Tampere University

DEBORAH KUPERSTEIN BLASCO

Exploring the Preventive Quality of Innovations in Adoption and Adoption Intention

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ACADEMIC DISSERTATION
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PREFACE

Coming from an "I'll do it tomorrow" culture, prevention has not always been my forte, so I would have never thought that my doctoral dissertation would revolve around this very subject. However, here I am. My research has taken me on a journey through the evolution of prevention, from the exciting development of the concept throughout history to its modern-day applications. I have also learned the how and why to make preventive decisions of my own (I might now be erring on the side of caution). My work has also shed light on the important role that prevention plays in contemporary society, where preventive decisions in environmental matters could significantly contribute to climate change mitigation and disease prevention.

Through this project, I seek to open the conversation on the preventive quality of innovations, a relatively unexplored topic that could have multiple practical applications that contribute to contemporary sustainability and resilience-building goals. This dissertation covers prevention and innovations, and the various elements bridging these two, seeking to shed some light on factors that promote the adoption of innovations with preventive qualities.

First, I would like to thank my supervisor Professor Saku Mäkinen and my follow-up group, Professor Teemu Laine, DSc. (Tech) Natalia Saukkonen, Senior Research Fellow Ulla Saari, and DSc. (Tech) Johanna Kirjavainen, who have all guided me throughout this path. Saku, you jumped on board from the very first day I pitched this topic when you said, "Debs, you might have something there," and gave me the confidence I needed throughout the way. Even though you have multiple roles across institutions, you continuously made me feel like being my supervisor was your leading role, always making time for me; your enthusiasm to keep learning inspires my path every day. Teemu, thank you for teaching me fundamental research skills during my time at the Cost Management Center. Natalia, thank you for being a role model in the doctoral path; your insights are valuable throughout my professional and personal paths. Ulla, thank you for taking the supervisory role without hesitation and guiding me this last year. Johanna, thank you for your support in the early stages of this work and for taking me in as a course assistant; you opened the doors for me to work with Saku.

Second, I would like to thank Professor Marko Torkkeli from LUT University for acting as the opponent of this dissertation. I would also like to express my most sincere gratitude to the pre-examiners of this work. I would like to thank Professor Ville Ojanen from LUT University and Professor Harri Haapasalo from the University of Oulu for the feedback on my work; your comments provided valuable remarks that helped me prepare for the defense. I would also like to thank Professor Bas Hillebrand, whose comments represented significant modifications in the first version of my work and improved it in ways I could not have figured out myself.

Third, I would like to thank Professor Miia Martinsuo for the feedback in the internal reviewing process and constant support along the way. I would also like to thank Anna Halonen for all the assistance, but especially, thank you for the uplifting words. Miia and Anna, thank you for providing the resources and encouragement that make this doctoral program very special.

Fourth, I would also like to express my gratitude to my colleagues who helped me write papers and conduct research; special thanks to Jussi Valta, Laura Valtonen (thank you for being my conference trip buddy), Tuomas Korhonen, and colleagues from the Center for Innovation and Technology Research and the Cost Management Center at Tampere University.

Fifth, I would like to thank my friends for supporting me during this process by providing positive words. Finally, my family. Gina, thank you for being my companion in life; our friendship brings light to my days. Papi, thank you for your unconditional support and for showing me how far faith, love, and intention can take you. And mumsy, I am who I am because of you; our morning calls inspire me to wake up early every day and give my best. Being your daughter is my greatest pride; thank you for being my guiding light.

As I have learned in the study of prevention, future events are unknown and unexpected, and I am excited to see what the future has in store for me and the topic of prevention in diffusion studies. I started this project with the destination in mind, but I am thankful and lucky for all the experiences and lessons that enriched the journey.

Tampere, 4 April 2023

Deborah Kuperstein Blasco

ABSTRACT

Among the choices that can be made to address pressing sustainability issues and build resilient societies, the adoption of innovations with preventive qualities represents an opportunity with untapped potential. The preventive quality of innovations is a distinctive feature of innovations that is directed towards avoiding a future, possibly harmful event. However, the adoption of innovations with preventive qualities can be challenged, as their benefits are delayed in time and difficult to observe. Prevention entails proactivity, and this proactive approach can contribute to achieving contemporary sustainability objectives, thus warranting efforts to understand the adoption of innovations with preventive qualities.

The study of innovation adoption has seldom considered the preventive quality of innovations outside of health-related applications. However, there are many innovations with underlying qualities of prevention where this aspect could influence adoption; for example, information security behaviors preventing cyber-attacks, wearable devices preventing future diseases, and green innovations and behaviors preventing environmental damage. Studies focusing on the adoption and diffusion of these innovations have not considered this preventive quality. Therefore, there is a research opportunity to study the preventive quality of innovations.

This dissertation aimed to explore the preventive quality of innovations, particularly toward building this construct further and identifying factors influencing their adoption. This objective was achieved through the following two research questions (RQs). How do the preventive quality and perceived attributes of innovations influence individual and organizational adoption and intent to adopt? How can adopter characteristics and background factors influence the adoption and intention to adopt innovations with preventive qualities?

Six articles covered a series of innovations with preventive qualities across different empirical settings to answer the RQs. All the studied innovations have underlying qualities of climate change prevention and mitigation within the construction and energy sectors. These innovations include the adoption of wood as a building material (Articles I and VI), the purchase of photovoltaic systems (Article II), support for the communal adoption of prevention products and services (Article

III), and intent to adopt photovoltaic systems through third-party ownership (Articles IV and V).

This work was conducted using a mixed methods approach through qualitative and quantitative methods. Qualitative methods (in-depth interviews and content analysis) were applied to explore how adopters perceived innovations with preventive qualities. These methods also helped explore the influence of the characteristics of the unwanted event that the innovation seeks to avoid. Quantitative methods (surveys, regression modeling, and Partial Least Squares Structural Equation Modeling) were then used to identify traditional elements covered across studies of innovation adoption, such as the attributes of innovations and the user and background factors that influence adoption and adoption intention.

The findings of these studies helped answer two RQs. Regarding the first RQ, this study identified the preventive quality of innovations to have a positive and influential role in the intent to adopt the innovation; the ability of photovoltaic systems to contribute toward climate change mitigation was a predictor of the intent to adopt. The five attributes of innovations perform differently for innovations with preventive qualities. Relative advantage is less tangible and present in personal forms; trialability and observability can be challenged, as benefits are delayed in time; compatibility might be context specific, as it requires individuals to be motivated toward a goal of prevention; and complexity from cause-and-effect relationships is high. Regarding the second RQ, adopter characteristics and background factors have been identified to influence the adoption of innovations with preventive qualities; these include gender, education, and knowledge about environmental issues.

Prevention might be challenging to foster; consequently, innovations with preventive qualities can be perceived as difficult to adopt and diffuse. However, this work found the preventive quality of the innovation to be influential and positive over adoption and adoption intention. Hence, findings in this work highlight the need to conceptualize preventiveness as a construct of innovations to understand better and promote the adoption of innovations with preventive qualities.

