CASE STUDY: ANALYZING ADOPTION READINESS OF POROUS CONCRETE IN OLYMPIA, WASHINGTON

by

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ABSTRACT

Case Study: Analyzing Adoption Readiness of Porous Concrete in Olympia, Washington

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In the Pacific Northwest, climate change is projected to manifest largely through shorter, more intense rainy seasons, leading to runoff contamination, flooding, and groundwater disruption. As urbanization and climate change awareness increase, green technologies like porous concrete (PC) are being considered to mitigate urban runoff, flooding, and the urban heat island (UHI) effect. By utilizing the theory of Technological Acceptance Modeling (TAM) to assess perceived usefulness and ease of use, this study explores public attitudes towards PC in Olympia, Washington. PC, with its multi-layer structure, offers a series of solutions by facilitating drainage, removing contaminants, mitigating UHI effects, and reducing noise pollution. This study engaged Olympia residents through surveys distributed at sustainability-focused locations, aiming to understand their readiness to adopt PC. Key survey findings indicate a strong interest in learning about PC. Additionally, survey respondents emphasized stormwater pollutant removal and flood prevention as the most relevant features of PC. Coupled with those findings, concerns about installation and maintenance costs persist. Results indicate that lower uncertainty and increased familiarity with PC can further enhance adoption readiness. While PC holds significant promise for sustainable urban development, addressing public knowledge gaps and financial concerns is crucial for its broader adoption.

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Lastly, thank you to my two cats who forced me to take needed breaks and absorbed so much of my stress with your company.

Introduction

Adoption of green technologies is increasing alongside urbanization, and awareness of the changes in climate heading our way are becoming more widespread (Kuller et al., 2019; Shandas et al., 2020). One major way that climate change manifests in the Pacific Northwest is through changes in the rainy season. Projections have shown rain events to be shortening slightly in duration while increasing in intensity (Mass et al., 2011). Nonporous surfaces exacerbate issues associated with high amounts of rain by contributing to runoff contamination, flooding, and disruption of groundwater recharge (Abdollahian et al., 2018). A large portion of nonporous surface exists as pavement (i.e., sidewalks, parking lots, driveways, and roads). Porous Concrete (PC) is a technology that can replace impervious paved surfaces and serve as a drainage system. PC consists of a relatively thin top porous layer with a second, larger layer of aggregate below it. At the bottom, water can be slowly released back into the ground locally or channeled into the stormwater drainage system. Other services include mitigation of Urban Heat Island (UHI) effect, peak flow attenuation, water filtration, and reduced sound pollution (Miao et al., 2019b; Sansalone et al., 2012; Zhang et al., 2021; Zhong et al., 2018). When it comes to organized groups of people like neighborhoods, workplaces, social groups, and other communities, many researchers turn to theories such as Technological Acceptance Modeling (TAM) to measure willingness to adopt a new technology (Sharp et al., 2011). Specific to this study, TAM can help us to understand adoption readiness for a specific form of green infrastructure: porous concrete. This study aims for a better understanding of attitudes towards PC in Olympia, Washington by asking, “What is the nature of participants’ perceived usefulness and ease of use surrounding porous concrete?” and “Are there any demographic correlations with adoption readiness of PC among participants?”

To answer these questions, the public must be engaged. By providing an avenue for people to not only learn about PC, but also express their perspectives on it, this study presents opportunities to understand parts of Olympia’s local community, and gauge levels of adoption readiness. This study utilized surveys distributed at four locations that were selected for their likelihood of attracting individuals with sustainability-focused and progressive worldviews.

Literature Review

This review discusses technological adoption as a concept, then places it in context with green infrastructure exemplified through the technology of porous concrete. Next, I will review each of the services associated with PC: (1) mitigation of the urban heat island (UHI) effect (Chen et al., 2019; Liu et al., 2018, 2020); (2) peak flow attenuation (Kim et al., 2019; Miao et al., 2019a); (3) water filtration (Pilon et al., 2019; Sansalone et al., 2012; Selbig et al., 2019) and (4) reduced sound pollution (Zhong et al., 2018). The goal is to show how these services can be brought into practice by incorporating the conceptual framework for the criteria of decision making known as technological acceptance modeling. Multiple criteria must be considered when responding to the complex nature of services like stormwater management (Kuller et al., 2019) or pollutant removal (Pilon et al., 2019) because perceptions around infrastructure are multidimensional and interdisciplinary.

Green infrastructure is a broad term, but more technologies within its purview are emerging as innovations (Miao et al., 2019). In urbanized areas, substantial portions of the land are covered by impermeable surfaces like glass, metal, concrete, asphalt, and roofing material. When rain falls onto these surfaces, it washes over them, collects contaminants along the way, and transports them into stormwater drainage systems. Drastic increases in impermeable surfaces (i.e., roads and roofs) are altering the natural hydrological cycle in urban centers (Antunes et al., 2020). Most urban water systems are integrated on a very large scale, in a centralized structure, and in many cases carry stormwater runoff directly to a nearby body of water via these piped systems (Quezada et al., 2016).

In particularly rainy areas like Olympia, WA, innovations in permeability could help address a series of issues including pollution, climate change, environmental awareness, and personal wellbeing, which are mentioned later in more detail. There is evidence that residents who participated in other studies acknowledge benefits of green stormwater infrastructure such as porous concrete (PC), but they also express concerns about the projects giving rise to novel issues and community conflicts (Meenar et al., 2022).

Green Infrastructure vs. Gray Infrastructure

Traditional (a.k.a. gray) infrastructure refers to built structures, such as roads or buildings, and supply channels motivated primarily by market-related factors and is very seldom perceived as a tool for sustainability. Cost effectiveness, durability/lifespan, or convenience in an urban area are some primary motivators in the planning and design of gray infrastructure. On the other hand, the goal of green infrastructure is to provide the economic, social benefits of traditional gray infrastructure while also pursuing environmental benefits through a medium that also cultivates climate resilience and/or conservation of biodiversity. Green infrastructure seeks to mimic the functions of ecosystems in urban spaces and emphasizes the preservation, restoration, and integration of nature (Quezada et al., 2016).

Established Framework for Technological Adoption

Technological Acceptance Model

The Technological Acceptance Model (TAM) was developed by Fred Davis in 1989 to understand and predict how users accept a newly adopted technology. The results of his study highlighted two major factors that influence adoption readiness: **perceived usefulness (PU)** and perceived ease of use (EU). Perceived usefulness is the belief that the technology will achieve its goal more effectively than related technologies (i.e., other pavements, or other stormwater management systems). Perceived usefulness of an innovation determines its capacity to meet one or more goals (Carlet, 2015). In the context of this review, the goals of PC are described later under the *Services associated with PC* section. Perceived ease of use is the extent to which users find the performance of the innovation to be free of effort. There is evidence that perceived ease of use significantly influences users' perceived usefulness (Carlet, 2015). In other words, the easier something is to use, the more useful it is. To give an example, ease of use in the context of PC could be related to factors such as cleaning. Depending on how easy it is to clean, users will determine how useful PC would be to them over time.

