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Impact of Climate Change on Transportation Infrastructure: Comparing Perception Differences between the US Public and the Department of Transportation (DOT) Professionals

Olugbemi Mosunmola Aroke [1], Behzad Esmaeili [2,*] and Sojung Claire Kim [3]

[1] Sid and Reva Dewberry Department of Civil, Environmental and Infrastructure Engineering, George Mason University, Nguyen Engineering Bldg., Suite 2622, Fairfax, VA 22030, USA; oaroke@gmu.edu
[2] Sid and Reva Dewberry Department of Civil, Environmental and Infrastructure Engineering, George Mason University, Nguyen Engineering Bldg., Suite 1405, Fairfax, VA 22030, USA
[3] Department of Communication, George Mason University, Horizon Hall 5165, Fairfax, VA 22030, USA; skim205@gmu.edu
* Correspondence: besmaeil@gmu.edu

Abstract: With over 1.1 billion trips made daily for work, education, or leisure, transportation systems are vital to the functioning of cities in the United States. However, these systems are highly vulnerable to the impacts of climate change. The current study investigated perception differences about climate change between transportation professionals (N = 22) and the general public (N = 2034). The study revealed that (i) transportation professionals find climate change important, worrisome and harmful to themselves and future generations; (ii) knowledge of climate change and its consequences on transportation systems is limited on average among the general public; (iii) the public holds higher levels of misperceptions about climate change; (iv) the general public is more willing to embrace the suggestions of family and friends than climate scientists regarding the issue; (v) the general public holds a higher perception of behavioral control and confidence in their ability to carry out mitigative actions; and (vi) the public has lower information-seeking intentions about climate change. Based on the study findings, areas where perceptions differ may be considered during policy formulation and implementation processes to encourage pro-environmental behavioral changes that will reduce anthropogenic carbon emissions and enhance the functionality of transportation infrastructure.

Keywords: climate change; transportation infrastructure; DOT professionals; U.S. general public; perception differences; anthropogenic carbon emissions; mitigation and adaptation; conservative actions; policy suggestions

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1. Introduction

Transportation infrastructure in the United States is vital to sustaining the nation's economy, societies, safety, and community well-being. However, transportation infrastructure has limited agility and is increasingly vulnerable to extreme weather events that threaten the long-term functionality of these systems by degrading infrastructural integrity and performance [1]. Such effects manifest in the form of frequent maintenance [2], increased repair costs [3], heavier traffic [4], expanded need for emergency response facilities [1], and secondary economic costs to businesses and communities who rely on transportation networks to restore system performance during breakdown [5]. The increasing prevalence of adverse effects demands deeper consideration and preparation for future extreme weather events, especially as political and social attention moves to infrastructural degradation.

Transportation professionals and the general public are two important stakeholder groups whose actions will impact the consequences of climate change for transportation infrastructure. The former are responsible for the formulation and implementation of

climate change mitigation and adaptation policies, while the latter play a vital role by acting on these policies via behavioral changes and lifestyle modifications. Because climate scientists attribute increases in carbon emissions to human activity [6], environment professionals consider public behavioral change when developing climate change–related policies to adapt transport infrastructure to the effects of extreme weather events. Such policies may require individuals to modify energy-consuming habits, travel modes, leisure activities, and general lifestyle choices [1,7]. While such policy inroads may face some consensus, public support of these mitigation and adaptation policies will depend on certain individual factors such as attitudes, existing (mis)beliefs about climate change, factual knowledge about the issue, perceptions of harm to present and future generations, and awareness of climate change consequences on transportation infrastructure, which all necessitate consideration for the successful implementation of these policies.

The present study, therefore, empirically investigated the existing knowledge and beliefs about the impact of climate change on transportation infrastructure in the United States and assessed barriers to mitigative actions, as well as the adoption of environmentally-friendly habits. Inquiry about public awareness of climate change and attitudes toward the adoption of green choices presents a unique opportunity to examine the extent to which the general public is willing to take steps to modify behaviors for reducing anthropogenic carbon emissions and how this enthusiasm falls behind, matches, or surpasses DOT professionals. The study not only ascertains public awareness levels of the impact of extreme weather events on transportation systems but also clarifies whether pro-environmental behavioral intentions are promising enough to assess the reduction of the negative impact of climate change on transportation infrastructure on a national scale.

2. Background

Transport infrastructure networks are vital to the functioning of cities. They form the backbone of commerce, social interaction, and access to services [8]. Despite the fact transportation systems are essential for economic activities, they are highly vulnerable to the impacts of climate change. For example, rising sea levels increase the severity of damage to infrastructure; floods impact the performance of transportation networks by increasing travel times and disrupting personal and business journeys; heat waves impair the integrity of road pavements; and wildfires and winter storms interrupt road, rail, and air transportation [8–12]. In addition, most pavement designs are based on historical climate variables that did not account for disturbances from changing climate over the course of their lifetime [13]. Therefore, DOT professionals may benefit from incorporating climate projections into the design, construction, and maintenance of infrastructure to improve the functionality and reliability of transport systems against the impact of extreme weather events.

2.1. Public Involvement in Policy Decisions

The success of climate change initiatives and the enactment of mitigation and adaptation policies require support and participation by transportation stakeholders including the general public [9,14,15]. The involvement of stakeholders such as scientists, economists and government institutions translates technical solutions into practical and feasible policy recommendations through dialogue and negotiations [16]. It also facilitates the production of ideas and shared knowledge, while fostering collegiality among stakeholders [17]. Notably, the reality that extreme events aggravated by human activities may severely impact transportation infrastructure has sparked urgency in understanding what it will take to mobilize people and resources to mitigate such events, and has led to considerable intellectual and financial efforts to understand the drivers of action or inaction in mitigating and adapting to potential climate impacts [18]. To this end, work has been done to involve the global community through public awareness in order to incorporate lay knowledge and alternative perspectives in the development of potential solutions to complex global problems like climate change [19,20]. Public involvement in policy formulation is also ad-

vocated for by the U.S. Department of Transportation (DOT) as a fundamental component of the transportation planning process. Failure to take public views into consideration when making decisions on climate risk management may result in misunderstanding, neglect, or opposition, thereby discouraging the required acceptance of climate policies from those who will be affected by them [21]. Thus, considering that readiness to adapt will require collaboration to solve collective problems despite differing interests, perspectives, and areas of responsibility [17], the general public should be considered when making transportation decisions to encourage their buy-in of related policies.

2.2. Knoweldge about Climate Change

One of the barriers to engagement and public action is limited knowledge about the causes and consequences of climate change [22–25]. The performance of environmentally friendly actions and willingness to commit to long-term sustainability efforts also depend in part on an individual's level of climate literacy [26–29]. However, despite consensus among scientists that climate change is occurring, there is a degree of uncertainty about the issue, and the level of public awareness on the topic has been low and varied, on average. The fact that nearly half of the public remains skeptical about climate change or the need to take action is coupled with the growing partisan divide over the last decade within the United States regarding support for climate policies [6,30,31]. However, disseminating accurate knowledge in a comprehensible manner can influence attitudes and motivate individuals to take responsible actions in support of climate-protection policy measures [26,27,32,33].

Although there are manifold benefits in having a nation informed about the impact of climate change on the resilience of transportation infrastructure, certain barriers to creating awareness exist. These challenges include low public support, inadequate resources, competing personal and economic priorities, political division, and a dearth of public discussion about climate change [31,34–36]. While these barriers potentially create fewer opportunities for the support of climate change policies, ways to increase public awareness may be intensified through education programs to enhance basic understandings and to encourage informed scientific discussions and multi-scale engagements [37–39]. Similarly, some maintain that social media use may also be optimized, with a focus on affective imagery to communicate the risks of climate change, wherein informative stories may be made personally relevant to individuals who hold biased views and attitudes towards environmental protection [30,37,40]. Within such informational efforts, messages spreading fear about the devastating effect of climate change are less impactful than those focused on educating people regarding their role in mitigation and possible adaptation measures [20,39]. In sum, research into these informative channels suggest efforts to reduce public ignorance may facilitate a clearer understanding of the importance of the issue and raise awareness levels that will encourage mitigative actions through environmentally beneficial modifications in lifestyle.

2.3. Perceptions about Climate Change

An individual's perception is related to his/her beliefs, attitudes, judgments and feelings, as well as their political, cultural, or societal dispositions [33,41,42]. Risk perception is also shaped by factors such as personal values, level of trust in government and institutions, and cultural biases formed through social relations [6,43–46]. Like many environmental problems, climate change becomes discernible through increased scientific knowledge and awareness of its adverse consequences as obtained via observation, personal experience, or informational sources like the media. On the other hand, misperception of climate change risks may result from ignorance, the complexity of the issue as a global topic, ambiguous communication about its danger and diverse interpretations of climate-related information [33,47,48]. These misperceptions may constitute a barrier to engagement and inhibit the adoption of climate-friendly lifestyles.