Future research should delve deeper into the preventive quality, which has now been measured as an influence over adoption; however, could it also be a mediator to other characteristics of innovations? Other avenues for future research include studying the factors behind the adoption of other types of innovations with preventive qualities in cross-cultural settings. Finally, an important research avenue is the further exploration of the characteristics of the unwanted event (namely probability and severity) and the role these play in adoption.

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ORIGINAL ARTICLES

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Article II. Kuperstein-Blasco, D., Valtonen, L., Saloranta, E., & Mäkinen, S. Influence of innovation attributes with preventive nature of innovation on intent to adopt: The case of photovoltaic systems in mass markets (2022). *Proceedings of the 2022 IEEE Technology and Engineering Management Conference TEMSCON Europe*, 1(1), 32–39. https://doi.org/10.1109/TEMSCONEUROPE54743.2022.9801946

Article III. Kuperstein-Blasco, D., Valta, J., & Mäkinen, S. (2022). Household support to adopt preventive innovations to mitigate climate change: A case of Finnish apartment buildings. *Proceedings of the 2022 International Conference on Engineering, Technology, and Innovation ICE-IAMOT*, 1(1), 311–318. https://doi.org/10.1109/ICE/ITMC-IAMOT55089.2022.10033288

Article IV. Kuperstein-Blasco, D., & Mäkinen, S. (2022). Adoption of a service with preventive innovation characteristics. *Proceedings of the Eurasia Business and Economics Society EBES Conference*, *1*(2), 453–458.

Article V. Kuperstein-Blasco, D., & Mäkinen, S. (in review). Recognizing the preventive quality in the adoption of innovations: the case of third-party ownership photovoltaic systems. Submitted to *Heliyon*.

Article VI. Kuperstein-Blasco, D. (2022). Incumbent actions in adopting preventive innovations: Cases in the Finnish construction sector. *Proceedings of the 2022 Industrial Engineering and Engineering Management IEEM Conference,* 1(1), 990–994. https://doi.org/10.1109/IEEM55944.2022.9989901

Author's contributions to the articles

The first paper was part of my work with the Cost Management Center at Tampere University. All authors developed the idea of the paper as a research output for the Wood for Good project. For this article, I contributed to data gathering (for interviews that were carried out in English), data analysis (interview coding in Atlas.ti software, and result presentation through visual representations of the data), and writing the original draft (contributions mainly in theoretical background and results sections). I was responsible for submitting and developing the paper based on peer-review comments.

Articles II to V were developed with my colleagues from the Center for Innovation and Technology Research at Tampere University and the Department of Mechanical and Materials Engineering at the University of Turku. The idea for Article II was developed in collaboration with co-authors from data collected by one of the co-authors. I contributed to writing the original draft, particularly the theoretical background, discussion, and results sections. For the results section, I interpreted the data analysis by one co-author by creating visual representations and identifying the implications of each significant variable to the dependent variable. I also submitted and further developed the paper based on peer-review comments. Furthermore, I presented the paper at the 2022 TEMSCON conference, held virtually in May 2022.

The idea for Article III was developed in collaboration with all co-authors from identified future study settings from Article II. For this article, I contributed to writing the original draft, specific sections on the theoretical background, discussion, and results. I created visual representations for the results section (tables included in the paper). I identified the best-fitting model and the implications of each variable to the dependent variable. Furthermore, after peer review, I played a leading role in paper submission and development and presented the paper at the 2022 ICE-IAMOT conference in Nancy, France, in June 2022.

The idea for Article IV was developed with the co-author, following future study settings from Articles II and III. For this paper, I conducted the quantitative data analysis (multiple linear regression modeling in SPSS software). I collaborated in the writing process, particularly with sections on the theoretical background, methodology, and discussions. I also had a leading role in paper submission and carried out the presentation of the paper at the 2022 EBES conference, held virtually in July 2022.

The idea for Article V was developed with the co-author seeking to explore prevention as a standalone construct over adoption intention. For this paper, I analyzed quantitative data (partial least squares structural equation modeling with SmartPLS4 and SPSS). I collaborated in the writing process, specifically with sections on the theoretical background, methodology, data analysis, and results. I will also take the leading role in submission and will be responsible for further developing the paper based on peer-review comments.

Article VI was developed as an independent publication where the idea was based on findings from Article I. This paper utilized the same dataset as Article I, for which data gathering was the only task not carried out independently but also in collaboration with members of the Cost Management Center at Tampere University. I presented this paper at the IEEM22 conference in Kuala Lumpur, Malaysia, in December 2022.

1 INTRODUCTION

1.1 Background and motivation

A quick online search on how to avoid unwanted events leads to strategies for hazard awareness, protection, and prevention. Being prepared for future unwanted events is a natural human trait that has been a cornerstone for species survival, historically acknowledged as the commonsense approach to misfortune, and is reflected in old proverbs, such as "an ounce of prevention is worth a pound of cure." However, people are hopelessly irrational in decision-making (Klein et al., 1993, p. 13), and there is a significant divergence between proverbial wisdom and action that continues to puzzle many (Fielding, 1978).

Prevention entails stopping something from happening; it leads to a non-event (Rogers, 2003, p. 234), so how can one see the benefits of stopping something that has not happened or might not happen at all? This complex relationship between prevention and delayed or unobservable benefits afflicts innovations with direct or underlying preventive qualities. The preventive quality of innovations is a distinctive feature of innovations that is directed towards avoiding a future, possibly harmful event. This preventive quality describes an innovation's feature regarding prevention.

Efforts to study the adoption of innovations through their preventive quality and the benefits gained from prevention have been mostly directed toward health innovations (Cohen & Head, 2013; D'Souza et al., 2013; Lin & Bautista, 2017). However, there are other innovations with preventive qualities whose adoption has not been widely studied considering the role of the preventive quality; for example, business innovations for data loss prevention (Arbel, 2015), information security innovations for cyber-attack prevention (Mirtsch et al., 2021; Wynn et al., 2013) and green innovations for environmental damage prevention (Deltas et al., 2014).

Today, prevention seems timelier than ever. Preventive behavior is necessary for many areas in our lives, including health (disease prevention; Head & Cohen, 2012), business (data loss prevention; Arbel, 2015), and sustainability (climate change mitigation; Pardo Martínez et al., 2018). Prevention entails proactivity, and this proactive approach could contribute to contemporary sustainability objectives, such as those included in the Agenda for Sustainable Development of the United Nations (UN, 2021), in which sustainability refers to meeting the needs of the present without compromising the ability of future generations to meet their needs (UN, 2021).