Additional Criteria for Technological Adoption

Compatibility (personal or community benefit)

Existing literature finds compatibility (CO) to be a significant player for innovation adoption. Compatibility influences adoption readiness because it can bridge the middle ground between the feasibility of a new technology (innovation) and the needs of the community (policy). Greater CO between innovation and policy allows users to experience the technology through a familiar context (Carlet, 2015; Damanpour & Schneider, 2009). In other words, high CO means less of a knowledge gap, which means more familiarity, which allows for higher feasibility. Decision makers evaluate CO of specific innovations, such as green infrastructure, to tackle these issues. This suggests that a greater sense of compatibility between community and technology (in this case PC) is desirable. The more aligned those two things are from the start, the higher the sense of usefulness and ease of use. This, as described in TAM theory, can greatly contribute to higher levels of adoption readiness (Carlet, 2015; Rogers et al., 2008).

Internal Readiness (comprehension and affordability)

Perceived internal adoption readiness in the context of this study is the extent to which adopters perceive their community as ready to embrace and effectively utilize PC. Internal readiness consists of two primary components. The first is the perceived internal capacity to understand the management, planning, or engineering of PC. The second is the perceived availability of financial resources to support PC's adoption. Researchers propose that positive organizational readiness influences attitudes by enhancing perceived ease of use and usefulness (Carlet, 2015). Lack of familiarity with an innovation increases risk and uncertainty, hindering adoption and implementation rates. Conversely, communities equipped with resources and understanding of the innovation experience lower uncertainty and perceived complexity, thereby increasing the likelihood of adoption. Early adopters may have a stronger sense of internal readiness and therefore find the same innovation to be easier and more useful than late adopters. There is evidence that levels of internal readiness positively influence perceived usefulness and ease of use due to a reduced sense of complexity surrounding an adoption (Carlet, 2015).

Porous Concrete

Porous concrete had its origins well before its use in green infrastructure. Starting in 19th century Europe with a second emergence post WWII, PC reduced construction costs during times of scarce materials. Air voids were created through the absence of sands/fine aggregates and carefully controlled amounts of water, which compensated for volume. In the 1970s, the United States began using PC in the context that this paper applies to it – green infrastructure (Chopra & Wanielista, 2006). These days, the definition of PC commonly refers to a technology which absorbs, controls, and mitigates runoff through a porous surface with underlying layers of varying materials and depths (depending on factors such as desired functionality and cost) which help prevent hazards associated with runoff and flooding (Kim et al., 2019; Moretti et al., 2019; Tota-Maharaj et al., 2021; Yu et al., 2021). Most PC is composed of a top-level draining asphalt/concrete layer, a subsequent aggregate layer which absorbs runoff, and a reservoir layer. The above-mentioned air voids, which were originally a means of reducing cost, are what create the permeable surface layer. The reservoir is sometimes made of a waterproof membrane which directs runoff back into the nearest storm drain. Other times, it consists of channels which allow for local and gradual groundwater recharge (Antunes et al. 2020).

Services Associated with PC

Pollutant Removal

Stormwater runoff poses a risk to water quality by transporting pollutants. Problematic substances like suspended solids, phosphorus, nitrogen, oils, heavy metals, and pathogens, can be transported into local rivers, streams, and groundwater, leading to deteriorating water quality, and harming aquatic ecosystems (Moretti et al., 2019; Tota-Maharaj et al., 2021; Yu et al., 2021). These pollutants are most prominent during the start of a rain event in what is referred to as the "first flush." Between rain events, pollutants accumulate on roads and other impermeable surfaces. Subsequently, the next rain event's initial runoff carries significantly higher pollutant concentrations than throughout the rest of the precipitation period (Randrianarimanana et al., 2017). Common definitions of first flush can be categorized into two types: A "concentration" first flush, which focuses strictly on the pollutant concentration, and a "mass" first flush, which depends on the flow of water in addition to pollutants (Maniquiz-Redillas et al., 2022). This thesis refers to the concentration-specific definition. There is evidence that PC's top layer traps most pollutants from runoff, which means cleaning may be readily achievable (Kuruppu et al., 2019). Also, PC has been shown to be highly effective at runoff treatment since the channels through which the water moves are much smaller than, for example, the space between cobblestone bricks. This allows for slower yet more thorough filtration of the runoff (Kim et al., 2019).

Peak Flow Attenuation

Flooding due to heavy precipitation events is the most serious weather-related threat for the West Coast of the United States (Warner et al., 2012). Between 1980 and 2008, flooding events in California, Oregon, and Washington caused more than $11 billion in damages. Since 1955, flooding associated with heavy precipitation accounts for roughly 68% of presidential disaster declarations in Washington State and 66% of declarations in Oregon, and 35 of 192 declarations in California (Mass et al., 2011). Some models project changes in annual average precipitation due to an augmented seasonality to the rain cycle with wetter autumns/winters and drier summers (Mote & Salathé, 2010). These increases in intensity, duration, and frequency of precipitation may negatively affect stormwater and wastewater facilities, augment urban flood risk, and lead to other public safety and water quality issues (Morgan et al., 2021). Since heavy rain events are projected to become more common in the PNW as climate change advances, there is a calling to prepare for an increase runoff flows as well.

During rain events, the rate in which the runoff enters the drainage system can be slowed down by using technologies like PC. One study examined the varying impacts of development under four distinct rainfall conditions: 1-year, 2-year, 5-year, and 10-year periods. Findings indicated that SLIDRS (Sustainable Low-Impact Development Retrofit Strategies), including PC, effectively reduced peak flows and overall runoff volume (Miao et al., 2019b). These results show promise of a practical solution for addressing urban flooding issues in the local area.

Evaporative Cooling

Pavement can trap significant amounts of heat and prevent evaporative cooling which makes urban areas hotter than the surrounding environment. This is known as Urban Heat Island (UHI) effect. Especially during summer months, heat waves can exacerbate UHI effects and negatively impact human health and wellbeing when temperatures get too high (Haselbach et al., 2011). There is evidence that PC can be an effective method of UHI alleviation in both wet and dry conditions, but most effectively through evaporative cooling (Chen et al., 2019). Residual moisture in PC left over from previous rain events combined with the high internal surface area of PC allow for faster removal of stored heat and lower surface temperatures compared to traditional concrete for one or two days after rainfall, as well as reduced potential for thermal shock (Haselbach et al., 2011). Researchers from one study were able to develop a type of "evaporation-enhancing" PC that could lower surface temperature by an additional 9.4 °C, resulting in a summertime surface temperature 15.3 °C cooler than traditional concrete (Liu et al., 2020).