Due to the importance of this concept in influencing people's willingness to adopt climate-friendly lifestyles over time, the current study investigates the difference in risk

perceptions of DOT professionals and the general public in order to assess existing awareness levels of climate change and its consequences, including ascertaining the level of support these respective groups manifest for carbon-reduction policies that necessitate behavioral changes for improved transportation infrastructure reliability.

2.4. Point of Departure

There is a 97% consensus among leading climate scientists that human activities are contributing to global warming [49]. The rapid rate of climate change has a significant impact on transportation due to extreme temperature rise, intense precipitation events, and more frequent hurricanes, drought, and rising sea levels. The effect of climate change on transportation systems is exasperated by the fact that almost 53% of the U.S. population lives in coastal regions vulnerable to flooding of roads, railways, transit systems and runways. In addition, the annual cost of maintaining the U.S. road network is approximately $134 billion [50], a cost that will increase by 10–20% through 2030 due to climate change [51].

Despite its significance, there is resistance, false beliefs and lack of engagement on this issue among key stakeholders such as the U.S. public and the transportation professionals involved in the design and construction of transportation infrastructure. A climate change study by Cook et al. [52] contend that when the U.S. public was asked to identify the proportion of scientists that agree on human-caused global warming, the average response was about 50%. This large consensus gap has real world consequences as it appears that stakeholders do not fully understand the urgency and magnitude of the impact of climate change. If key stakeholders correctly understand the consequences of climate change on transportation, they will be more likely to adopt recommended actions and support climate policy and mitigation efforts. In addition, since the adoption of pro-environmental behavior will have a lasting impact on the way that transportation systems adapt to climate change in the coming years, this project aims to systematically investigate the extent to which the general public and transportation professionals understand, interpret, and respond to climate change and its associated risks. The study will also assess factors that shape the beliefs of both stakeholder groups and whether the differences in perception fundamentally compel or constrain pro-environmental behavior adaptations toward mitigating the potential consequences of climate change on transportation infrastructure in the United States. Although not directly influencing climate change policy changes, the results of this research could lay a foundation for a more robust risk assessment during infrastructure planning and management. Understanding how the risk perception of the U.S. public and DOT professionals are shaped and the potential gaps between the two may compel decision makers (i.e., policy makers) to ponder upon developing more sustainable infrastructural design and maintenance strategies that take public (mis)perceptions into account and modify long-term plans accordingly. It will also assist the communication of risk information to experts, policy makers and the general public when making transportation decisions.

3. Research Methodology

The present study investigated the current knowledge, belief, and perception differences between transportation professionals and the general public regarding climate change and its impact on transportation infrastructure. To achieve this objective, an online survey instrument was employed using Qualtrics software [53], which was validated via a pilot test with the Virginia Department of Transportation (VDOT) employees and students of a large East Coast University before being disseminated broadly among the target populations. Constructs that assess attitudes, subjective norms, perceived behavioral control and intentions to take mitigative steps to reduce the impact of climate change on transportation infrastructure were evaluated.

3.1. Data Collection Process

The DOT professionals and the general public represented the target populations in the current study. To distinguish between the two groups and their respective importance in achieving the research objectives, the respondents in the first group were considered experts in the area of design, construction, maintenance and policy formulation for the sustainability of transportation infrastructure. The second group comprised the US public who may have limited understanding of the consequences of climate change on transportation infrastructure, but are nonetheless impacted by the policies developed by transportation professionals, and their activities significantly affect the functioning of these systems. The research team contacted the Sampling Survey International (SSI) firm for data collection from a nationally representative sample of the U.S. public (N = 2034). Members of the public were contacted via phone calls that lasted for about fifteen (15) minutes per individual on average. Since it was not unexpected that the public would possess relatively limited knowledge about the issue, potential respondents were provided with some background about the topic of climate change and its potential impacts on the environment and transportation infrastructure. The relevance of some of the questions to achieving the study objectives were also briefly discussed in a random fashion. However, some conversations were quicker than others and no transportation professional was contacted on the phone considering their expert knowledge on the topic. Thereafter, the questionnaire was distributed via email through a link to the survey.

Similarly, a short list of transportation professionals was generated by the research team through an online search of the publicly accessible website of all U.S. DOTs. In an attempt to reach a maximum number of respondents and at least one representative from all 50 DOTs, phone calls were made to the professionals to familiarize them with the research, after which the questionnaire was distributed to consenting participants via an email that contained a brief description of the study and a survey link. The professionals represented various levels of management, including senior research scientists, engineers, strategic planners, environmental scientists, research associates, division managers, and executive administrative assistants, with an average work experience of 16 years. Data collection was conducted for one month and responses were tracked in the Qualtrics software, with reminders sent to participants after 7 days of no response. To capture more contextual and detailed information about the DOT professionals, a follow-up questionnaire was developed and distributed to respondents who agreed to be contacted for participation in a follow-up survey after two weeks.

3.2. Survey Instrument

The survey instrument contained a series of questions on a five-point Likert scale ranging from 1 (low) to 5 (high). Thirty-five constructs about climate change (adapted for use as employed in Akerlof et al. [54] and Leiserowitz et al. [55]) were examined as displayed in Table 1.

Cronbach's alpha was used to evaluate the internal consistency of these constructs and showed statistically adequate levels of reliability with values around the acceptable level of 0.70 or higher [56].

3.3. Data Preparation

Sections contained multiple items for a thorough assessment of a measured construct. Where item questions elicited opposite responses to the subject of interest, these items where reverse-scored to obtain a consistent measurement across the items on average. Thereafter, the mean values of all items that comprised responses to the measured construct were calculated to obtain a combined index that was utilized for permutation analysis. Analysis was carried out to investigate the significant differences in the mean responses of both transportation professionals and the general public.

3.4. Data Analysis Using Permutation Simulations

The goal of the research was to compare the difference in mean responses of DOT professionals and the general public to ascertain if the difference in responses were statistically different from zero through permutation analysis [57]. The statistical testing of the difference in mean responses between both groups was structured in terms of null and alternate hypotheses as follows:

- H_0: There is no difference between the mean responses of transportation professionals and the general public
- H_A: There is a difference between the mean responses of transportation professionals and the general public

Table 1. List of constructs utilized in study.

S/N	Measured constructs
1	Importance of climate change
2	Worry about climate change
3	Perception of personal harm
4	Perception of harm to future generations
5	Concern about climate change
6	Awareness of climate change
7	Attention to sources of information on climate change
8	Knowledge about climate change
9	Awareness of the causes of climate change
10	Awareness of the consequences of climate change
11	Perception about climate change
12	Misbelief about climate change
13	Perceived importance of conservative actions
14	Frequency of car use in previous year
15	Frequency of air travel in previous year
16	Willing conservative actions
17	Alternative modes of transportation
18	Concern about climate change impact on transportation
19	Knowledge of climate change impact on transportation
20	Perceived severity of climate change on transportation systems
21	Perceived negative impact of climate change
22	Perceived barriers to action
23	Institutional efforts to address climate change
24	Social normative beliefs
25	Control beliefs
26	Behavioral beliefs
27	Perceived social norms
28	Perceived behavioral control
29	Attitudes
30	Behavioral intentions
31	Intention to engage in climate change discussions
32	Trust in information sources
33	Information-seeking intentions
34	Research support for climate change
35	Climate change policy support

Due to the mixed-normality between the U.S. public and the DOT group distributions (N = 2034; N = 22), the assumption of normality between both groups was not met, thereby hindering the use of parametric tests for statistical analysis. Parametric tests assume that data are distributed normally, samples from different groups are independent, and variances between groups are equal [58]. However, when these assumptions are not met due to obvious departures from normality, it is prudent to use nonparametric tests [59]. Nonparametric tests are powerful alternatives to parametric statistics because they make no assumptions about population parameters and are more robust than their parametric counterparts in the presence of outliers, missing data and small sample sizes [60]. As a

result, a nonparametric randomization technique was utilized to surmount the challenges associated with the mixed normality of the data in the current study. Randomization techniques include bootstrapping, jackknife and permutation methods. However, permutation analysis is one of the most preferred randomization techniques due to its more robust nature compared with its parametric counterparts when faced with typical challenges associated with outliers or extreme distributions [60,61]. Unlike parametric tests, permutation tests are considered to be distribution-free and therefore, not bound by the assumption of being drawn from a normal population [62,63]. In other words, permutation tests help to rehabilitate the power of parametric tests under conditions of non-normality [57,64].

Since the basic idea behind a permutation simulation is to generate a reference distribution by recalculating a test statistic for several permutations of the data [65], data were randomly re-assigned without replacement multiple times to generate a distribution of possible outcomes. Next, a test statistic was calculated from the raw data by computing the absolute difference between the mean responses of the DOT professionals and the general public from both raw and permuted samples respectively. This difference is regarded as one of many but equally possible outcomes that could have arisen by chance, and therefore yields a probability for the test from which statistical inferences can be made [66,67]. Thereafter, the significance of the permutation test—which is the probability of obtaining a result equal to, or more extreme than the test statistic of the actual sample, given that the null hypothesis is true—was calculated and represented by its *p*-value.