Among the choices that individuals and organizations could make to achieve contemporary sustainability goals and build resilient societies is the selection of sustainable consumption and production patterns (UN, 2021). For this, the adoption of innovations with preventive qualities represents an opportunity with untapped potential. For example, with environmental innovations, we can deter climate change or mitigate its consequences (Overstreet et al., 2013), particularly when implementing these innovations in carbon-intensive sectors, such as the construction or energy sector. However, when we think about *clean* technologies, we seldom describe them as preventive. Furthermore, preventive behavior is challenging to foster because it requires individuals to be future-oriented (Allander & Lindahl, 1997) and motivated toward goals in prevention (Werle, 2011).

Environmental technologies and innovations have commonly been studied under "eco-innovations," referring to innovations that reduce the harm and deterioration of the environment (Leal-Millán et al., 2017). However, previous studies on eco-innovations (e.g., Driessen & Hillebrand, 2002; Rennings, 2000) have not incorporated the preventive quality into the innovation construct.

On the other side, research focusing on prevention in innovations dates to the late 1800s, but it has been mostly directed toward health innovations. Prevention research and successes have come primarily from economic and social pressure (Fielding, 1978). For example, most publications in the early 2000s focused on human immunodeficiency virus (HIV) prevention (e.g., Ross & Williams, 2002; Sikkema, 2005), as this epidemic was at its peak during these years. Present societal issues (UN, 2021) are creating pressure for researchers to currently focus on disease (Rizk et al., 2022) and climate change prevention (Pardo Martínez et al., 2018).

Recent publications focusing on prevention and climate change highlight how the effects of climate change can be averted and alleviated through different practices and policies, including strategies to prevent diseases from increased heat and sun exposure (Makin, 2011; Martinez et al., 2018) or for the adoption of health programs that fight climate-sensitive infections (Tong et al., 2016). Other studies focus on public perceptions (Pardo Martínez et al., 2018), preferences (Glenk & Fischer, 2010), and behaviors (Milinski et al., 2008) related to climate change prevention. Previous research has focused on identifying factors that promote or deter the adoption of these practices and innovations. However, little attention has been given to understanding the preventive quality as a construct of innovations.

1.2 Research objective and research questions

Understanding the factors influencing the adoption of innovations with preventive qualities presents an exciting research opportunity that could serve to meet contemporary sustainability and resilience goals. Therefore, this dissertation seeks to address a research opportunity identified in the study of innovation adoption by focusing on the preventive quality of innovations, particularly by *building this construct and exploring factors influencing their adoption and adoption intention*. Two main research questions (RQs) are proposed to meet this objective:

RQ1: How do the preventive quality and perceived attributes of innovations influence individual and organizational adoption and intent to adopt?

RQ2: How can adopter characteristics and background factors influence the adoption and intent to adopt innovations with preventive qualities?

A series of innovations is studied in different empirical settings at individual and organizational levels to answer the RQs. This dissertation investigates the adoption and adoption intention of innovations with preventive qualities related to climate change prevention and mitigation within the construction and energy sectors. The completed study seeks to build grounds for further research that can facilitate an understanding of and build the construct of prevention in the adoption of innovations.

1.3 Research scope and outline

This work focuses on the preventive quality of innovations and its role in adoption and adoption intention for innovations with preventive qualities related to climate change prevention and mitigation. The adoption of innovations refers to the selection of an innovation by an individual or organization (Rogers, 2003, p. 11). This work's main objects of analysis include the innovation and its attributes, the preventive quality of the innovation, and the adopters and background factors.

This dissertation is structured in a way that covers aspects identified as influential in the adoption of innovations by diffusion scholars (Rogers, 2003; Ryan & Gross, 1950). These aspects include the innovation and its characteristics (Rogers, 2003; Ryan & Gross, 1950) covered in Articles I, II, IV, and V, the adopter (Schultz et al., 2005) covered in Articles III and IV, and background factors (Dietz et al., 2002) covered in Articles I to VI. Additionally, this work explores the attributes of the unwanted event that the innovation seeks to prevent (Hofmann, 2016) in Article VI. This dissertation studies innovations as products (Articles I, II, III, and VI) and services (Articles III, IV, and V).

All innovations studied in this dissertation belong to the construction and energy sectors, two of the most carbon-intensive sectors (Huang et al., 2018). These two sectors are also known for their path dependency, which could deter the diffusion of new practices and technologies (Apajalahti & Kungl, 2022; Mahapatra & Gustavsson, 2008), where path dependency refers to previous decisions or practices affecting the present. Initiatives to break out of these paths are one of the basic questions in sustainability research.

Among the solutions to reduce carbon dioxide emissions in the construction sector, the incorporation of low-carbon building materials, such as wood, has been discussed (Viholainen et al., 2021). Seeking to analyze this pattern, Articles I and VI study the factors influencing wood material selection in school public procurement processes in Finland. Article I identifies potential paths leading to the stipulation of building material requirements in tender documents and a series of triggers for and deterrents to incorporating wood materials. This publication explores decision-making dynamics and factors behind the adoption of wood materials, calling for further analysis of the preventive quality of wood materials.

Similarly, the adoption of solar photovoltaic systems can potentially reduce greenhouse gas emissions in the energy sector (Wolske et al., 2017). Articles II, IV, and V explore this topic, focusing on individual adoption. Article II explores whether the preventive nature of innovations can influence the intent to adopt an innovation through a survey study. In this work, photovoltaic (PV) systems are classified as preventive. Through a statistical analysis, a linear regression model is created. This model identifies four significant variables associated with the intended period of PV system adoption. The significant variables are all related to the attributes of innovations, as described in diffusion studies, yet no variables associated with prevention are identified as statistically significant. This study explores the purchase of PV systems, and purchase cost is one of the most significant barriers to the adoption of PV systems; thus, the researcher sought to examine the role of prevention in other modes of ownership and to focus on only one aspect of prevention for study settings derived from this publication.

Covering innovations corresponding to the energy and construction sectors, Article III explores the factors that support the adoption of products and services oriented to environmental protection. This study focuses on Finnish apartment buildings, identifying the factors that lead to the support of communal housing projects to improve the environmental friendliness of the building. In this case, the investments of housing companies are classified as preventive, as they depict underlying qualities of prevention concerning environmental protection. A linear regression model is created through a survey study and statistical analysis. The model identifies three significant variables associated with supporting housing association projects that seek to improve environmental friendliness; these variables are related to adopter and usage factors. The study provides a path toward understanding the adoption of product and service innovations with preventive qualities.

Focusing on a trend for third-party ownership in the energy sector (Rai et al., 2016), Article IV investigates the adoption intention of photovoltaic systems through third-party ownership: renewable electricity contracts. Through a survey study, this work explores attributes of innovations and demographic and preventive factors that influence the intent to adopt the service. A statistical analysis of the survey responses yielded a linear regression model. This model identifies demographic variables, the attributes of innovations, and prevention variables that significantly influence the intent to adopt. Furthermore, the article finds that adopters have no interest in reputational benefits. These results bring to light the factors behind the adoption of innovations with preventive qualities.