Road Noise Reduction

Road noise is largely generated from air being compressed and then released between the road and a vehicle's tires as it travels. Researchers have explored alternative pavement surfaces to mitigate road noise, with PC being a promising solution. Since PC is covered in tiny holes and passageways, the air can expand into these areas as the tires roll over the surface, reducing road noise. In 2021, Zhong et al. published a review which found that alternative materials, such as oil palm kernel shell and cockle shell, can partially replace aggregates to produce even quieter PC pavements. Furthermore, they determined that a linear relationship exists between pore connectivity and acoustic absorption, indicating that well-connected pores enhance noise reduction. Theoretical models examined in the review successfully predicted PC's acoustic absorption by improving connectivity within the porous structure.

Barriers to Adoption

Maintenance

PC maintenance must be done on a much more frequent basis than traditional pavements, given the porous and multi-layered structures within the system. Clogging is the primary cause for performance failures, largely due to fine pieces of the pavement being worn off and into the pores (Welker et al., 2013). Furthermore, there is evidence that shorter term, heavier rain events introduce more substantial loads of particulate matter than lighter rain events (Kim et al., 2019). PC is rigid, and cracking can readily occur after their load-bearing capacity is surpassed. These crack patterns then propagate throughout the system, allowing water to flow in faster. As a result, clogging accelerates owing to the higher flow rate (Kim et al., 2019; Sansalone et al., 2012). Thankfully, proper upkeep has been shown to allow for an almost full recovery of the system. One study by (Kuruppu et al., 2019) examined two methods for maintaining PC: vacuuming and sonication (power washing). Using these methods, 96% and 99% of the initial performance could be recovered after clogging, respectively. Results also indicated that quarterly maintenance is necessary to maintain a PSS performance of at least 0.02 mm/s.

Uncertainty

There are key uncertainties, both scientific and socio-political, that impede PC adoption. Despite proven advantages over grey infrastructure, PC implementation (as well as green infrastructure in general) remains slow due to concerns about performance, costs, and willingness to pay (Thorne et al., 2018). Limited conceptual knowledge of green infrastructure technology such as PC also heavily plays into concerns of uncertainty. Lack of familiarity with an innovation increases risk and uncertainty, hindering adoption and implementation rates. Conversely, communities equipped with resources and understanding of the innovation experience lower uncertainty and perceived complexity, making adoption more likely (Carlet et al., 2015; Thorne et al., 2018). Socially, many potential stakeholders express uncertainty towards methods of gaining public support and are weary of regulations that are not typically associated with infrastructure (Carlet, 2015; Shandas et al., 2020). Overcoming these uncertainties is crucial for successful GI implementation.

To summarize, climate change is intensifying precipitation patterns in Washington State and urbanization continues to expand. Therefore, the need for sustainable infrastructure is increasingly valuable. PC offers a multifunctional approach by addressing multiple issues such as urban heat island effect, peak flow attenuation, pollutant removal, and reduced sound pollution (Miao et al., 2019; Sansalone et al., 2012; Zhang et al., 2021; Zhong et al., 2018). However, its integration into existing urban structures necessitates a comprehensive evaluation based on the criteria outlined in this literature review. TAM serves as a guiding framework to determine readiness for acceptance of PC (Carlet, 2015). Perceptions of usefulness, ease of use, compatibility, and internal readiness have been shown to significantly influence the adoption innovations such as PC. Understanding these factors requires a holistic approach that acknowledges the multidimensional and interdisciplinary nature of infrastructure planning (Ellis et al., 2004). Challenges surrounding PC implementation such as maintenance requirements, vulnerability to clogging, and conceptual uncertainty are key barriers to acceptance. Adoption of PC as a form of green infrastructure is a step towards sustainable urban development.

Case Study

Methods

The above-mentioned criteria for TAM were integrated into a survey. TAM concepts were woven into the survey using both deductive and inductive language coding. This study utilized surveys composed in Google Forms; a digital format meant to conserve paper resources and provide convenience to participants. surveys that were distributed based on convenience sampling protocols according to (Kanazawa, 2024). Most questions were multiple choice. To ensure that responses properly addressed the questions, most multiple-choice questions included an open-answer option. This design was to allow participants to include things relevant to, but not included in, the survey. Deductive and inductive coding methods were both applied to this study, described in more detail below.

Coding for Ease of Use and Perceived Usefulness

The deductive coding for this study was set up beforehand to determine how participants perceive ease of use in this study, the survey provided eight statements to be rated on a 6-point Likert scale from "strongly agree" to "strongly disagree" as shown in (Figure 4). The statements were split into three categories: three questions related to costs (IR), two related to personal compatibility (CO), and three questions related to performance (PU). The goal was to see if internal readiness, compatibility, or perceived usefulness are the most prominent factors in participants' perceived ease of use. In a similar fashion, the five features of porous concrete mentioned in the Barriers to Adoption section were ranked on a scale of "not relevant" to "highly relevant" to see how respondents view PU.

Inductive coding was applied to the open responses provided by participants regarding any concerns or curiosities they had. When transcribing responses, mentions of costs, clogging or cleaning were factored into considering a person's perceived ease of use. Other concerns mentioned multiple times were filtration limits, lifespan, and partial function (only sufficient when combined with other green technologies), factored into a respondent's PU for this analysis.

Site Selection

Participants were selected as random passers-by and handed surveys at four locations: two of which are the Olympia Food Co-op East and West locations, as well as The Evergreen State College and the San Francisco Street Bakery. I chose Evergreen's campus and the two Olympia Food Co-op locations because people there tend to have a more sustainability-focused, progressive (as opposed to conservative) worldview. The key difference between these locations is that the average age of participants will likely be lower at Evergreen. My fourth location was San Francisco Street Bakery's on-site bulletin board.

Data Collection

Collections of survey results took place over two weeks from February 12th to March 23rd, 2024. Participants were given two options for taking the survey. The first option was to scan a QR code that I provided, using their own phone. The link opened the survey webpage on their device, at which point they were able to take the survey on the spot, or later in their own time. The second option, for those who were not interested or able to scan QR codes, was for me to record their email addresses and send them the link to the survey at the end of the day. To help ensure random selection of participants, I stood near the entrance/exit with a repeating 5-minute timer. At the conclusion of each 5-minute increment, I asked the next person that passed me to take the survey. During the times I was not present, flyers remained posted with QR codes as well as my email address for people to access any time within the collection period. All flyers and QR codes were removed at the conclusion of the collection period.