The permutation *p*-value is given as:

$$\text{Permuational } p-\text{value} = \frac{\text{Number of times test statistic from permuted data} \geq \text{original test statistic}}{\text{Total number of permutations}} \quad (1)$$

Because the precision with which the *p*-values is derived for approximate randomization tests depends largely on the number of iterations or re-shuffling created through the permutation process [68], 100,000 resamples were used in the current study to test for statistically significant differences in the responses between the transportation professionals and the general public. The research team utilized the Deducer package in Java Graphical User Interface (GUI) for R 1.7–9 of the open-source statistical package R version 1.4.1106 to perform the permutation simulations at a 5% level of statistical significance ($p < 0.05$). The analysis results are discussed in subsequent sections.

4. Results

In total, 2434 responses were received from the general public and 42 from the transportation professionals. Excluding partial responses from the database, 2034 and 22 responses were analyzed from both groups respectively, representing a response rate of 84% and 52%, respectively. Professionals included engineers, senior research scientists, designers, strategic planners, division managers and executive administrative assistants. The results of the permutation simulation analysis indicated that the views of the transportation professionals differed from the views of the general public in 19 out of 35 measured constructs. Hence, the null hypothesis of no difference between the mean responses of transportation professionals and the general public was rejected.

With values ranging from 1 through 5 indicating the apportionment of weight from a minimum of (1) to a maximum of (5) for the measured construct, a closer look at the output shows that the DOT professionals, more than the general public, viewed the issue of climate change as important to them (M_{DOT} = 4.23, M_{public} = 3.62) and worrisome (M_{DOT} = 4.09, M_{public} = 3.40); and held a stronger perception of personal harm (M_{DOT} = 4.09, M_{public} = 3.40) as well as harm to future generations (M_{DOT} = 4.36, M_{public} = 3.84). Likewise, the DOT professionals were more concerned about climate change (M_{DOT} = 4.09, M_{public} = 3.56), more aware of the issue (M_{DOT} = 3.64, M_{public} = 3.09), possessed greater factual knowledge (M_{DOT} = 1.00, M_{public} = 0.54), held a stronger perception about climate change events (M_{DOT} = 3.88, M_{public} = 3.73) and greater valid beliefs about the topic (M_{DOT} = 4.16, M_{public} = 3.57). Similarly, the DOT professionals were more

willing to take conservative actions to reduce the effect of climate change (M_{DOT} = 4.49, M_{public} = 4.08), and recorded a greater concern (M_{DOT} = 4.27, M_{public} = 3.60), knowledge (M_{DOT} = 4.27, M_{public} = 3.69) and perceived severity (M_{DOT} = 3.41, M_{public} = 3.26) of the impact of climate change on transportation infrastructure. Additionally, more DOT professionals than the general public agreed to the importance of social influence on personal actions (M_{DOT} = 2.91, M_{public} = 3.21), displayed a greater information-seeking intention about the issue (M_{DOT} = 4.16, M_{public} = 3.46) and recorded a stronger support for research on climate change (M_{DOT} = 4.23, M_{public} = 3.74).

However, despite displaying greater knowledge about the issue of climate change, the DOT professionals recorded a higher frequency of car use (M_{DOT} = 4.82, M_{public} = 4.07) and air travel (M_{DOT} = 1.77, M_{public} = 1.66) compared to the general public. They also expressed a weaker perception of behavioral control (M_{DOT} = 3.12, M_{public} = 3.62) of climate change. Table 2 shows the *p*-values of the statistically significant constructs, as well as the mean, standard deviations (SD) and Cronbach's alpha (reliability scores) of responses from both stakeholder groups.

Table 2. Comparison of responses between transportation professionals and the general public.

			DOT Professionals			U.S. Public		
S/N	**Measured Constructs**	***p*-Values**	**C's Alpha**	**Mean**	**SD**	**C's Alpha**	**Mean**	**SD**
1	Importance of CC	0.00	-	4.23	0.95	-	3.62	1.21
2	Worry about CC	0.00	-	4.09	1.08	-	3.40	1.28
3	Perception of personal harm	0.03	-	4.09	1.08	-	3.40	1.28
4	Perception of harm to future generations	0.00	-	4.36	0.93	-	3.84	1.26
5	Concern about CC	0.00	-	4.09	1.12	-	3.56	1.26
6	Awareness of CC	0.01	-	3.64	0.83	-	3.09	0.81
7	Knowledge of CC	0.00	-	1.00	0.00	-	0.54	0.50
8	Perception of CC	0.05	0.78	3.88	1.25	0.80	3.73	1.09
9	Belief about CC	0.00	0.93	4.16	1.20	0.80	3.57	1.23
10	Frequency of car use in previous year	0.00	-	4.82	0.39	-	4.07	1.17
11	Frequency of air travel in previous year	0.02	-	1.77	0.52	-	1.66	0.87
12	Willing conservative actions	0.02	0.68	4.49	0.77	0.75	4.08	1.22
13	Concern about CC impact on transportation	0.00	-	4.27	0.86	-	3.60	1.15
14	Knowledge about CC impact on transportation	0.00	-	4.27	0.91	-	3.69	1.09
15	Perceived severity of CC on transport systems	0.02	-	3.41	1.27	-	3.26	1.26
16	Perceived social norms	0.02	0.66	2.91	1.03	0.72	3.21	1.14
17	Perceived behavioral control	0.00	0.74	3.12	1.38	0.83	3.62	1.12
18	Information seeking intentions	0.00	0.91	4.16	0.91	0.81	3.46	1.20
19	Research support for CC	0.01	0.80	4.23	0.95	0.90	3.74	1.14

5. Discussion

5.1. Importance of Climate Change

The findings revealed that the DOT professionals found the topic of climate change more important and worrisome compared to the general public. The DOT professionals were more concerned about the issue and its impact on transportation systems. They also held a greater harm perception to themselves and future generations. While the awareness about global climate change is considerably high, the issue continues to be of low priority for the American public compared to other pressing national and environmental issues perceived to have direct local relevance and a greater sense of urgency, such as the economy,

education, and healthcare [68–71]. Interestingly, our results showed that psychological distancing of the impact of climate change among the public appeared to reduce concerns about the issue. For instance, the perception that climate change would harm future generations was significantly stronger than those of personal harm for both the US public and the DOT professionals. We speculate that it is partly because individuals tend to perceive greater risk for geographically and temporally distant people and places, such that climate change risks are perceived as nonpersonal and concerning the future [48,70,72,73]. As a result, the abstractness of climate change and perceived intangibility of its associated consequences impacts both the level of attention paid to its urgency and willingness to engage in pro-environmental behaviors to tackle the issue [68,74,75]. The implication of a reduced risk perception or trivializing the consequence of climate change, if unchecked, is a potential barrier to public engagement which may cripple the motivation to take personal actions to mitigate the problem. Therefore, the study encourages decision makers to be attentive—and responsive—to public misperception and its possible influence on successful mitigation efforts.

5.2. Knowledge of Climate Change

Our analyses revealed that more DOT professionals than the public recorded significant knowledge of the issue, agreeing that climate change is caused by CO2 produced from human activities. Although a sizeable proportion of the public understood that carbon dioxide is increasing the most in the atmosphere, when knowledge of climate change and awareness of its cause and consequences were assessed, relatively fewer individuals were aware of the scientific facts about the issue—including the substance increasing the most in the atmosphere due to climate change—and showed more difficulty in discerning CO2 produced by human activity, naturally-occurring CO2 and acid rain as a cause of climate change.

While some studies suggest that cultural values and political beliefs play a notable role in skepticism about climate change [48,76], others have identified ignorance or misunderstanding on the part of the public [69]. For instance, an early study [70] observed that the public commonly confuses climate change with other environmental issues—such as stratospheric ozone depletion, air pollution and weather—due to a lack of focused education on climate change. Ignorance about the issue and reluctance to take mitigative actions has been attributed to a range of factors, including climate fatigue, skepticism, misleading media representations, and inability to comprehend the topic [21,77]. Particularly, some people reject human-caused climate change because they lack knowledge of the scientific consensus due to the complexity of the matter [78,79]. Moreover, people are usually influenced by concepts that are easy to visualize, but to many, issues like climate change seem abstract or amorphous. This may explain why individuals may focus on short-term and simple facets of the topic like heat waves and temperature increases, rather than detailed long-term concepts of climate change [80]. Therefore, increasing scientific literacy through the dissemination of accurate scientific information is important for the public to understand the threat posed by climate change in order to bring the US public on board to support policy and adaptation strategies necessary to reduce the effect of climate change on natural and transport systems.