Studying the same trend of third-party ownership in the energy sector (Rai et al., 2016), Article V studies the role of the preventive quality of innovations on their adoption intention. This article examines data collected from an online survey measuring intention to adopt. The study tests a series of hypotheses grounded in the preventive quality of innovations and the Diffusion of Innovations theory through Partial Least Squares Structural Equation Modeling. Findings reveal that innovations' preventive quality and relative advantage influence adoption significantly and positively. This study identifies the preventive quality of innovations as a standalone construct that acts as the most significant contributor to the dependent variable.

Finally, Article VI responds to the future study settings identified in Article I and explores the adoption of wood materials as an innovation with preventive qualities. The context of the article is an interview study that analyzes the public procurement of school buildings built from wood. This study finds that the probability and severity of an unwanted event make incumbents more likely to select wood materials. Future-oriented benefits are not deterrents to adoption but are often used to argue potentially larger investments. The article overviews prevention-related benefits derived from building materials and highlights what construction sector incumbents ponder when adopting innovations.

This dissertation is divided into five chapters organized as follows. Chapter 1 serves as an introduction that presents the background and objective of the dissertation, the corresponding RQs, and the scope of work. Chapter 2 presents a literature review of the concepts relevant to the dissertation that were also covered across the research articles. Specifically, this section introduces the topic of prevention, describes innovations and their classifications, provides a historical perspective of prevention and innovations across time, identifies factors influencing the adoption of innovations, and presents previous literature on the preventive quality of innovations. Chapter 3 provides each publication's research approach, context, data collection, and analysis methods. Chapter 4 presents the findings for each article, discusses the key findings according to the scope of the dissertation, and answers the RQs. Chapter 5 serves as a conclusion, in which theoretical and practical implications are discussed, the reliability and validity of the study are assessed, and limitations and future study settings are identified.

2 THEORETICAL BACKGROUND

2.1 Prevention

Prevention is the action of stopping something from happening. There are three different forms of prevention, as indicated in the traditional taxonomy of prevention: primary, secondary, and tertiary (Fielding, 1978). Primary prevention involves avoiding unwanted events altogether. Secondary prevention involves early detection and remediation. Tertiary prevention involves responses to alleviate or mitigate the consequences after the unwanted event has been experienced. Taking smoking as an example for the three levels of prevention, primary prevention would be discouraging the initial acquisition of the habit, secondary prevention would be offering smoking reduction and cessation programs to those who are addicted to it, and tertiary reduction would be providing medical therapy for those afflicted with diseases attributable to smoking (Fielding, 1978).

Closely linked to prevention is the risk attitude, which is a chosen response to uncertainty and is driven by perception (Hillson & Murray-Webster, 2007, p. 39). Perception is a key driver of risk attitudes, as it determines how a situation is seen, thus guiding the chosen response toward the situation (Hillson & Murray-Webster, 2007, p. 8). There are four primary risk attitudes: risk-averse, risk-tolerant, risk-neutral, and risk-seeking. Risk-averse individuals have a low tolerance for ambiguity and seek security. Risk-tolerant individuals are reasonably comfortable with uncertainty and accept risk as part of a normal situation. Risk-neutral individuals see risk-taking as part of the price worth paying for future benefits and are neither risk-averse nor risk-seeking. Finally, risk-seeking individuals fully welcome challenges of uncertainty, and the thrill of the chase can outweigh the potential for harm.

Prevention is widely covered in the insurance literature. When an asset is subject to loss because of an undesirable situation, a rational agent seeks protection that can reduce the probability or magnitude of the loss (Hofmann, 2016). In insurance economics, utility functions depend on the probability of unwanted events with specific loss sizes (Rees & Wambach, 2008); loss prevention addresses the probability and severity of the loss.

There are more elements considered in insurance economics studies, such as insurance cover and premium, existing wealth (Rees & Wambach, 2008), and market dynamics (Hofmann, 2016); however, these elements are oriented toward insurance policy purchases. This work will cover the attributes of the unwanted event in an exploratory fashion, namely probability and severity.

Probability is the extent to which an unwanted event is likely to occur; in non-technical contexts, it refers to situations where some undesirable event may occur (Hansson, 2004). Probability is associated with a loss of a specific size (Rees & Wambach, 2008), identified as severity, referring to how harmful the event and its consequences might be. The measures of probability and severity are frequently used when modeling expected loss (Cohen, 1984).

Probability and severity can be affected by subjective perceptions. While there are scales to determine the severity of unwanted events (e.g., severity scales for natural disasters or diseases), individuals might have different perceptions of the severity of events. Similarly, the probability of an unwanted event can be estimated; for example, individuals know whether they are cautious or reckless drivers (Rees & Wambach, 2008) and can therefore expect or deny the possibility of an unwanted event.

There are different ways in which individuals can prevent unwanted events. Prophylaxis, the action taken to avoid disease, has been widely discussed in the context of disease prevention (Fielding, 1978). Similarly, curtailment behavior has been covered in the context of climate change prevention and mitigation (Murphy, 2008, p. 216). Another way to prevent unwanted events is through preventive investments (Hofmann, 2016) or the adoption of innovations with preventive qualities (Rogers, 2002).

2.2 Innovations and their classifications

The scope of this research is innovations with climate change prevention and mitigation qualities; all concepts covered in this work are directed toward technologies with preventive qualities. Before exploring this subject matter, it is important to take one step back and understand the concept of innovation, which will be relevant throughout this work.

The history of the concept of innovation is characterized by ambivalence and tensions. The history of innovations deserves a work of its own, but it will only be briefly covered in this manuscript to highlight the complexities behind the subject.

In brief, the concept of innovation has a Greek background—*kainotomia*—dating back to the fifth century BCE. At first, the term meant "cutting fresh into" (Godin, 2015, p. 10). The term was later used by Greek philosophers when referring to the introduction of political change and by Latin writers when referring to renovation. While the concept was first introduced with a positive meaning, there were centuries when it was used with a pejorative connotation, particularly within religion, in which it shared a place with heresy and within the law, in which revolutionaries were referred to as "innovators of state" (Godin, 2015, p. 10).

Current representations of the term focus on novelty or newness. Joseph Schumpeter, the father of modern innovation studies, depicted innovation as doing things differently (Sweezy, 1943). The definition used in this dissertation is that of Everett Rogers, who proposed the Diffusion of Innovations (DOI) theory. According to Rogers, an innovation is "an idea, practice, or object perceived as new by an individual or other unit of adoption" (Rogers, 2003, p. 11). In this definition, the word "perceived" is critical, as it implies that whether an idea is objectively new does not matter, but the potential adopter's perception measures newness. If an idea seems new to an individual, it is an innovation (Rogers, 2003, p. 11).