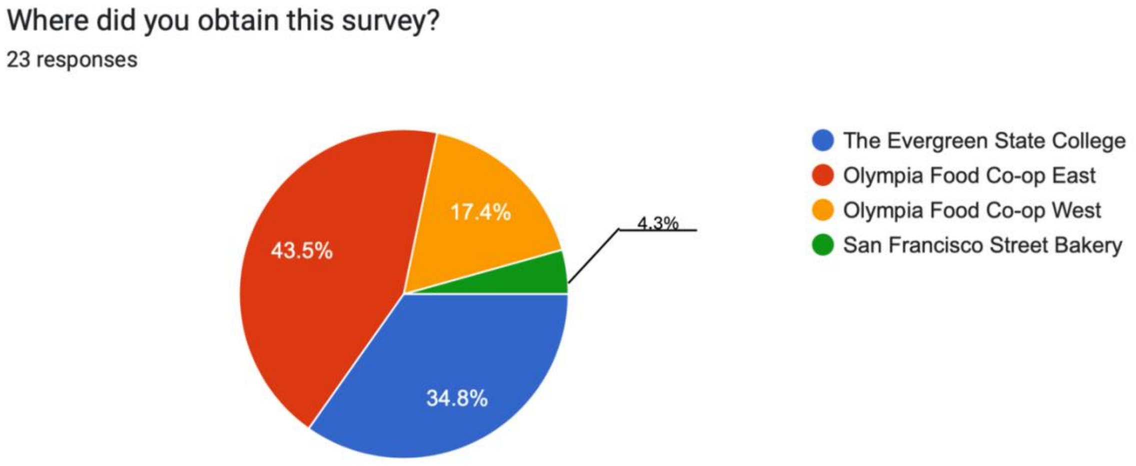
Results

Demographics

Of the four locations, the east side Olympia Food co-op had the most participants at 43.5% of responses (Fig. 1). I would imagine this is due to the high-level of traffic compared to the other survey sites, as well as the fact that since the participants were out grocery shopping that may have provided a more opportune time for people to participate or make arrangements to participate later. Most respondents were between the ages of 18 and 44 with respondents 45 and up representing only 18% of the group (Fig. 2). 63.6% of respondents were White, with the next largest group, Asian, being only 13.6% of respondents. Black and Hispanic respondents each made up 9.1% of the group, and the remaining 4.4% identified as Native American (Fig. 3).

Figure 1

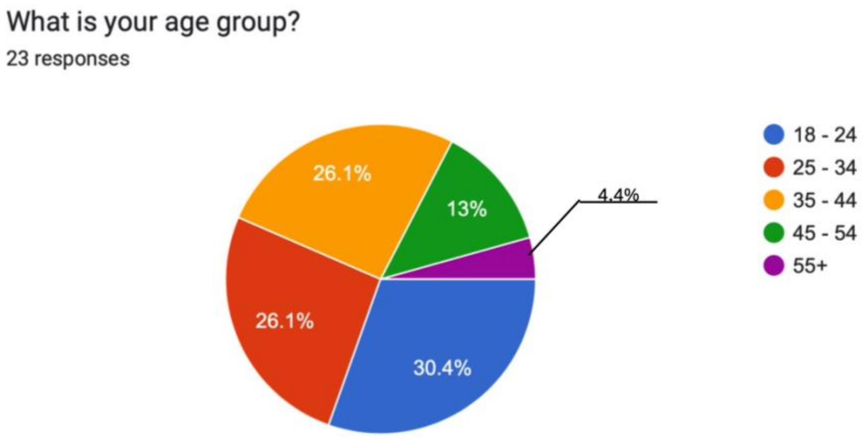
Survey Location Popularity



Note. These locations were chosen in because they have public bulletin boards for the survey flyers. Chart created in Google Sheets.

Figure 2

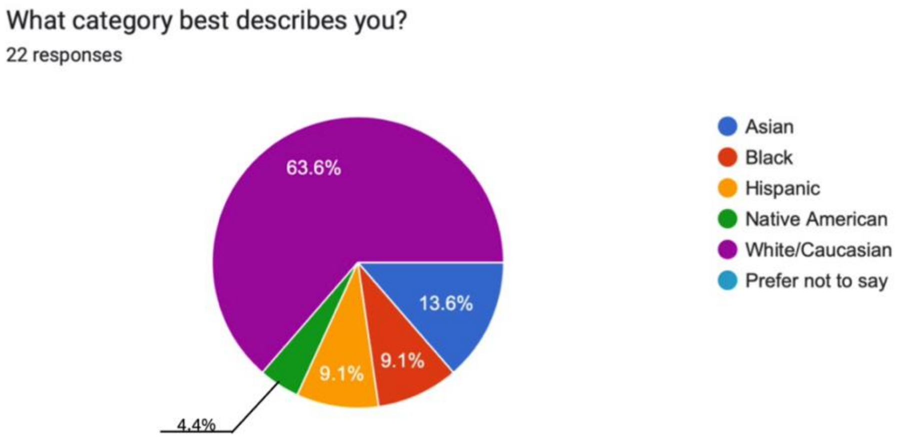
Proportions of Participant Age Groups



Note. Chart created in Google Sheets.

Figure 3

Racial/Ethnic Identities of Respondents

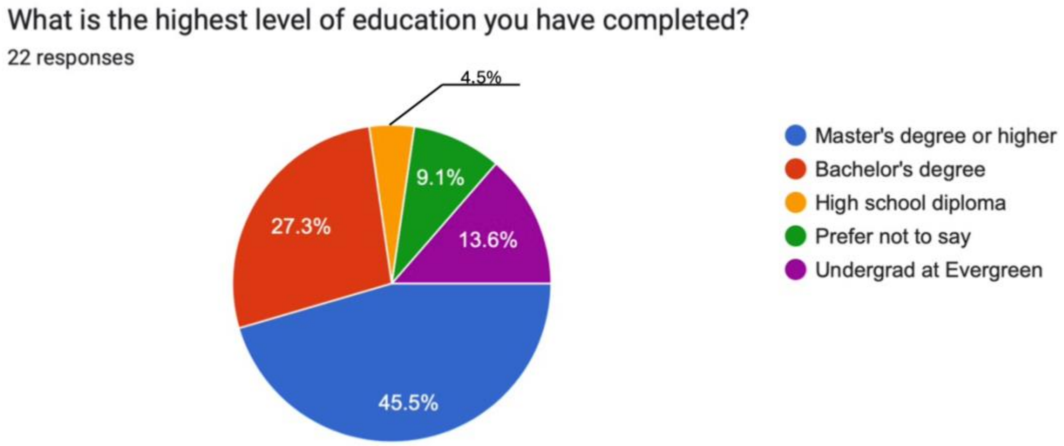


Note. One respondent did not answer this question. Chart created in Google Sheets.

A second finding that stood out was the similarity in proportion of users with a master's degree or higher (45.5% of respondents) (Fig.4) and annual income below $25,000 (43.5% of respondents) (Fig. 5), as well as the similar proportions between having a bachelor's degree (27.3% of respondents) (Fig. 4) and making $75,000 to $100,000 per year (21.7% of participants) (Fig. 5). This suggests that the participants with the highest degree levels are not necessarily the highest income earners. Half of the respondents were single, and almost 1 in 10 participants chose not to disclose their marital statuses (Fig. 6).