5.3. Awareness of Climate Change Consequences

Although there is scientific consensus that anthropogenic greenhouse gases (GHG) have significantly affected the world's climate with adverse consequences on human and natural systems [81], awareness of its impact on human and natural systems does not seem high among the general public [51,78,82]. In the current study, more transportation professionals than the general public stated that climate change would adversely impact public transportation systems and personal travel, increase the risk of delays and disruptions in public transportation systems, and be likely worsened by car and truck travel in the next three years. Considering the impact of extreme weather events on the U.S. infrastructure, it

may be beneficial to inform the public regarding the advantages of proactive mitigation and adaptation measures to reduce the severity of climate change-related events. However, more individuals than the DOT professionals held stronger normative beliefs on the issue and consented that the government and significant others expect them to take mitigative actions to ease the impact of climate change on transportation systems.

The sense of urgency attached to the issue of climate change and willingness to perform a pro-environmental conduct may be mediated by news and other published sources on which the public depend to expand their knowledge about environmental issues [78,83,84].

5.4. Belief about Climate Change

The results disclosed that DOT professionals possess more factual beliefs about climate change, with a larger proportion of them indicating that burning of fossil fuels has caused serious damage to the planet's climate and that most global warming is due to an increase in GHGs and human CO2 emissions. Also, a greater percentage of the general public held certain misperceptions about the issue by inaccurately assuming that climate change is just a natural fluctuation and humans are too insignificant to have a real impact on global temperature. Although there is consensus among more than 97% of climate scientists that human-caused global warming is happening, previous studies have observed that most individuals tend to discount climate science and express some degree of uncertainty that anthropogenic climate change is occurring or the need for the topic to be among top national priorities [85–88]. Several factors impact misperceptions, such as individual characteristics, culture, and socioeconomic status [89]; lack of personal experience of extreme events [72]; personal beliefs that cause most individuals to reject information that contradicts prevalent opinion or 'cherry-picking' climate data to back up personal assumptions [90,91]; political orientation [73]; limited climate-related knowledge such as the impact of GHG emissions on the environment [92,93]; and media presentation of climate change information as controversial and uncertain [94]. Inaccurate beliefs due to misinformation or incorrect mental models of climate change have negative environmental consequences that underscore the need to disseminate accurate and relatable scientific information that would influence policy support for mitigative actions and willingness to adopt pro-environmental behavior.

5.5. Information-Seeking Intentions

Somewhat unexpectedly, the general public had a lower intention to seek information about climate change than DOT professionals. The public reported that with a higher percentage than DOT professionals, they knew enough or were likely to tune out of the topic. These findings may be due to a variety of factors, including the diversity of media and interpersonal informational sources that impede understanding [94]; public view of the topic as abstract, distant, and impersonal [95]; politicization of the issue [76]; or a reduced ability to process facts due to limited prior knowledge, world view, or social and institutional factors [69]. Moreover, despite the importance of interpersonal communication about climate change, most individuals rarely discussed the topic with family and friends. Interpersonal communication about climate change is critical to increasing public understanding of the problem and building community engagement. Likewise, social and moral framings of climate-related information—such as sharing personal stories and narratives of everyday experiences of how climate change harms people and worsens infrastructure functionality—may clarify complex science with comprehendible narratives, rather than communicating facts and figures or purely scientific information [95]. More empirical research is needed to parse out the processes or mechanisms behind these behavioral intentions.

5.6. Energy Conservation Efforts

The findings revealed that the DOT professionals expressed more willingness to drive economically, recycle, turn off unused lights, save water by taking short showers, and buy environmentally-friendly products to reduce the consequences of climate change. On the other hand, a larger proportion of the general public indicated that reducing anthropogenic CO2 would greatly minimize the negative effect of climate change on transportation systems. They, however, acknowledged that carrying out mitigative actions like recycling, less driving, and reducing electricity usage requires conscious efforts, time, and knowledge.

Our results concur with past studies wherein some people showed concern and engaged in actions to mitigate and adapt to the global crisis while others seemed hesitant to accept, support, or actively engage in activities that represent good environmental practice for reasons such as absence of motivation [96]; a tendency to prioritize self-interest and undervalue the environment [75]; unease with performing the behavior [97]; lack of resources to take action [98]; and psychological barriers that include negative attitudes from personal ideologies [99]. Moreover, some individuals do not know where to start, or are unable to understand appropriate mitigation actions for reducing atmospheric GHG concentrations [100]. For instance, consistent with the findings of earlier studies, efforts are geared toward low-impact behaviors such as recycling and reducing waste when discussing ways to address climate change, while more impactful actions like driving economically or reducing energy consumption are usually downplayed [101,102]. Indeed, taking pro-environmental actions is challenging and sometimes requires monetary investments, significant effort, or reduced comfort or convenience which may cause people to prioritize options that are convenient or inexpensive [75,99]. Other psychosocial constructs such as values, beliefs, attitudes, subjective norm and perceived behavioral control play a major role in influencing environmentally friendly behavioral choices [103–106]. Behavioral responses to contested social issues like climate change are usually enforced according to social expectations that pertain to passive rules for regulating such behavior which are susceptible to potential biases from the media and internal psychological processes [75,107]. As a result, individuals may have positive intentions to engage in environmentally responsible behaviors if they identify with social norms that reinforce performance of the behavior, or may be inhibited from taking part in collective action if there is no perceived support from others regarding energy conservation and compliance with carbon-reduction policies [89,100]. Therefore, our findings encourage public educational intervention efforts, such as outreach programs that address climate literacy challenge by illustrating how unchecked energy consumption may be replaced with activities that effectively mitigate the negative effect of climate change—such as cycling. By engaging public education around interventions that encourage low-energy lifestyles and seek to reduce economic, sociocultural, political and structural barriers to energy conservation, policy makers may find greater returns in collective pro-environmental actions.

5.7. Alternative Modes of Transportation

The results demonstrated that DOT professionals utilized cars and air trips very frequently for work and leisure in the previous year compared to the general public. However, in contrast to the public, the DOT professionals expressed preparedness to walk, bike or utilize public transit for trips less than five miles, carpool, shop online as an alternative to travel and reduce air trips relative to previous years.

Consistent with the observation of previous studies (e.g., [108–110]), actions taken by individuals to consider reduced or zero-carbon transport modes still have room for improvement, and this behavior change appears to be the least supported conservationist action by both DOT professionals and the public. Most suggestions by transportation professionals to combat climate change focus on encouraging reduced energy usage for mobility by prioritizing non-motorized modes over vehicular modes, and public transportation over private car travel [111]. Public transportation and carpooling generate relatively less carbon emissions because of the advantage of transporting more passengers at a time

and are more energy and land-use efficient than car travel, bringing about a corresponding decrease in air pollutants and other externalities linked to automobility [112]. Cycling is also cost effective and abates energy consumption and environmental pollution, providing transport, health, and social benefits such as reduced economic expenditure and mental relaxation [109,113]. Although the motor car is a major contributor to GHG emissions and air pollution, it remains the widely preferred mode of transportation [109]. Likewise, air travel is one of the most favored but considerably damaging modes for passenger transport with high CO2 emissions [114].

However, the unwillingness of the general public to modify travel behavior may result from psychological, social, economic, and physical barriers such as effort, relative financial costs, and social approval. These include placing a premium value on identity, image, and social recognition toward driving a car while neglecting concerns about its environmental impacts [74,111]; feelings of powerlessness and resignation to global issues [48]; discouragement from taking action when individuals negatively perceive reduced mitigation efforts by others [110,115]; and resistance to accept personal responsibility by adopting denial mechanisms to shift the blame to governments, businesses or others [116]. Therefore, there is a need to develop environmental consciousness among the general public by encouraging the adoption of zero or reduced-carbon transportation modes whenever possible as well as using a combination of education interventions, regulations, incentives and land use modifications. For example, policies on company car benefits may be modified to consider the advantage of reducing carbon emissions from passenger travel [112] Additionally, the cost of fuel-efficient cars may be reduced [117] and a reduction in fossil-fuel usage and car-travel demand may be achieved by means of carbon and fuel tax increases [111]. Moreover, cities may be redeveloped with urban design features and made more compact, such that more efficient road spaces are developed to encourage the adoption of sustainable transport modes [118–120].

5.8. Perceived Behavioral Control (PBC)

The general public recorded higher levels of perceived behavioral control compared to the DOT professionals. They also expressed confidence in their ability to take steps to ease the impact of climate change on transportation systems in the next six months. These results may be due to DOT professionals viewing their personal choices as having a low impact on a large scale as a result of their knowledge about climate change data and the transportation modes that generate the most GHSs. As a result, DOT professionals may discount their ability to reduce the negative consequences of climate change due to holding beliefs that the frequency of carbon emissions generated by other transport modes such as road freights and air flights may diminish the potency of their individual actions, and may rather focus on environmental policies that will have a tangible impact on improving the long-term reliability of transportation infrastructure to the adverse impact of climate change.