Rogers (1983, p. 171) categorized innovations adopted to lower the probability of an unwanted future event as preventive innovations. However, there are many innovations with underlying qualities of prevention that are not only adopted for preventive purposes. Thus, this work focuses on the preventive quality of innovations, covering innovations with main and underlying preventive qualities.

While there is some agreement regarding what the term "innovation" represents, many definitions exist for different types of innovations. There is currently ambiguity in the way the word is operationalized and used. Furthermore, there is no consistency in the dimensions of innovations (Garcia & Calantone, 2002). Innovations are frequently classified into typologies that identify the degree of innovativeness of the innovation or its innovative characteristics. For example, there are dichotomous classifications of radical/incremental innovations (Rogers, 2003) or disruptive/sustaining (Christensen, 1997), triadic categorizations of low/moderate/high innovativeness (Kleinschmidt & Cooper, 1991), and tetra-categorizations of incremental/modular/architectural/radical innovations (Henderson & Clark, 1990).

Among other classifications that do not measure innovativeness are the product, service, and process typologies and the technological versus administrative innovation typologies. While the former classification describes whether the innovation has a tangible reference, the latter group separates innovations into those with technical applications and those seeking to change an organization's structures and processes (Keeley et al., 2013).

The *preventive quality* label in this work does not categorize the innovation but describes a main or underlying feature of the innovation concerning prevention. Among the innovations that can be given the preventive quality label, there are green or eco-innovations that seek to prevent and reduce environmental harm (Leal-Millán et al., 2017). Green innovations have been studied widely, ranging from topics on green innovation strategy (Soewarno et al., 2019) and types of green innovations (Xie et al., 2019) to the role of green innovation in environmental performance (Singh et al., 2020). However, previous studies on the adoption of green innovations (e.g., Driessen & Hillebrand, 2002; Rennings, 2000) have not incorporated the preventive quality into the innovation construct.

Worth mentioning is the difference between the adoption and diffusion of innovations. Diffusion is the process by which an innovation is communicated and spread through certain channels over time among the members of a social system (Rogers, 2003, p. 11). By contrast, adoption refers to the selection of an innovation by a unit of adoption (individual or organization). The context of this work is the adoption of innovations.

2.3 Prevention in innovations across time

Studies dealing with innovations and prevention date back to the 1800s. This section provides a historical overview of prevention in innovations as presented in the academic literature. The history of how prevention has been part of innovation studies and innovative practices helps us understand how this concept has evolved into what it is today. This historical overview illustrates long-standing attitudes to prevention, which have influenced the adoption of products and services of prevention since the 19th century.

2.3.1 1800s–1900s

At the beginning of the 19th century, great plagues had just been overcome, and the size of the population was steadily increasing. Mid-century, the evolution of the scientific method (and its application to the practice of medicine) and public health programs changed the nature of healthcare (Carlson, 1983). By this time, causal relationships were identified between health and environmental factors, such as the effects of sewage and water quality on the health of those exposed to them, so there were greater efforts to address these factors.

The first publications that included prevention and innovations appeared in scientific or medical journals. These publications depicted prevention as a new idea, as highlighted by Caley (1887), who identified prevention in medicine as a forward movement. According to Caley (1887), preventive actions are regarded as the business of public health systems and not of medical practitioners and even less of the community and proposed that preventable disease could not be tackled with the expert knowledge of the few but with the cooperation of many. Caley also highlighted that prevention is as important as the treatment of disease.

Early publications identified diverse innovations as tools for prevention (e.g., vaccines and the legislation promoting them). Work safety innovations were also introduced, such as a solution to dangerous conditions in building window cleaning, where cleaning could be done from the inside ("The Prevention of Window Cleaning Accidents," 1895). Finally, veterinary medicine strategies were covered in these early publications; for example, the British Medical Journal published an innovative method to prevent the spread of rabies ("The Prevention of Hydrophobia," 1885).

2.3.2 The early 1900s

By the turn of the century, a better understanding of the factors predisposing individuals to injuries and illnesses paved the way for preventive efforts to address them (Kemper, 1927). However, the growth of cities brought about new challenges and diseases associated with stress, unhealthy environmental conditions, and lack of rest and exercise, such as heart disease, diabetes, respiratory diseases, and cancer (Carlson, 1983).

Publications in the early 1900s reflected a wider acceptance of prevention and innovations. For example, Ward (1935) identified various factory accidents and introduced innovative methods to prevent them, such as creating a guard for paper-cutting guillotines. Ward also recognized prevention as a progressive science, stating that methods accepted during a particular time may no longer be applicable at other times. Other articles covered health applications (Kleinschmidt, 1944) or accident prevention and insurance, in which Kemper (1927) stated that loss prevention is as essential as indemnity.

Publications at this time also reflected a greater understanding of how innovations are accepted and adopted. For example, Ward (1935) identified the importance of evidence to support innovation and enable its general acceptance, which was later identified as *observability* in diffusion studies.

2.3.3 Mid-to-late 1900s

By the second half of the century, there was a clear understanding of innovation, prevention, and the elements behind their acceptance. Innovation studies dealing with prevention explored innovation and its attributes, dissemination strategies, and external influences, and they provided multiple applications. Rogers' DOI theory was published in 1962 and gained a broad presence in publications that covered prevention and innovation.

During the 1970s, the main discussion was about setting standards and legislation for prevention. Corrigan (1971) identified standards to facilitate prevention and accompanying legislation to ensure compliance. Corrigan analyzed standards and legislation in the context of the Poison Prevention Packaging Act, which was created to protect children from accidentally ingesting toxic substances by requiring safety packaging (a taken-for-granted standard nowadays).

Publications also called for a greater emphasis on prevention. Lave and Lave (1977) described preventive techniques as lacking and stated that therapeutic and preventive healthcare programs should be evaluated using the same criteria. Similarly, Freymann (1975) identified a general agreement that an illness prevented is preferred over a disease successfully treated.

By the 1980s, the volume of publications on prevention and innovations increased significantly. These publications explored multiple applications of prevention and innovations, including sexually transmitted diseases (Friedman et al., 1988; Margolis, 1981; Ostrow, 1989), public health disease prevention (Basch et al., 1988; Blackburn, 1983; Brandt, 1983; Butts & Beck, 2019), and workplace accident prevention (Fishback, 1987; Howard et al., 1988; Kaluzny et al., 1986). Notably, in 1989, Ostrow used the term "protective innovations" for behavioral and technological innovations created to prevent the transmission of HIV.

By the 1990s, prevention efforts started to be aligned with research on the attitudes, perceptions (Durfee, 1999), and values (Simons-Morton et al., 1997) of potential adopters. The innovation narrative was more complete; DOI vocabulary gained popularity in preventive practices (Durfee, 1999; Parham et al., 1993).

