupt" local barriers to innovation and development, but these barriers can be more personal than structural in practice, and can generate harassment or even threats of violence to entrepreneurs who threaten informal rent-seeking economies run by elite actors. For these and other reasons, the most successful urban climate entrepreneurs in Dhaka are typically not 20-somethings with the newest and freshest "big ideas", but an older generation in their 40s and 50s who have the cultural knowledge of the city to know where political leverage pins lie and can be exploited for progress. Entrepreneurs in Dhaka must know the intricacies of how to run a business—

any business—before they can succeed in building an innovative one, which typically does not directly challenge existing rent-seeking behaviors.

Likewise, attempting to leapfrog or otherwise circumvent municipal bureaucracies leads to short-term gains at the expense of long-term applicability. Many of Dhaka's most promising pilot innovations used the informal system by design or otherwise exploited gaps in the formal system, but this was counter-productive over time. As one accelerator head explained, "anyone who has tried to scale a great idea into a formal project without municipal authorities has led to mistrust—and even banning of some (startups)" [119]. In addition, municipal buy-in, while difficult and time-consuming to achieve, benefited startups by offering complementary human resources, access, and perhaps most importantly longer project timeframes that reduced counter-productive scaling pressures.

Third, the above two points intersect with critical perspectives on the governance of urban climate change and how this impacts upon issues of markets, technology and justice. Economic and political interests in promoting technological solutions for environmental sustainability and climate change are adjacent to theories of ecological modernization [120]. Here, the notion of "eco-innovation" and green technologies benefit both states and the market in mobilizing capital and investment in the service of sustainability. While this literature addresses the adoption and promotion of industrial technologies and economic reorientation, digital technologies are increasingly part of urban climate adaptation and sustainability discourse [121]. A focus on technology as the driving solution to sustainability concerns is echoed in Dhaka vis-à-vis the promotion of pro-poor digital technologies. Yet, as the Dhaka example shows, technological solutions are likely not universally appropriate to solve all challenges, particularly those borne primarily by the poorest or most vulnerable.

We reflected upon alternative explanations for our above analysis. As our interviews were limited at twenty, we may have a skewed understanding of effectiveness at the project level. Moreover, our selection pool relied on "winners" of the tech boom at the design level (those who succeeded with their ideas), and "losers" at the recipient level (individuals who have not escaped informal settlement living). Broadening the scope of our participants in a post-pilot stage would more comprehensively answer our main questions and help capture "missing" groups not represented within our analysis. These include but are not limited to climate migrants living in different informal communities in Dhaka than those studied, migrants who settled to places other than Dhaka, vulnerable urban populations less motivated by climate-induced triggers, tech startups and workers not ingrained within Dhaka's startup scene, and similar.

In addition, we also considered the uniqueness and broader applicability of the Dhaka and Bangladesh cases. Discussions of "efficiency", bureaucratic trajectories and the consequences of business decisions can ostensibly have deep political ramifications for the most vulnerable members of a given community, particularly when target recipient audiences are considered illegitimate by political actors. Bangladesh has taken an authoritarian turn in many aspects since 2015, these changes expand calculations of what is "political", what is "efficient", and what is "valuable" for society, among others. Last but not least, we recognize that the tech/innovation scene globally tends to support startups that are profitable but only have superficial positive contributions to communities over counterparts that are less profitable but more impactful, and therefore this is not a Dhaka (or Global South) problem. Future research and more comprehensive field assessments could help pinpoint Dhaka's uniqueness or broader generalizability.

We close by reiterating that the formulation and implementation of priorities and actions for climate adaptation are inherently political [122], and an over-reliance on technological solutions may ultimately undermine equity and sustainability [123,124]. Conversely, approaches that re-design simple or existing ideas in new ways may face fewer barriers to development, enjoy greater familiarity with use and uptake among users, and promote shorter time horizons for development and rollout. COVID-19 also carries profound impacts. One accelerator head said that while those innovations that are strictly online in nature have succeeded, most all projects requiring personal interactions have been postponed or outright scrapped [125]. This may have lasting negative impact for informal communities, where internet access is sparse, if innovators will continue to gravitate towards internet-based ideas.

Moreover, the most effective and inclusive solutions will likely not lie in technological advancement alone. Technological innovation prioritizes and legitimizes certain types of knowledge—and policy responses—over others. A more rewarding and effective forward path may be in understanding how to employ simple technologies, repurpose existing ideas and practices, and more efficiently engage vulnerable urban populations in their own development trajectories in the service of more robust societal adaptation to a changing climate. This approach may be more likely to reduce (rather than amplify) social injustice, and build (rather than compartmentalize) tripartite relationships between government, society and environment. These interactions constitute the core friction in creating more socially just and effective urban climate adaptation solutions for those most vulnerable.

Author Contributions: Conceptualization, J.M. and K.H.; methodology, J.M. and K.H.; data collection, J.M.; validation, J.M. and K.H.; formal analysis, J.M. and K.H.; investigation, J.M. and K.H.; resources J.M. and K.H.; data curation, J.M. and K.H.; writing, J.M. and K.H.; visualization, J.M. and K.H. All authors have read and agreed to the published version of the manuscript.