5.9. Research Support for Climate Change

The study found that DOT professionals supported research on the effect of climate change on transportation systems and federal funding for this research more than the general public. Funding is critical to addressing the global climate crisis in the areas of technology development, knowledge enhancement and capacity building at local, national and global levels. Emerging concerns also exist regarding whether external funds match local needs to pursue the research and development of sustainable urban infrastructure [121–123], the preference for short-term quantifiable results at the expense of longer-term studies with greater economic impact [124], and the yardsticks utilized to prioritize research needs. Such prioritization could address, for example, the choice of research on the advancement of technological remedies to climate change by natural and technical scientists or an inquiry into climate change-related attitudes, norms, incentives and politics by social science researchers [121]. Therefore, there is a need for better funding

coordination and transparency to ensure that financial resources are integrated within national development plans and allocated more efficiently to address knowledge gaps in both natural and social climate research.

The degree to which transportation systems may be affected by intense weather events also necessitates the need for organized research synergies among atmospheric scientists, transportation stakeholders, nongovernmental organizations and environmental advocacy groups. Examples of current transport-relevant research include an evaluation of the performance of metropolitan planning organizations toward implementing strategies to reduce transportation-producing greenhouse gas emissions [117]; life-cycle approach to quantifying the energy and carbon footprints of urban transportation infrastructure [119]; developing a framework to integrate the risk of infrastructure failure into transportation asset–management practices [125]; constructing climate models to evaluate the risk of future global warming and the need to achieve net-zero emissions [126]; developing a metric framework to measure resilience of the U.S. passenger rail service to climate risk and track changes over time [127]; and investigating transportation infrastructure resilience to recovery from natural disasters, as well as the impact of protection strategies against sea-level rise on various modes of transportation [128].

6. Limitations

It is important to recognize some limitations in the current study. First, the notable difference in sample sizes between the U.S. public and DOT professionals may impact the generalizability of the results. It is recommended that future studies obtain a proportionate amount of data from both groups to surmount the challenges associated with mixed normality of data during statistical analysis. The sample size of the surveyed DOT professionals was also small. Although hard-to-reach population, for a more robust study outcome, data should be elicited from a sufficient number of professionals across U.S. departments of transportation. Second, the current study did not explore the causes of action or inaction by individuals toward climate change. Future research could supplement our findings with in-depth interviews or focus groups to better understand such reasoning. Despite these limitations, the present study was able to identify potential barriers to the adoption of ecofriendly lifestyles and presented an opportunity for transportation planners and managers to account for the risk perceptions and climate literacy of both stakeholder groups when making transportation infrastructure related decisions.

7. Conclusions

The concentration of GHGs in the atmosphere from human activities has increased the frequency of climate change events, which degrade the structural integrity and performance of transportation infrastructure, thus highlighting the need for policies that motivate individuals to modify energy consumption habits and adopt pro-environmental lifestyles. The present study assessed the influence of attitudes, beliefs, and intentions toward climate change and its related policy support. It also examined the perception differences between transportation professionals and the general public on the consequences of climate change on transportation infrastructure and the readiness to adopt pro-environmental behavior. Although the study observed a relatively lower level of awareness about climate change and its consequences among the general public than the DOT professionals, the perception of behavioral control and expression of confidence in the ability to carry out mitigative actions among the US public is promising.

It is also interesting to observe that relatively more DOT professionals indicated support for an international treaty to reduce CO2 emissions by 90% by the year 2050. They also recorded that at least 20% of electricity should be generated from renewable energy sources. Conversely, the general public expressed support for the provision of tax rebates for individuals who purchase energy-efficient vehicles or solar panels. The transportation sector is the largest contributor of GHG emissions and accounts for about 28% of total U.S. emissions and nearly 30% of the European Union's total carbon dioxide (CO2) emissions,

out of which nearly three quarters (72%) comes from road transportation [129,130]. GHGs—including water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxides (NxO), and ozone (O3) produced primarily from burning fossil fuels and originating from human activity—trap heat in the atmosphere and induce extreme weather events such as floods, droughts and increased global average temperatures that accelerate the impact of climate change [81,131]. It was suggested by the Intergovernmental Panel on Climate Change [132] that a projected need for greenhouse gas (GHG) concentrations to be stabilized at 1990 levels would require reducing global emissions of CO2 by more than 60%, methane by 15–20%, and nitrous oxide and chlorofluorocarbons (CFCs) by about 70–85%. With the rapid increase in transport demand, considering that transportation heavily depends on fossil fuels to function, the resultant effect of these gases in terms of intense weather patterns may have dire consequences on both natural and managed systems. Therefore, government and relevant stakeholders may find long-term benefits in reducing GHG emissions via environmental policies and actions that consider the use of renewable energy sources, while providing tax rebates for individuals who purchase energy-efficient vehicles. Furthermore, transportation infrastructure should be designed, constructed and maintained in a manner that optimizes operability and resilience in order to combat deterioration from climate change and preserve the structural integrity of these systems.

In sum, the current study compared the perceptions of both DOT professionals and the general public regarding climate change. This was a necessary exercise because individuals who hold favorable attitudes toward environmental responsibility and possess a strong personal norm that their actions can contribute to easing the impact of climate change may be willing to engage in energy-conservation endeavors despite the associated costs or discomfort. In parallel, although the study demonstrated that transportation professionals are relatively better informed about the issue, these experts recorded lower levels of perceived behavioral control. In other words, the public expressed a greater confidence in their ability to take mitigative steps to ease the impact of climate change on the transportation system. Correspondingly, although shy of statistical significance, it is important to recognize that some survey results—such as frequency of car use and air travel, engagement with the media on climate change issues, and belief in walking and biking habits to lessen the impact of climate change on transportation systems—portrayed some measure of hesitance from the DOT professionals in making personal sacrifices to address the issue of climate change. Therefore, the study emphasizes the need for collective responsibility in addressing the matter and collaboration among transportation managers, policy makers and the general public for a more effective mitigation effort. Decision makers are also encouraged to incorporate possible effects of current variations in public perception as they develop adaptation strategies during the planning, design and operation of transportation infrastructure. The DOT professionals may also consider support for the provision of tax rebates for members of the public who purchase energy-efficient vehicles in order to encourage environmental actions and harmonize efforts to achieve global GHG emission targets.