Figure 4

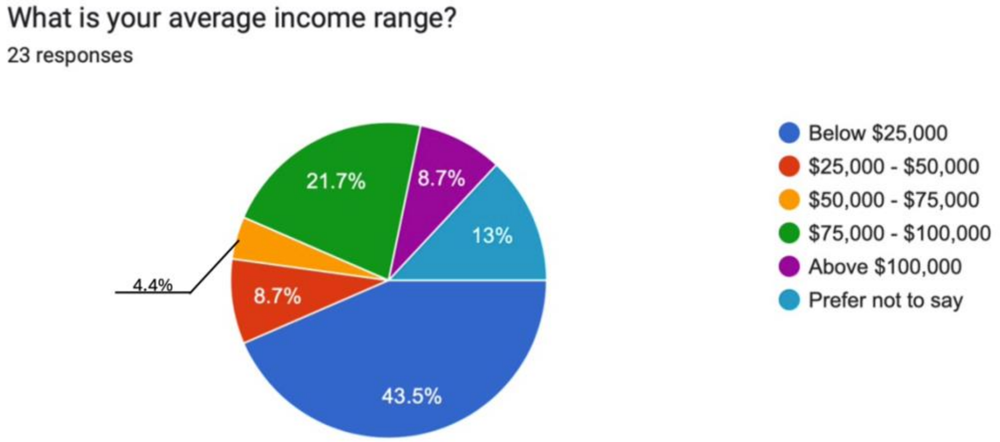
Levels of Completed Education Among Participants



Note. One respondent did not answer this question. Chart created in Google Sheets.

Figure 5

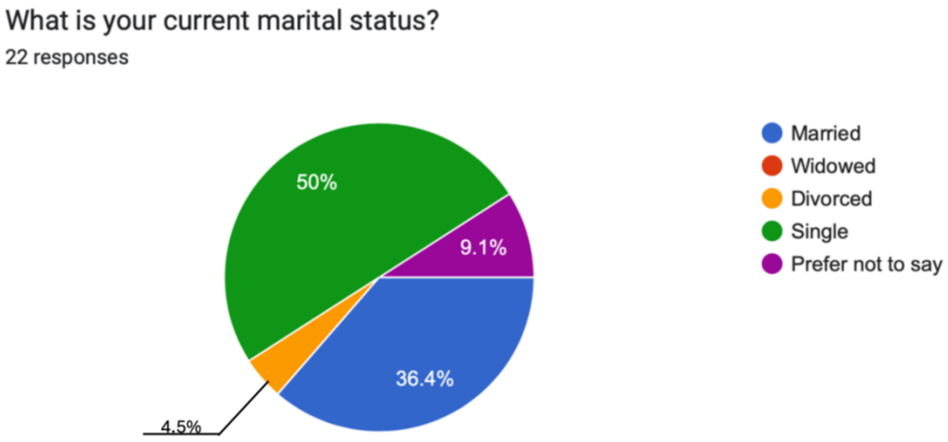
Average Income Ranges Among Participants



Note. Chart created in Google Sheets.

Figure 6

Participant Marital Statuses



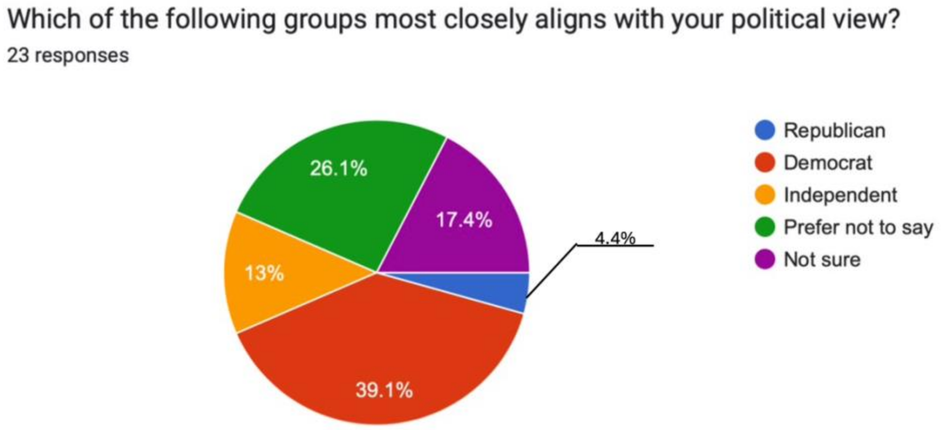
Note. One respondent did not answer this question. Chart created in Google Sheets.

To my surprise, although I chose locations which I considered to be progressive-minded, political alignment was shown to be one of the most diverse sets of respondents, with 17.5% of them choosing “unsure” (Fig.7).

One other interesting outcome of the study showed that most participants had only lived in Olympia for some time between one and five years (Fig. 8) and were living in rental households (Fig. 9). This is an invitation to conduct the study again in five or more years to see if the housing trend changes among participants.

Figure 7

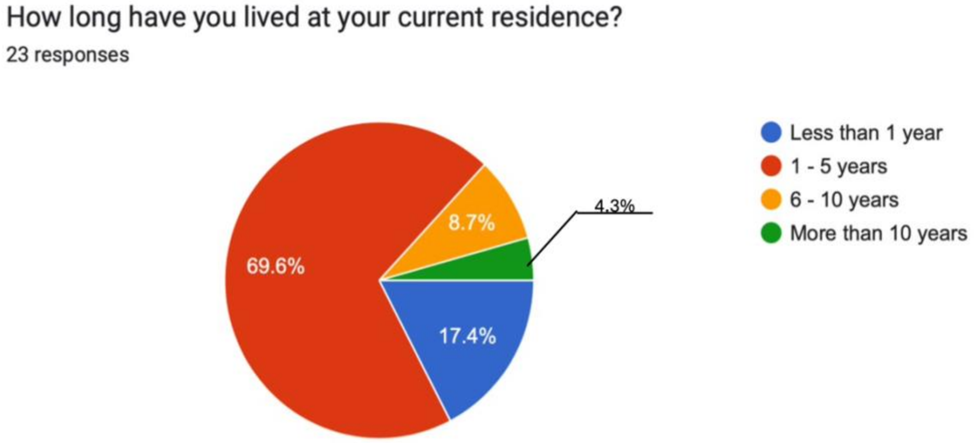
Political Alignments Among Participants



Note. Chart created in Google Sheets.

Figure 8

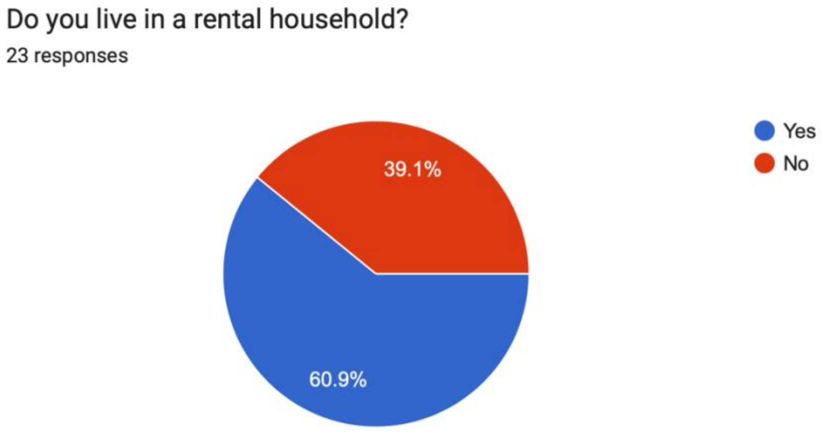
Residence Time in Years Among Participants



Note. Chart created in Google Sheets.