During this decade, Schneider (1988) was the first to mention prevention within innovation studies in an environmental context. This work identified prevention as the key to addressing hazardous waste pollution and innovative technologies as the tools to achieve emission reductions. Furthermore, laws called for toxic pollution prevention innovation plans (Guinn, 1994). Policies and prevention programs recognized organizations with innovative processes or devices in waste treatment and pollution abatement (Bobertz, 1992; EPA, 2021), focusing heavily on environmental protection through prevention. Publications sought to communicate the effectiveness of prevention compared with end-of-pipe approaches (Guinn, 1994), and environmental measures were viewed holistically, considering waste management, prevention, and integration (Wolters et al., 1995).

However, various deterrents existed to the adoption of prevention and preventive measures. For environmental technologies, guidelines for emissions were issued based on the best-performing technologies, even though innovative prevention technologies could have triggered more stringent limitations (Bobertz, 1992). Therefore, reducing environmental discharges was identified as a disincentive for pollution prevention. In the case of healthcare, very little funding was allocated to prevention research, representing 0.32% of the US healthcare budget in 1992 (Farquhar, 1996).

By the end of the decade, there was a better understanding of prevention in research, but there was a clear need to disseminate prevention programs and research outputs (Farquhar, 1996; Johnson et al., 1996; Valdiserri, 1996). Publications also identified the time-lapse dimension as a deterrent to the adoption of preventive measures; Farquhar (1996) highlighted that the "less dramatic and longer duration for a preventive measure to demonstrate its effects" is a determinant of inattention to prevention issues and dissemination research. Similarly, Allander and Lindahl (1997) described prevention as difficult and slow, in which "the lack of an adequate time perspective [is] among the greatest obstacles to prevention."

2.3.4 2000s onwards

From the turn of the century, twice as many articles have been published as in all previous decades combined. By this time, innovation studies have become widespread. Most articles related to prevention do not directly refer to innovation for prevention but primarily identify calls for innovations (Sawe, 2012) and innovative interventions (Grossman et al., 2011) as part of future research opportunities related to prevention.

In the 21st century, diffusion theory has been considered valid across myriad disciplines and has become more significant in prevention studies. Diffusion theory has been used to understand and promote the dissemination of prevention programs. For example, Sikkema (2005) identified that an effective HIV prevention intervention requires elements from social cognitive and DOI theory, mainly focusing on communication channels and social systems. On the other hand, Buller et al. (2007) used the concept of *opinion leadership* from diffusion theory to study the effect of endorsement on the dissemination of a smoking prevention program and identified that opinion leaders helped improve dissemination rates.

In articles whose main topic is related to innovations for prevention, the conversation was focused on HIV prevention, as this epidemic was at its peak during the first decade of the 21st century (e.g., Morisky & Tiglao, 2010; Ross & Williams, 2002; Schwarze & Hoffmeister, 2010; Sikkema, 2005). Other applications include innovations for policy and public health (Roe, 2004; Scrimshaw et al., 2001), prevention of financial and diplomatic crises (Haufler, 2009; Hopmann, 2018), and environmental and pollution prevention (Bennear, 2007; Müller et al., 2007).

Finally, articles depict the increased popularity of using digital and social media as tools for intervention and education regarding preventive behavior and innovations. For example, Morisky and Tiglao (2010) used storyboards to implement educational interventions to prevent sexually transmitted infections, and Bull (2014) explored the use of social media tools, such as Twitter and Facebook, and text messaging for the promotion of testing for sexually transmitted diseases. Finally, some studies cover mobile technology applications to increase engagement in prevention activities and as reliable sources for self-reported data collection (Grossman et al., 2011; Lin & Bautista, 2017). This historical overview illustrated the origin of attitudes that influence the adoption of innovations related to prevention.

2.4 Factors influencing the adoption of innovations

The adoption of innovations is the selection of an innovation by a unit of adoption, whether by an individual or a community (Rogers, 2003). As the scope of this research is innovations with qualities of climate change prevention and mitigation, the main discussion in this section will be oriented toward the factors influencing the adoption of these innovations.

2.4.1 Perceived attributes of innovations

Innovations should not be considered equivalent units of analysis (Rogers, 2003, p. 15). They can be distinguished through five characteristics as perceived by individuals, also known as the perceived attributes of innovations. These characteristics—relative advantage, trialability, observability, compatibility, and complexity—are relevant to distinguish innovations. This section will present these attributes and identify how they perform for innovations with underlying qualities of prevention, as highlighted in the existing literature.

Relative advantage is the degree to which an innovation is considered better than the previous idea (Rogers, 2003, p. 15). It is regarded as the strongest predictor of the adoption of innovations (D'Souza et al., 2013; Rogers, 2003, p. 232). Whether an innovation has a significant objective advantage is not too relevant, as the degree of relative advantage can be measured with economic, social prestige, personal, satisfaction, and convenience factors (Rogers, 2003, p. 16); what matters is the adopter's perception of the advantage.

The existing literature identifies that innovations with preventive qualities have difficulty transmitting relative advantage, as their benefits are delayed in time (Allander & Lindahl, 1997) and difficult to observe (Rogers, 1988). In diffusion studies, the time-lapse to see benefits is part of the relative advantage. For innovations with preventive qualities, the time lapse from adoption to beneficial consequences can be longer than that for other types of innovations (Rogers, 2003, p. 236), as is the case with insurance policies or contingency plans if they are never utilized (Overstreet et al., 2013). However, empirical settings depict a high relative advantage for some innovations with preventive qualities, such as HPV vaccines (D'Souza et al., 2013) and water conservation innovations (Lamm et al., 2017).

Trialability is the degree to which an innovation might be experimented on a limited basis (Rogers, 2003, p. 16). Ideas that can be tried on a limited basis are more likely to be adopted than those that cannot, as this represents less uncertainty for adopters (Ryan & Gross, 1950). Innovations with preventive qualities are often characterized by difficult or impossible trialability (Labay & Kinnear, 1981; Rogers, 1988). These innovations seek to reduce the probability of an unwanted event or to mitigate the severity of the consequences of the unwanted event; therefore, how can the event that adopters hope to avoid be tried out?

Another side of trialability is divisibility, which means that new ideas can be tried through installment plans (Rogers, 2003, p. 16). While it might be impossible to experience the trialability of some innovations for prevention (e.g., one cannot wear a seatbelt halfway nor get a lower dose of a vaccine), it is possible to experience other innovations on a limited basis (Sung & Slocum, 2004); e.g., getting a partial supply of electricity from solar panels or opting for a 30-day free trial of an antivirus software program.

Observability is the degree to which the results of an innovation are visible to others; the easier it is for individuals to see the results of an innovation, the more likely they are to adopt it (Rogers, 2003, p. 16). While some ideas are easy to observe and communicate to potential adopters, others are difficult to observe and describe. As the results of innovations with preventive qualities are delayed, they are not very observable (Rogers, 1988). Some innovations might also have non-observable benefits until they are implemented, such as insurance policies and contingency plans (Overstreet et al., 2013). However, the innovation can be visible and stimulate peer discussion among members of a social system (Korcaj et al., 2015). Similarly, peer observation can promote the diffusion of innovations (D'Souza et al., 2013).