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References

1. Zimmerman, R. Global Climate Change and Transportation Infrastructure: Lessons from the New York Area. *N. Y. City Panel Clim. Chang.* **2019**, *11*, 1–11.
2. Moretti, L.; Loprencipe, G. Climate Change and Transport Infrastructures: State of the Art. *Sustainability* **2018**, *10*, 4098. [CrossRef]
3. Liao, T.; Kumar, I.; Dojutrek, M.; Labi, S. Updating Secondary Climate Attributes for Transportation Infrastructure Management. *J. Infrastruct. Syst.* **2018**, *24*, 1–12. [CrossRef]
4. Diakakis, M.; Boufidis, N.; Grau, J.; Andreadakis, E.; Stamos, I. A systematic assessment of the effects of extreme flash floods on transportation infrastructure and circulation: The example of the 2017 Mandra flood. *Int. J. Disaster Risk Reduct.* **2020**, *47*, 1–17. [CrossRef]
5. Kafalenos, R.; Leonard, K. Chapter 4: What Are the Implications of Climate Change and Variability for Gulf Coast Transportation. In *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*; U.S. Climate Change Science Program: Washington, DC, USA, 2019; pp. 1–104.
6. Wang, J.; Kim, S. Analysis of the Impact of Values and Perception on Climate Change Skepticism and Its Implication for Public Policy. *Climate* **2018**, *6*, 99. [CrossRef]
7. Pregnolato, M.; Ford, A.; Dawson, R. Analysis of The Risk of Transport Infrastructure Disruption from Extreme Rainfall. In Proceedings of the 12th International Conference on Applications of Statistics and Probability in Civil Engineering, ICASP12. Vancouver, BC, Canada, 12–15 July 2015; pp. 1–8.
8. Gilmore, A.; St Clair, T. Budgeting for climate change: Obstacles and opportunities at the US state level. *Clim. Policy* **2018**, *18*, 729–741. [CrossRef]
9. Markolfa, S.; Hoehne, C.; Fraser, A.; Chester, M.; Underwood, S. Transportation resilience to climate change and extreme weather events—Beyond risk and robustness. *Transp. Policy* **2019**, *74*, 144–186. [CrossRef]
10. Streletskiy, D.; Suter, L.; Shiklomanov, N.; Porfiriev, B.; Eliseev, D. Assessment of climate change impacts on buildings, structures and infrastructure in the Russian regions on permafrost. *Environ. Res. Lett.* **2019**, *14*, 1–16. [CrossRef]
11. Alexander, S.; Agrawal, A.; Hooper, A.; Boswell, M. *Harmonizing Climate Change Mitigation and Adaptation in Transportation and Land-Use Planning in California Cities*; Mineta Transportation Institute Publications: San Jose, CA, USA, 2020; pp. 1–77.
12. Stoner, A.; Daniel, J.; Jacobs, J.; Hayhoe, K.; Scott-Fleming, I. Quantifying the Impact of Climate Change on Flexible Pavement Performance and Lifetime in the United States. *Transp. Res. Rec.* **2019**, *2673*, 110–122. [CrossRef]
13. Howe, P.; Mildenberger, M.; Marlon, J.; Leiserowitz, A. Geographic variation in opinions on climate change at state and local scales in the USA. *Nat. Clim. Chang.* **2015**, *5*, 1–8. [CrossRef]
14. Attari, S.; Krantz, D.; Weber, E. Climate change communicators' carbon footprints affect their audience's policy support. *Clim. Chang.* **2019**, *154*, 529–545. [CrossRef]
15. Venturini, G.; Hansen, M.; Andersen, P. Linking narratives and energy system modelling in transport scenarios: A participatory perspective from Denmark. *Energy Res. Soc. Sci.* **2019**, *52*, 204–220. [CrossRef]
16. Pyrialakou, V.; Gkritz, K.; Liu, S. The use of focus groups to foster stakeholder engagement in intercity passenger rail planning. *Case Stud. Transp. Policy* **2019**, *7*, 505–517. [CrossRef]
17. Rumore, D.; Schenk, T.; Susskind, L. Role-play simulations for climate change adaptation education and engagement. *Nat. Clim. Chang.* **2016**, *6*, 745–750. [CrossRef]
18. Carlton, J.; Mase, A.; Knutson, C.; Lemos, M.; Haigh, T.; Todey, D.; Prokopy, L. The effects of extreme drought on climate change beliefs, risk perceptions, and adaptation attitudes. *Clim. Chang.* **2016**, *135*, 211–226. [CrossRef]
19. Rahimi, M. Public Awareness: What Climate Change Scientists Should Consider. *Sustainability* **2020**, *12*, 8369. [CrossRef]
20. Karakosta, C.; Flamos, A.; Forouli, A. Identification of climate policy knowledge needs: A stakeholders consultation approach. *Int. J. Clim. Chang. Strateg. Manag.* **2017**, *10*, 772–795. [CrossRef]
21. Lorenzoni, I.; Pidgeon, N. Public Views on Climate Change: European and USA Perspectives. *Clim. Chang.* **2006**, *77*, 73–95. [CrossRef]
22. Sullivan, A.; White, D. An Assessment of Public Perceptions of Climate Change Risk in Three Western U.S. Cities. *Weather Clim. Soc.* **2019**, *11*, 449–463. [CrossRef]
23. Hamilton, L.; Fogg, L. *Physical-World Knowledge and Public Views on Climate Change*; University of New Hampshire Scholars' Repository: Durham, NC, USA, 2019; pp. 1–16.
24. Sommer, L.K.; Swim, J.; Keller, A.; Klöckner, C. Pollution Pods: The merging of art and psychology to engage the public in climate change. *Glob. Environ. Chang.* **2019**, *59*, 1–13. [CrossRef]
25. Blue, G. Scientism: A problem at the heart of formal public engagement with climate change Gwendolyn Blue. *Int. J. Crit. Geogr.* **2018**, *17*, 544–560.
26. Tobler, C.; Visschers, V.; Siegrist, M. Consumers' knowledge about climate change. *Clim. Chang.* **2012**, *114*, 189–209. [CrossRef]
27. Ho, S.; Yang, X. Communication, cognitive processing, and public knowledge about climate change. *Asian J.* **2018**, *28*, 449–467. [CrossRef]
28. Hurlimann, A.; Browne, G.; Warren-Myers, G.; Francis, V. Barriers to climate change adaptation in the Australian construction industry—Impetus for regulatory reform. *Build. Environ.* **2020**, *137*, 235–245. [CrossRef]

29. Drummond, A.; Hall, L.; Sauer, J.; Palmer, M. Is public awareness and perceived threat of climate change associated with governmental mitigation targets? *Clim. Chang.* **2018**, *149*, 159–171. [CrossRef]
30. Luo, Y.; Zhao, J. Motivated Attention in Climate Change Perception and Action. *Front. Psychol.* **2019**, *10*, 1–12. [CrossRef]
31. Lee, T.; Markowitz, E.; Howe, P.; Ko, C.; Leiserowitz, A. Predictors of public climate change awareness and risk perception around the world. *Nat. Clim. Chang.* **2015**, *5*, 1014–1022. [CrossRef]
32. Libarkin, J.; Gold, A.; Harris, S.; McNeal, K.; Bowles, R. A new, valid measure of climate change understanding: Associations with risk perception. *Clim. Chang.* **2018**, *150*, 403–416. [CrossRef]
33. Homsy, G. Unlikely pioneers: Creative climate change policymaking in smaller U.S. cities. *J. Environ. Stud. Sci.* **2018**, *8*, 121–131. [CrossRef]
34. Romsdah, R.; Blue, G.; Kirilenko, A. Action on climate change requires deliberative framing at local governance level. *Clim. Chang.* **2018**, *149*, 277–287. [CrossRef]
35. Iturriza, M.; Labaka, L.; Ormazabal, M.; Borges, M. Awareness-development in the context of climate change resilience. *Urban Clim.* **2020**, *32*, 1–15. [CrossRef]
36. Pietsch, J.; McAllister, I. A diabolical challenge: Public opinion and climate change policy in Australia. *Environ. Politics* **2010**, *19*, 217–236. [CrossRef]
37. Wang, S.; Corner, A.; Chapman, D.; Markowitz, E. Public engagement with climate imagery in a changing digital landscape. *Wiley Interdiscip. Rev. Clim. Chang.* **2018**, *9*, 1–18. [CrossRef]
38. Mavrodieva, A.; Rachman, O.; Harahap, V.; Shaw, R. Role of Social Media as a Soft Power Tool in Raising Public Awareness and Engagement in Addressing Climate Change. *Climate* **2019**, *7*, 122. [CrossRef]
39. Smith, R. Risk perception and adaptive responses to climate change and climatic variability in northeastern St. Vincent. *Res. J. Environ. Sci.* **2018**, *8*, 73–85. [CrossRef]
40. Neves, A.; Brand, C. Assessing the potential for carbon emissions savings from replacing short car trips with walking and cycling using a mixed GPS-travel diary approach. *Transp. Res. Part A* **2019**, *123*, 130–146. [CrossRef]
41. Santoro, S.; Pluchinotta, I.; Pagano, A.; Pengal, P.; Cokan, B.; Giordano, R. Assessing stakeholders' risk perception to promote Nature Based Solutions as flood protection strategies: The case of the Glinščica river (Slovenia). *Sci. Total Environ.* **2019**, *655*, 188–201. [CrossRef]
42. Lorenzoni, I.; Nicholson-Cole, S.; Whitmarsh, L. Barriers perceived to engaging with climate change among the UK public and their policy implications. *Glob. Environ. Chang.* **2007**, *17*, 445–459. [CrossRef]
43. Douglas, E.; Reardon, K.; Täger, M. Participatory action research as a means of achieving ecological wisdom within climate change resiliency planning. *J. Urban Manag.* **2018**, *7*, 152–160. [CrossRef]
44. Smith, E.; Mayer, A. A social trap for the climate? Collective action, trust and climate change risk perception in 35 countries. *Glob. Environ. Chang.* **2018**, *49*, 140–153. [CrossRef]
45. Lorencová, E.; Loucková, B.; Vackáru, D. Perception of Climate Change Risk and Adaptation in the Czech Republic. *Climate* **2019**, *7*, 1–13.
46. Echavarren, J.; Balžekienė, A.; Telešienė, A. Multilevel analysis of climate change risk perception in Europe: Natural hazards, political contexts and mediating individual effects. *Saf. Sci.* **2019**, *120*, 813–823. [CrossRef]
47. de Mello-Théry, N.A.; Caldas, E.; Funatsu, B.; Arvor, D.; Dubreuil, V. Climate Change and Public Policies in the Brazilian Amazon State of Mato Grosso: Perceptions and Challenges. *Sustainability* **2020**, *12*, 5093. [CrossRef]
48. Shi, J.; Visschers, V.; Siegrist, M. Public Perception of Climate Change: The Importance of Knowledge and Cultural Worldviews. *Risk Anal.* **2015**, *35*, 1–19. [CrossRef]
49. Doran, P.; Zimmerman, M. Examining the scientific consensus on climate change. *Eos Trans. Am. Geophys. Union* **2009**, *90*, 22–24. [CrossRef]
50. Chinowsky, P.; Price, J.; Neumann, J. Assessment of climate change adaptation costs for the U.S. road network. *Glob. Environ. Chang.* **2013**, *23*, 764–773. [CrossRef]
51. Larsen, P.; Goldsmith, S.; Smith, O.; Wilson, M.; Strzepek, K.; Chinowsky, P.; Saylor, B. Estimating future costs for Alaska public infrastructure at risk from climate change. *Glob. Environ. Chang.* **2008**, *18*, 442–457. [CrossRef]
52. Cook, J.; Lewandowsky, S.; Ecker, U. Neutralizing misinformation through inoculation: Exposing misleading argumentation techniques reduces their influence. *PLoS ONE* **2017**, *12*, e0175799. [CrossRef]
53. Qualtrics Seattle, Washington, USA. 2021. Available online: https://www.qualtrics.com (accessed on 2 February 2021).
54. Akerlof, K.; Grutter, B.; Maibach, E.W. *Maryland's Six Climate Change Audiences: A Global Warming's Six Americas Audience Segmentation*; Center for Climate Change Communication, George Mason University: Fairfax, VA, USA, 2014; pp. 1–96.
55. Leiserowitz, A.; Maibach, E.; Roser-Renouf, C.; Rosenthal, S.; Cutler, M. *Climate Change in the American Mind: May 2017*; Yale Program on Climate Change Communication: New Haven, CT, USA, 2014; pp. 1–48.
56. Bonetti, D.; Wright, T. Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning. *J. Organ. Behav.* **2015**, *36*, 3–15. [CrossRef]
57. Ernst, M. Permutation Methods: A Basis for Exact Inference. *Math. Stat.* **2004**, *19*, 676–685. [CrossRef]
58. Sawilowsky, S.; Fahoome, G. *Statistics through Monte Carlo simulation with FORTRAN*; Journal of Modern Applied Statistical Methods Inc: Rochester Hills, MI, USA, 2003.