Figure 9

Proportion of Homeowners Compared to Renters Among Participants



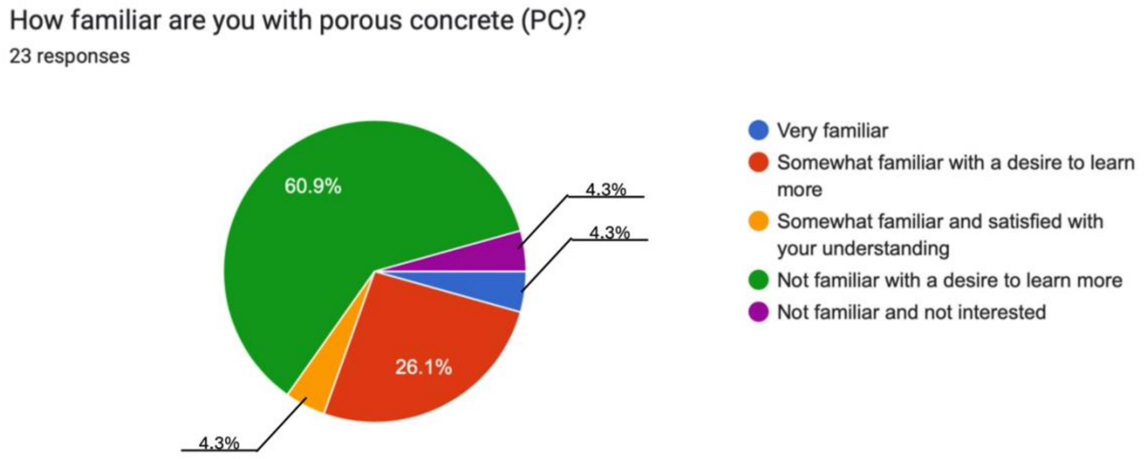
Note. Chart created in Google Sheets.

Familiarity

60.9% of respondents classified themselves as an individual that is not familiar with porous concrete but has a desire to learn more about it. The second most abundant response group belongs to the “somewhat familiar with a desire to learn more” category (Fig. 10). Combined, this shows that 87% of participants want to learn more about PC, which indicates a high level of interest.

Figure 10

Perceived Familiarity with Porous Concrete



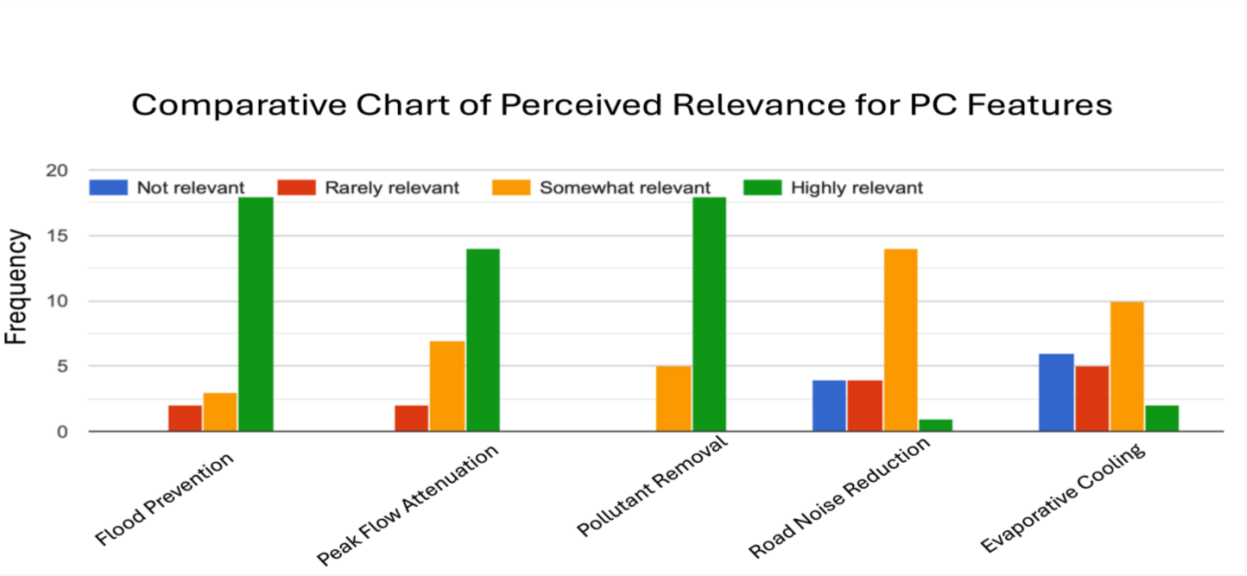
Note. Chart created in Google Sheets.

Relevance and PC Function

Among the five categories of PC features, stormwater pollutant removal ranked first and relevance with 18 respondents considering it highly relevant and five respondents finding it somewhat relevant (Fig. 11). Flood/standing water prevention came in second, also with 18 respondents finding it to be highly relevant, but two of the remaining five found it to be rarely relevant (Fig. 11). While peak flow attenuation also showed high perceived relevance, there was more variation in perception compared to the aforementioned features.

Figure 11

Perceived Relevance of Porous Concrete Features



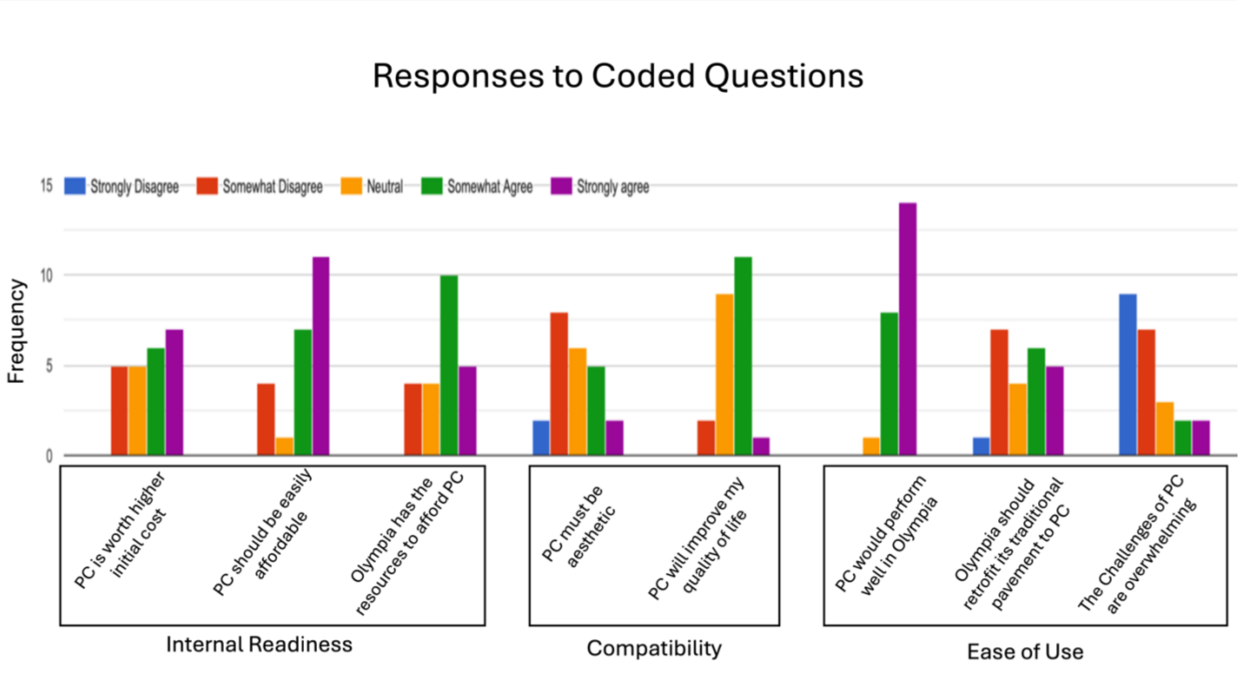
Note. This chart provides a visual comparison of perceived relevance among given PC features. Chart created in Google Sheets.