Compatibility refers to the degree to which an innovation is perceived to be consistent with existing values, past experiences, and the needs of potential adopters; ideas that are more compatible with the values and norms of a social system are adopted more rapidly than those that are not (Ozaki, 2011; Rogers, 2003, p. 16).

Innovations with preventive qualities are often not very compatible with adopters' values, attitudes, or lifestyles (Rogers, 1988). Low compatibility can be identified in the slow adoption rate of specific innovations, such as seatbelts, which took decades of public safety campaigns to get most of the population to adopt (Rogers, 2003, p. 234). According to Rogers (2003, p. 16), the adoption of an incompatible innovation often requires the adoption of a new value system, which is a relatively slow process. However, empirical settings have identified strong technical compatibility between existing mechanisms and innovations with preventive qualities. For example, Roßnagel (2006) found a high degree of compatibility in electronic signature usage, and Philips and Lindquist (2021) identified compatibility as one of the most important characteristics influencing the adoption intention of green infrastructure innovations.

Finally, *complexity* refers to the degree to which an innovation is perceived as difficult to understand and use (Rogers, 2003, p. 16). Ideas that are simpler to understand will be adopted more quickly than those that require the adopter to develop a new understanding (Kinnunen, 1996). While innovations with preventive qualities are not necessarily more complex to understand and use than others, the cause-and-effect relationships can be complex, as identified in previous literature (Rogers, 1988). For example, D'Souza et al. (2013) found that the complexity of the human papillomavirus (HPV) influenced the adoption rate of the HPV vaccine; other factors that deterred vaccine uptake included misinformation and side effects. Similarly, complexity has been negatively related to the intention to adopt eco-innovations, including eco-labeled products (Hosseinikhah Choshaly, 2019), water supply systems (Bediako et al., 2018), and agricultural innovations (Dan et al., 2019).

2.4.2 Adopter characteristics

Studies on the adoption of innovations with preventive qualities, namely eco-innovations (Jansson et al., 2017; Ji & Chan, 2019), have highlighted the roles of values, personal norms, attitudes, and environmental concerns over adoption intention. Four human **values** are considered to influence environmental beliefs and behaviors: biospheric, altruistic, egoistic, and hedonic (Bouman et al., 2018). Biospheric values reflect concern for all living species; these values are most strongly related to pro-environmental beliefs and behaviors. Altruistic values reflect concern for other human beings' fair treatment and welfare. Individuals with altruistic-environmental attitudes are concerned about environmental problems because these affect other people (Schultz et al., 2005). Egoistic values reflect concern for personal resources, power, or achievement; egoistic environmental attitudes reflect concern for the environment but at a personal level. For example, individuals with egoistic environmental attitudes are concerned about air pollution because of its adverse effects on their health (Schultz et al., 2005). Finally, hedonic values focus on attaining pleasure, positive feelings, and effort reduction (Bouman et al., 2018).

Biospheric and altruistic values are known as *self-transcendence* values, and egoistic and hedonic values are known as *self-enhancement* values. Self-transcendence values positively predict environmental behavior, whereas self-enhancement values tend to correlate with environmental behavior negatively (Schultz et al., 2005).

Environmental **concern** has been identified as an influential construct explaining pro-environmental behavior; these choices are based on individual evaluation of what is right or wrong (Lindenberg & Steg, 2007). For example, Organ et al. (2013) identified that environmental concerns contribute to energy efficiency refurbishment in owner-occupied housing. Similarly, Arroyo et al. (2019) identified that normative motivators related to environmental concerns are significantly relevant in the adoption of green energy but are conditioned by the economic capacity of consumers.

However, various empirical settings have found environmental behavior to stem from nonenvironmental concerns, such as the desire for comfort, freedom, or to save money (Diaz-Rainey & Ashton, 2015). Lindenberg and Steg (2007) found environmental concerns to account only for low-cost environmental behavior, while high-cost behaviors resulted from gain goals. Similarly, Hu et al. (2016) found that consumers choose green dwellings not because of their environmental values but because of their health and comfort benefits. Economic incentives usually have a more substantial influence over other factors as these rewards yield an advantage that makes up for the cost and uncertainty involved with technology adoption (Cheung et al., 2017). Environmental concern has also been found to vary across adopter groups of green innovations, where early adopters show higher levels of concern over late adopters (Palm, 2020).

Willingness to sacrifice for the environment has also been identified as a relevant contributor to pro-environmental behavior. Willingness to sacrifice for the environment reflects how individuals place the environment's well-being at the expense of self-interest, effort, and cost (Chen & Zheng, 2016). The operationalization of this construct is derived from the commitment to the environment, and individuals that display this characteristic usually have a solid biospheric value orientation (Rahman & Reynolds, 2016). Willingness to sacrifice for the environment has been found as a predictor in green purchase behavioral intentions (Rahman & Reynolds, 2016), as well as a mediator between green values (Rahman & Reynolds, 2016) and personal norms (Han & Hyun, 2018) and behavioral intentions.

Finally, the concept of environmental self-assets (Saari et al., 2020) was also explored. Environmental self-assets refer to knowledge about environmental issues and experience handling these issues (Sonenshein et al., 2014). Empirical findings by Saari et al. (2020) found consumers' environmental-self assets to influence their brand experiences, however, mediated by educational level.

2.4.3 Background factors

Behavioral studies of prevention have identified the influence of background factors describing the characteristics of an individual, such as socioeconomic status, education, age, and gender (Fielding, 1978). These factors have also been identified as significant predictors of the adoption of innovations for environmental protection, yet empirical findings offer mixed views.

Regarding **age**, there is a common belief that young people are more likely to engage in pro-environmental behavior; this has also been identified in empirical settings, such as the survey study by Weber (2016) measuring perceptions of climate change. However, other studies have identified the opposite—a positive relationship between pro-environmental behavior and aging (Wang et al., 2021), in which older people are more likely to avoid environmental harm (Wiernik et al., 2016).

Myriad settings have analyzed the role of **gender** in pro-environmental behavior and behavioral intentions. Studies by Xiao and Hong (2010), Mertens et al. (2021), and Dietz et al. (2002) identified that female respondents show more significant environmental concern and more positive attitudes toward the environment than men do. According to Blocker (1997), this is assumed to happen because women traditionally have the household role of a caregiver. However, Vicente-Molina et al. (2018) identified gender role stereotypes as irrelevant to everyday pro-environmental behaviors, such as green purchasing and recycling, commonly attributed to domestic work. According to their study, the varying results of existing studies can be attributed to progress in gender equality.

The role of **education** in pro-environmental behavior has also been assessed, in which a higher level of education is usually associated with greater environmental knowledge and concern (Xiao & Hong, 2010; Xiao & McCright, 2015). However, an opposing view is presented by Wang et al. (2021), who found through a multi-national study that people with the lowest levels of education perform more actively in terms of pro-environmental behavior than those with higher education levels; this finding, though, was found to be influenced by the effects of age on education.