59. LaFleur, B.; Greevy, R. Introduction to Permutation and Resampling-Based Hypothesis Tests. *J. Clin. Child Psychol.* **2009**, *38*, 286–294. [CrossRef]
60. Rao, K.; Drikvandi, R.; Saville, B. Permutation and Bayesian tests for testing random effects in linear mixed-effects models. *Stat. Med.* **2019**, *38*, 5034–5047. [CrossRef]
61. Bradley, J. *Distribution-Free Statistical Tests*; Prentice-Hall: Englewood Cliffs, NJ, USA, 1968.
62. Elliffei, D.; Elliffe, M. Rank-permutation tests for behavior analysis, and a test for trend allowing unequal data numbers for each subject. *J. Exp. Anal. Behav.* **2019**, *111*, 342–358. [CrossRef]
63. Potvin, C.; Roff, D. Distribution-free and robust statistical methods: Viable alternatives to parametric statistics. *Ecology* **1993**, *74*, 1617–1628. [CrossRef]
64. Gamm, B.; Gerard, P. Testing the differences between two color measurement probability distributions using Hotelling's T2 test and the permutation test. *Color Res. Appl.* **2019**, *45*, 196–207. [CrossRef]
65. Adams, D.; Anthony, C. Using randomization techniques to analyze behavioral data. *Anim. Behav.* **1996**, *51*, 733–738. [CrossRef]
66. Knijnenburg, T.; Wessels, L.; Reinders, M.; Shmulevich, I. Fewer permutations, more accurate P-values. *J. Bioinform.* **2009**, *25*, 161–168. [CrossRef]
67. Gleason, J. Comparative Power of The Anova, Randomization Anova, and Kruskal-Wallis Test. Ph.D. Thesis, Graduate School of Wayne State University, Detroit, MI, USA, 2013.
68. Leiserowitz, A. American Risk Perceptions: Is Climate Change Dangerous? *Risk Anal.* **2005**, *25*, 1433–1442. [CrossRef]
69. Whitmarsh, L. Skepticism and uncertainty about climate change: Dimensions, determinants and change over time. *Glob. Environ. Chang.* **2011**, *21*, 690–700. [CrossRef]
70. Wolf, J.; Moser, S. Individual understandings, perceptions, and engagement with climate change: Insights from in-depth studies across the world. *Adv. Rev.* **2011**, *2*, 547–569. [CrossRef]
71. Bieniek-Tobasco, A.; Rimal, R.; McCormick, S.; Harrington, C. The Power of Being Transported: Efficacy Beliefs, Risk Perceptions, and Political Affiliation in the Context of Climate Change. *Sci. Commun.* **2020**, *42*, 776–802. [CrossRef]
72. Ballew, M.; Leiserowitz, A.; Roser-Renouf, C.; Rosenthal, S.; Kotcher, J.; Marlon, J.; Lyon, E.; HGoldberg, M.; Maibach, E. Climate Change in the American Mind: Data, Tools, and Trends. *Environ. Sci. Policy Sustain. Dev.* **2019**, *61*, 4–18. [CrossRef]
73. Gregersen, T.; Doran, R.; Böhm, G.; Tvinnereim, E.; Poortinga, W. Political Orientation Moderates the Relationship between Climate Change Beliefs and Worry About Climate Change. *Front. Psychol.* **2020**, *11*, 1–12. [CrossRef] [PubMed]
74. Line, T.; Chatterjee, K.; Lyons, G. The travel behavior intentions of young people in the context of climate change. *J. Transp. Geogr.* **2010**, *18*, 238–246. [CrossRef]
75. Bouman, T.; Steg, L. Motivating Society-wide Pro-environmental Change. *One Earth* **2020**, *1*, 27–30. [CrossRef]
76. Geiger, N.; Swim, J. Climate of silence: Pluralistic ignorance as a barrier to climate change discussion. *J. Environ. Psychol.* **2016**, *47*, 79–90. [CrossRef]
77. Capstick, S.; Whitmarsh, L.; Poortinga, W.; Pidgeon, N.; Upham, P. International trends in public perceptions of climate change over the past quarter century. *Wiley Interdiscip. Rev. Clim. Chang.* **2015**, *6*, 35–61. [CrossRef]
78. Kovaka, K. Climate change denial and beliefs about science. *Synthese* **2019**, *198*, 1–20. [CrossRef]
79. Ungar, S. Knowledge, ignorance and the popular culture: Climate change versus the ozone hole. *Public Underst. Sci.* **2000**, *9*, 297–312. [CrossRef]
80. Clayton, S. Psychology and climate change. *Curr. Biol.* **2019**, *29*, 992–995. [CrossRef]
81. Hoegh-Guldberg, O.; Jacob, D.; Taylor, M. The human imperative of stabilizing global climate change at 1.5 °C. *Science* **2019**, *365*, 1–11. [CrossRef]
82. Hess, D.; Maki, A. Climate change belief, sustainability education, and political values: Assessing the need for higher-education curriculum reform. *J. Clean. Prod.* **2019**, *228*, 1157–1166. [CrossRef]
83. Swol, L.; Prahl, A.; Kol, M. The Effects of Discussion of Familiar or Non-Familiar Information on Opinions of Anthropogenic Climate Change. *Environ. Commun.* **2019**, *13*, 1128–1142. [CrossRef]
84. Lucas, C.; Davison, A. Not 'getting on the bandwagon': When climate change is a matter of unconcern. *Nat. Space* **2018**, *2*, 129–149. [CrossRef]
85. Yang, X.; Chen, L.; Ho, S. Does media exposure relate to the illusion of knowing in the public understanding of climate change? *Public Underst. Sci.* **2020**, *29*, 94–111. [CrossRef]
86. Poortinga, W.; Spence, A.; Whitmarsh, L.; Capstick, S.; Pidgeon, N. Uncertain climate: An investigation into public skepticism about anthropogenic climate change. *Glob. Environ. Chang.* **2011**, *21*, 1015–1024. [CrossRef]
87. Hart, P.; Nisbet, E.; Myers, T. Public attention to science and political news and support for climate change mitigation. *Nat. Clim. Chang.* **2015**, *5*, 541–545. [CrossRef]
88. Goldberg, M.; van der Linden, S.; Leiserowitz, A.; Maibach, E. Perceived Social Consensus Can Reduce Ideological Biases on Climate Change. *Environ. Behav.* **2020**, *52*, 495–517. [CrossRef]
89. Yu, T.; Chang, Y.; Chang, C.; Yu, T. A pro-environmental behavior model for investigating the roles of social norm, risk perception, and place attachment on adaptation strategies of climate change. *Environ. Sci. Pollut. Res.* **2019**, *26*, 25178–25189. [CrossRef]
90. Easterling, D.; Wehner, M. Is the Climate Warming or Cooling? *Geophys. Res. Lett.* **2009**, *36*, 1–10. [CrossRef]
91. Druckman, J.; McGrath, M. The evidence for motivated reasoning in climate change preference formation. *Nat. Clim. Chang.* **2019**, *9*, 111–119. [CrossRef]