Funding: This work is supported by funding from the Norwegian Research Council as part of the project Learning Flexibility: Complexity, Innovation & Inter-Urban Knowledge Transfer, project number 259906/E50.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Consolidated criteria for reporting qualitative research (COREQ) checklist and methods design

No	Item	Guide Questions/Description
	Domain 1: Research team and reflexivity	
	Personal Characteristics	
1.	Interviewer/facilitator	Authors and one Research Assistants (RA) based in Dhaka, Bangladesh, who worked as a facilitator, providing assistance and access as a trusted local member of the community
2.	Credentials	Author 1: PhD, Development Studies. Author 2: PhD, political science
3.	Occupation	Author 1: Senior Researcher and Post-Doctoral Fellow Author 2: Senior Researcher
4.	Gender	Author 1: Male. Author 2: Male. RA: Male.
5.	Experience and training	Authors have 10 years of extensive field experience each in developing country/crisis regions, specifically in conducting qualitative interviews with those in vulnerable communities. RA has 15 years of experience with climate issues and communities in Bangladesh
	Relationship with participants	
6.	Relationship established	No relationship with communities prior to study commencement.
7.	Participant knowledge of the interviewer	Each interviewee was given a brief introduction of the affiliation of the interviewers, description of the project and its aims, assurances that interview data and responses would be kept anonymous, and opportunity to withdraw at any time. Consent was verbal.
8.	Interviewer characteristics	See #7 and Methodology footnote in the article.
	Domain 2: study design	
	Theoretical framework	

No	Item	Guide Questions/Description
9.	Methodological orientation and Theory	Qualitative methodology was employed, specifically a perspectives method pinned to grounded theory/ethnography & uses content/contextual analysis.
	Participant selection	
10.	Sampling	Dhaka was selected due to the nature of business and economic development projects in the innovation/tech industry and Bangladesh's connection to climate change. Participants were business owners or leaders, tech industry gatekeepers, government officials, startup CEOs and similar, selected by snowball technique, facilitated by local guides.
11.	Method of approach	Face-to-face interviews, supplemented by three phone interviews and limited participant observation. Study conforms to the Norwegian National Committees for Research Ethics in the Social Sciences and Humanities (NESH) study design.
12.	Sample size	20 interviewees in three field visits in August 2019, September 2019 and February 2020.
13.	Non-participation	No refusals due to security reasons or disinterest in discussion, but some individuals (typically management and government personnel) did not reply to requests for interviews.
	Setting	
14.	Setting of data collection	Dhaka, Bangladesh. Typically offices of the interviewees, occasionally at a neutral location (e.g., coffee shop or hotel lobby).
15.	Presence of non-participants	Additional persons were occasionally present, and author/RAs often attempted to interview without their presence to encourage more candid replies. Findings reflected minimal difference between interviews in which said non-participants were present and those in which they were not present.
16.	Description of sample	20 interviews plus selected follow-ups over phone/email, see #12. Sample is 75% male owing to similar gender dynamics of local technology/innovation actors and ownership across Bangladesh. Most respondents were between 25 and 50 years of age.
	Data collection	
17.	Interview guide	Questionnaire provided upon request. Otherwise no guides or prompting given, as no definitive answers were targeted per the selected methodology.
18.	Repeat interviews	Several repeat interviews were conducted of key informants as relevant and to better triangulate findings.
19.	Audio/visual recording	N/A
20.	Field notes	Field notes were made during each interview and written up fully at the end of each day.
21.	Duration	Each interview was typically one to two hours in length.
22.	Data saturation	Partial saturation. Many interviews began to overlap on generalities of the Dhaka tech innovation landscape, but each interviewee had unique experiences navigating themselves/their companies through it.

No	Item	Guide Questions/Description
23.	Transcripts returned	Transcripts were not returned to participants for correction, but during interviews, responses of particular import were often asked twice to confirm responses.
	Domain 3: analysis and findings	
	Data analysis	
24.	Number of data coders	Author 1 processed the data.
25.	Description: coding tree	N/A per method.
26.	Derivation of themes	Themes were collated in advance from existing innovation-climate literature as relevant for Bangladesh, then derived from data for presentation and discussion.
27.	Software	N/A
28.	Participant checking	Several participants gave findings feedback, through both second interviews as well as in discussions with RA, who maintains connections with several participants.
	Reporting	
29.	Quotations presented	In-text representative quotations were employed, selected based upon representativeness of the sample as a whole.
30.	Data and findings consistent	Findings were driven by the data due to the methodology used. Thus, there was a strong correlation between the data and findings, and potential alternative explanations for such were studied and presented in the discussion section. As this is intended to be a pilot study, findings are by nature open-ended.
31.	Clarity of major themes	Major themes developed through interviews, and are discussed more extensively in the analysis section of the paper.
32.	Clarity of minor themes	Minor themes also arose, and are discussed in the analysis section of the paper, but these need more study.

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