<u>*Coded Statements*</u>

Deductively coded questions for internal readiness show high levels of acceptance, with no respondents claiming that they strongly disagree with any of the statements (Fig. 12). Furthermore, there were stronger levels of agreeance for PC being easily affordable than PC being wroth the higher initial cost. This suggests a combination of some willingness to pay, but with a desire for costs to be lowered if at all possible. In contrast, perspectives regarding aesthetic value and quality of life, which represent compatibility, were quite varied. This could indicate that people are more focused on practical functionality when it comes to porous concrete and less focused on aesthetic appeal or personal enjoyment when using it. Finally, the three graphs on the right are responses related to perceived ease use. One thing to note is that the last question (far right) gauges perceived of use in an inverted format by asking about how overwhelming porous concrete seems rather than how easy it seems.

Figure 12

Responses to Descriptively Coded Statements



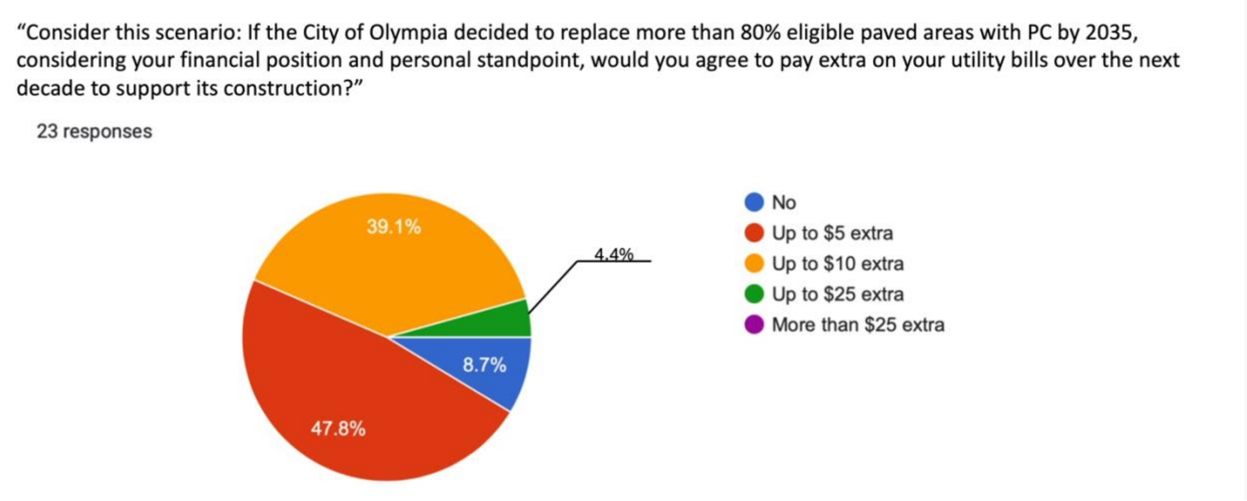
Note. Black boxes represent which criteria was coded for internal readiness, compatibility, and ease of use. Chart created in Google Sheets.

Public Payment

The survey results offer a clear snapshot of public sentiment regarding the financial support for the implementation of porous concrete (PC) in the City of Olympia. When asked if they would agree to pay extra on their utility bills over the next decade to support the replacement of more than 80% of eligible paved areas with PC by 2035, a significant majority of respondents indicated some level of willingness financially support the idea (Fig. 13). 47.8% of respondents were willing to pay up to $5 extra, 39.1% were willing to pay up to $10 extra, and 4.4% were willing to pay up to $25 extra on their utility bills. Only 8.7% of respondents outright rejected the idea of paying extra, and no respondents were willing to pay more than $25 extra. These findings suggest a moderately strong adoption readiness of PC among respondents, moderated by financial considerations. The fact that 91.3% of respondents are willing to pay *something* extra indicates broad acknowledgment of the potential benefits of PC and a general support for its implementation. That being said, the majority's preference to cap their additional payment at relatively low amounts (up to $10) underscores the importance of considering the financial impact on residents when planning the funding strategy for such projects. The relatively small percentage of respondents willing to pay up to $25 extra suggests that while there is strong conceptual support, the financial commitment may be a limiting factor.

Figure 13

Identifying Acceptable Costs for Public Payment of Porous Concrete



"Consider this scenario: If the City of Olympia decided to replace more than 80% eligible paved areas with PC by 2035, considering your financial position and personal standpoint, would you agree to pay extra on your utility bills over the next decade to support its construction?"