92. Sezen-Barrie, A.; Shea, N.; Borman, J. Probing into the sources of ignorance: Science teachers' practices of constructing arguments or rebuttals to denialism of climate change. *Environ. Educ. Res.* **2019**, *25*, 846–866. [CrossRef]
93. Buratti, S.; Allwood, C. The effect of knowledge and ignorance assessments on perceived risk. *J. Risk Res.* **2019**, *22*, 735–748. [CrossRef]
94. Nyhan, B.; Reifler, J. The roles of information deficits and identity threat in the prevalence of misperceptions. *J. Elect. Public Opin. Parties* **2019**, *29*, 222–244. [CrossRef]
95. Gustafson, A.; Ballew, M.; Goldberg, M.; Cutler, M.; Rosenthal, S.; Leiserowitz, A. Personal Stories Can Shift Climate Change Beliefs and Risk Perceptions: The Mediating Role of Emotion. *Commun. Rep.* **2020**, *33*, 121–135. [CrossRef]
96. Lehman, P.; Geller, E. Behavior analysis and environmental protection: Accomplishments and potential for more. *Behav. Soc. Issues* **2004**, *13*, 13–32. [CrossRef]
97. Aitken, N.; Pelletier, L.; Baxter, D. Doing the Difficult Stuff: Influence of Self-Determined Motivation Toward the Environment on Transportation Proenvironmental Behavior. *Ecopsychology* **2016**, *8*, 153–162. [CrossRef]
98. American Psychological Association. Available online: https://www.apa.org/news/press/releases/2020/02/climate-change (accessed on 5 May 2021).
99. Tolppanen, S.; Kang, J. The effect of values on carbon footprint and attitudes towards proenvironmental behavior. *J. Clean. Prod.* **2020**, *282*, 1–10.
100. Bostrom, A.; Hayes, A.; Crosman, K. Efficacy, Action, and Support for Reducing Climate Change Risks. *Risk Anal.* **2019**, *39*, 805–828. [CrossRef]
101. Whitmarsh, L. Behavioral responses to climate change: Asymmetry of intentions and impacts. *J. Environ. Psychol.* **2009**, *29*, 13–23. [CrossRef]
102. Pickering, G.; Schoen, K.; Botta, M.; Fazio, X. Exploration of youth knowledge and perceptions of individual-level climate mitigation action. *Environ. Res. Lett.* **2019**, *25*, 1–13.
103. Kollmuss, A.; Agyeman, J. Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Educ. Res. J.* **2002**, *8*, 239–260. [CrossRef]
104. Gkargkavouzi, A.; Halkos, G.; Matsiori, S. Environmental behavior in a private-sphere context: Integrating theories of planned behavior and value belief norm, self-identity and habit. *Resour. Conserv. Recycl.* **2019**, *148*, 145–156. [CrossRef]
105. Leung, Y.; Rosenthal, S. Explicating Perceived Sustainability-Related Climate: A Situational Motivator of Pro-Environmental Behavior. *Sustainability* **2019**, *11*, 231. [CrossRef]
106. Zahedi, S.; Batista-Foguet, J.; van Wunnik, L. Exploring the public's willingness to reduce air pollution and greenhouse gas emissions from private road transport in Catalonia. *Sci. Total Environ.* **2019**, *646*, 850–861. [CrossRef]
107. Leviston, Z.; Uren, H. Overestimating One's Green Behavior: Better-Than-Average Bias May Function to Reduce Perceived Personal Threat from Climate Change. *J. Soc. Issues* **2020**, *76*, 70–85. [CrossRef]
108. Anable, J.; Lane, B.; Kelay, T. *Review of Public Attitudes to Climate Change and Transport*; Department of Transportation: London, UK, 2006; pp. 1–228.
109. Cai, S.; Long, X.; Li, L.; Liang, H.; Wang, Q.; Ding, X. Determinants of intention and behavior of low carbon commuting through bicycle-sharing in China. *J. Clean. Prod.* **2019**, *212*, 602–609. [CrossRef]
110. Casaló, L.; Escario, J.; Rodriguez-Sanchez, C. Analyzing differences between different types of pro-environmental behaviors: Do attitude intensity and type of knowledge matter? *Resour. Conserv. Recycl.* **2019**, *149*, 56–64. [CrossRef]
111. Moriarty, P.; Honnery, D. Energy Efficiency or Conservation for Mitigating Climate Change? *Energies* **2019**, *12*, 3543. [CrossRef]
112. Metzler, D.; Humpe, A.; Gössling, S. Is it time to abolish company car benefits? An analysis of transport behavior in Germany and implications for climate change. *Clim. Policy* **2019**, *19*, 542–555. [CrossRef]
113. Corral-Verdugo, V.; Lucas, M.; Tapia-Fonllem, C.; Ortiz-Valdez, A. Situational factors driving climate change mitigation behaviors: The key role of pro-environmental family. *Environ. Dev. Sustain.* **2020**, *22*, 7269–7285. [CrossRef]
114. Chapman, L. Transport and climate change: A review. *J. Transp. Geogr.* **2007**, *15*, 354–367. [CrossRef]
115. Heimlich, J.; Ardoin, N. Understanding behavior to understand behavior change: A literature review. *Environ. Educ. Res.* **2008**, *14*, 215–237. [CrossRef]
116. Hares, A.; Dickinson, J.; Wilkes, K. Climate change and the air travel decisions of UK tourists. *J. Transp. Geogr.* **2010**, *18*, 466–473. [CrossRef]
117. Mullin, M.; Feiock, R.; Niemeier, D. Climate Planning and Implementation in Metropolitan Transportation Governance. *J. Plan. Educ. Res.* **2020**, 1–11. [CrossRef]
118. Aldred, R.; Watson, T.; Lovelace, R.; Woodcock, J. Barriers to investing in cycling: Stakeholder views from England. *Transp. Res. Part A* **2019**, *128*, 149–159. [CrossRef]
119. Wei, L.; Schmitz, S.; Becker, S.; Niehoff, N.; Schwartzbach, F.; von Schneidemesser, E. Erratum: Climate change and air pollution: The connection between traffic intervention policies and public acceptance in a local context. *Environ. Res. Lett.* **2019**, *14*, 1–11.
120. Mahat, T.; Bláha, L.; Uprety, B.; Bittner, M. Climate finance and green growth: Reconsidering climate-related institutions, investments, and priorities in Nepal. *Environ. Sci. Eur.* **2019**, *31*, 1–13. [CrossRef]
121. Overland, I.; Sovacool, B. The misallocation of climate research funding. *Energy Res. Soc. Sci.* **2020**, *62*, 1–13. [CrossRef]
122. Keenan, J.; Chu, E.; Peterson, J. From funding to financing: Perspectives shaping a research agenda for investment in urban climate adaptation. *Int. J. Urban Sustain. Dev.* **2019**, *11*, 297–308. [CrossRef]

123. Moser, S.; Ekstrom, J.; Kim JHeitsch, S. Adaptation finance archetypes: Local governments' persistent challenges of funding adaptation to climate change and ways to overcome them. *Ecol. Soc.* **2019**, *24*, 1–35. [CrossRef]
124. Chu, E. Transnational support for urban climate adaptation: Emerging forms of agency and dependency. *Glob. Environ. Politics* **2018**, *18*, 25–46. [CrossRef]
125. Chang, C.; Ortega, O.; Weidner, J. Integrating the Risk of Climate Change into Transportation Asset Management to Support Bridge Network-Level Decision-Making. *J. Infrastruct. Syst.* **2020**, *27*, 1–10. [CrossRef]
126. Forster, P.; Maycock, A.; McKenna, C.; Smith, C. Latest climate models confirm need for urgent mitigation. *Nat. Clim. Chang.* **2020**, *10*, 2–10. [CrossRef]
127. Tonn, G.; Czajkowski, J.; Kunreuther, H.; Angotti, K.; Gelman, K. Measuring Transportation Infrastructure Resilience: Case Study with Amtrak. *J. Infrastruct. Syst.* **2020**, *26*, 1–11. [CrossRef]
128. Sun, J.; Chow, A.; Madanat, S. Multimodal transportation system protection against sea level rise. *Transp. Res. Part D* **2020**, *88*, 1–12. [CrossRef]
129. European Parliament. Transport CO2 Emissions in the EU. 2019. Available online: https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics#:~{}:text=Transport%20is%20responsible%20for%20nearly,2050%20compared%20to%201990%20levels (accessed on 7 October 2020).
130. United States Environmental Protection Agency. Sources of Greenhouse Gas Emissions. 2020. Available online: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (accessed on 1 October 2020).
131. Dong, Y.; Hauschild, M.; Sørup, H.; Rousselet, R.; Fantke, P. Evaluating the monetary values of greenhouse gases emissions in life cycle impact assessment. *J. Clean. Prod.* **2019**, *209*, 538–549. [CrossRef]
132. IPCC-I. *Climate Change: The IPCC Scientific Assessment*; Cambridge University Press: Cambridge, UK, 1990; p. 364.