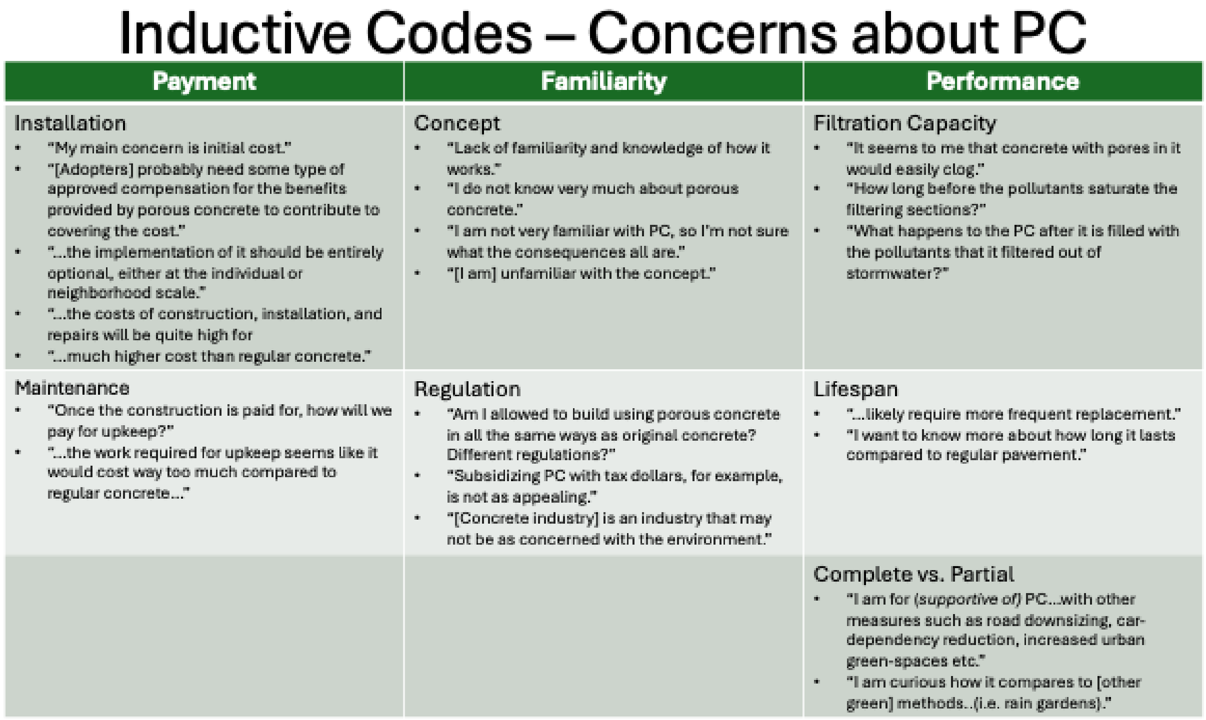
Note. Chart created in Google Sheets.

Inductive Codes

Many of the concerns associated with porous concrete were the costs of installation and maintenance, and there was some variation in the way respondents thought the costs should be covered publicly or left to individual choice (Table 1). This raised some questions about whether public sidewalks or private driveways/parking lots would receive greater support. In terms of interest, respondents expressed a need for more widespread awareness regarding PC.

Table 1

Inductive Codes Generated from Open-Answer Responses



Inductive Codes – Concerns about PC

Payment	Familiarity	Performance
Installation • "My main concern is initial cost." • "[Adopters] probably need some type of approved compensation for the benefits provided by porous concrete to contribute to covering the cost." • "...the implementation of it should be entirely optional, either at the individual or neighborhood scale." • "...the costs of construction, installation, and repairs will be quite high for • "...much higher cost than regular concrete."	Concept • "Lack of familiarity and knowledge of how it works." • "I do not know very much about porous concrete." • "I am not very familiar with PC, so I'm not sure what the consequences all are." • "[I am] unfamiliar with the concept."	Filtration Capacity • "It seems to me that concrete with pores in it would easily clog." • "How long before the pollutants saturate the filtering sections?" • "What happens to the PC after it is filled with the pollutants that it filtered out of stormwater?"
Maintenance • "Once the construction is paid for, how will we pay for upkeep?" • "...the work required for upkeep seems like it would cost way too much compared to regular concrete..."	Regulation • "Am I allowed to build using porous concrete in all the same ways as original concrete? Different regulations?" • "Subsidizing PC with tax dollars, for example, is not as appealing." • "[Concrete industry] is an industry that may not be as concerned with the environment."	Lifespan • "...likely require more frequent replacement." • "I want to know more about how long it lasts compared to regular pavement."
		Complete vs. Partial • "I am for (*supportive of*) PC...with other measures such as road downsizing, car-dependency reduction, increased urban green-spaces etc." • "I am curious how it compares to [other green] methods..(i.e. rain gardens)."

Note. This table shows response excerpts which indicated emergent themes among responses. Themes identified from the excerpts belonged to one of three groups: payment, familiarity, and performance.

Discussion

These findings have several implications. To start, the demographic composition of the respondents showed most participants resided in rental households and had lived in Olympia for only one to five years, possibly suggesting a transient population that may warrant future study on adoption readiness over time. Individuals who reside in their homes for longer than five years have a higher chance of encountering local green infrastructure than those who are more transient. Also, since almost two-thirds of the respondents were white, it would be interesting to conduct a similar survey study on reservation land or in another location where the minority demographics are more strongly represented to determine if that would illustrate significant differences in perspective.

Additionally, prominent levels of interest from participants were corroborated by responses indicating a high perceived relevance of various PC features. This supports the notion that lower levels of uncertainty are often linked to greater levels of adoption readiness (Carlet et al. 2015). The high levels of interest in and perceived relevance of PC's features also highlight a potential opportunity for local authorities and stakeholders to prioritize the implementation and promotion of PC as a sustainable stormwater management solution. These results underscore the importance of engaging with community members in public spaces to gather diverse perspectives on environmental initiatives like porous concrete.

While this thesis presents valuable insights on PC and adoption readiness, there are some shortcomings that future research could address. Firstly, the relied heavily on convenience sampling, limiting the generalizability of these findings. Participants were selected from locations known for their progressive and sustainability-focused worldview, which may bias the results towards more favorable opinions about PC. The research was also somewhat geographically confined to specific sites in Olympia. This potentially overlooked the perspectives of residents in other areas. Expanding the geographic scope and including a more representative sample could enhance the study's validity. Another possible limitation is the demographic representation of the sample. Most respondents were younger adults (18-44) and predominantly White, which may not reflect the views of older populations or more ethnically diverse groups. Incorporating more qualitative methods, such as interviews or focus groups, could provide richer, more nuanced data to supplement the data from this study.

Broader sampling across diverse locations, including urban and rural areas, could yield a more comprehensive understanding of public attitudes towards PC. Including underrepresented groups, such as minority populations or residents of reservation land, could reveal differing perspectives and enhance the inclusivity of the research. Longitudinal studies that track changes in public perception over time would also be valuable, as it would help to illustrate whether awareness and familiarity surrounding PC increases in the future. Additionally, since concerns largely related to costs, conducting cost-benefit analyses and studies on willingness to pay could help address financial concerns.

Conclusion

Increased adoption of green technologies in urban areas, coupled with growing awareness of climate change impacts, underscores the need for sustainable solutions to address environmental challenges. This study provides insights into the adoption readiness and public perception of porous concrete in Olympia, WA. By integrating the Technology Acceptance Model criteria of perceived ease of use, internal readiness, compatibility, and perceived usefulness into a survey, the research examined both deductively and inductively coded responses. Participants expressed a clear desire for more information about PC, underscoring the importance of public education and outreach in promoting sustainable technologies. The varied responses regarding costs and maintenance highlight the necessity of addressing financial feasibility and demonstrating the long-term benefits of PC to gain broader public support. Concerns primarily centered on installation and maintenance costs, as well as practical considerations such as cleaning and longevity. Implications of these findings also illustrated the need for continued research on adoption readiness over time, as well as opportunities for local authorities and stakeholders to prioritize the implementation and promotion of PC. Overall, the survey indicates a community that is receptive to the idea of porous concrete but emphasizes the need for an economically feasible approach to its adoption. Continued research and public education efforts are essential to further enhance adoption readiness and promote the resilience and sustainability of urban communities in the face of climate change.

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