Regarding **income**, higher income groups have been identified as more likely to engage in pro-environmental behavior (Blocker & Eckberg, 1997; Khare, 2015), particularly for *green product* purchases, as these are often identified as high-end products. Lower-income individuals tend to avoid wastefulness (Wang et al., 2021) and preserve more resources (Melasniemi-Uutela, 1994).

Contextual factors also play a significant role, as the adoption of green innovations has often been found to be context-specific (Hosseinikhah Choshaly, 2019). For example, Lee et al. (2017) identified that South Koreans were more willing to pay for renewable energy after the Fukushima disaster, in which individuals witnessed the severity of nuclear accidents. Similarly, Pardo Martínez et al. (2018) identified that Colombians were aware of the severe effects of climate change and considered it an important issue requiring more government and citizen initiatives. **Housing characteristics** are relevant contextual factors in this study as the empirical setting of publications II to V is location-dependent. Housing characteristics have also been studied along with pro-environmental behaviors. For example, for photovoltaic systems, the type of house is a significant factor for adoption, as apartment buildings usually do not have access to panel systems. Zhang et al. (2012) found that installation space and service infrastructure are barriers to the adoption of solar energy systems. Among the studied housing characteristics included in this study are the dwelling size, type of dwelling (apartment building, single-family home, multi-family home, etc.), and household management (is it self-owned, is the respondent renting, or subletting the dwelling).

Finally, peer behavior has also been found to influence the intention to adopt innovations with preventive qualities. While the benefits of some innovations can be difficult to observe (Rogers, 2002), the innovation itself can be visible and stimulate peer discussion (Korcaj et al., 2015); peer behavior offers social learning possibilities and sets a norm. Empirical findings in the adoption of innovations with preventive qualities highlight peer influence as a determinant of adoption behaviors; these applications include HPV vaccines (D'Souza et al., 2013), mHealth apps (Khan & Loh, 2021) and photovoltaic systems (Korcaj et al., 2015)

More elements could be considered when exploring the factors influencing the adoption of innovations other than those mentioned above. Examples are subjective norms (Korcaj et al., 2015), perceived usefulness (Masukujjaman et al., 2021), and perceived behavioral control (Alam et al., 2021; Korcaj et al., 2015; Wolske et al., 2017). However, the current exploratory research does not include these specific theoretical viewpoints on other factors.

2.5 Adoption of innovations with preventive qualities

Innovation studies discussing preventive qualities have been present since early medical publications promoting sickness prevention (e.g., Lance & McKenna, 1975; Sylvan, 1814). Since then, several authors have elaborated on and applied the concept across disciplines. A literature review containing the terms "prevention" and "adoption of innovations" shed light on the existing studies on the topic. The concept of preventive innovations is worth highlighting, as Everett Rogers proposed in the third edition of *Diffusion of Innovations*. According to Rogers (1983, p. 171), a preventive innovation is one that individuals adopt to reduce the probability of an unwanted future event. However, most publications do not use this term when referring to innovations with preventive qualities.

Existing publications on innovations with preventive qualities explore diverse topical areas. Most are grounded in health prevention through behaviors (Finch, 2011; Guo, 2018; Nielsen & Moldrup, 2007), disease awareness (Bertrand, 2009; Swendeman & Rotheram-Borus, 2010), or medical innovations such as vaccinations (Cohen & Head, 2013; D'Souza et al., 2013; Sherlaw & Raude, 2013).

Other applications include green innovations, business innovations, preventive maintenance, and education for prevention. Green innovation publications address pollution prevention (Deltas et al., 2014; Khanna et al., 2009), food waste prevention (Martin-Rios et al., 2018), and emission reduction (Drury et al., 2012; Pine et al., 2011; Zahari & Ramayah, 2017; Zhang et al., 2012). Business innovations include information security behaviors to prevent cyber-attacks (Mirtsch et al., 2021; Wynn et al., 2013), strategies to mitigate business risks (Köhler & Som, 2014), and workplace accident prevention strategies (Wong et al., 2021). Studies on educational programs for prevention focus on sexually transmitted diseases (Bertrand, 2004, 2009; Swendeman & Rotheram-Borus, 2010) and tobacco, drug, and alcohol abuse (Buller et al., 2007; Lachance, 2021; Parcel et al., 1989).

Various empirical studies have identified the factors influencing adoption in study settings through DOI theory, adopter characteristics, and background factors. For example, Lamm et al. (2017) recognized that the adoption rate of water treatment technologies depends on perceived complexity, perceived cost, and increased value from environmental-friendliness. In an intervention study on exercise behavior, Guo (2018) found that peer groups help promote acceptance among individuals. Bertrand (2004) identified communication channels, attributes of innovation, and adopter categories, as the most relevant concepts in the adoption of health innovations.

Also worth mentioning is the little attention paid in previous empirical settings —outside of insurance studies— to the attributes of the event that the innovation seeks to avoid or help mitigate. In insurance studies (Rees & Wambach, 2008), utility functions depend on the probability of unwanted events with specific loss sizes; loss prevention addresses the probability and severity of the loss. However, the characteristics and influence of the problem to be solved are seldom covered across innovation studies.

2.6 Synthesis of the theoretical background

The concepts presented in this theory background are relevant for the study settings included in this dissertation and for answering the identified RQs. From basic terms that provide essential fundaments to the reader to the specific elements influencing the adoption of innovations, this section highlighted the multiple dimensions that influence the adoption of innovations with preventive qualities.

Basic concepts of prevention help understand the goals and outcomes behind the adoption of innovations with preventive qualities. Knowing that prevention and preventive behavior depend on factors such as risk attitudes and the perceived characteristics of the unwanted event unveils the complex background connected to innovations with preventive qualities. By bringing up concepts from insurance literature, this section identifies the opportunity to connect existing knowledge of insurance adoption to understand the adoption of innovations with preventive qualities. Insurance literature, however, is heavily focused on economic factors (Rees & Wambach, 2008) and can be complemented by perspectives from innovation adoption literature.

Innovation adoption literature presents definitions, classifications, and a brief history behind innovation, the most covered term across this work. By presenting different innovation typologies, this section seeks to better define innovations with preventive qualities, where the preventive label describes a feature of the innovation concerning prevention, and does not seek to categorize it into an existing typology (e.g., radical vs. incremental (Rogers, 2003), disruptive vs. sustaining (Christensen, 1997), or product vs. process).

Linking the topics of prevention and innovation, the historical overview illustrates long-standing attitudes associated with prevention and innovation. This overview depicts why prevention can be difficult to foster and in place why innovations with preventive qualities can be challenging to adopt.

This discussion of innovations across time paves the way for the introduction of previous studies on the adoption of innovations. The aspects introduced in this review and utilized as a baseline for the studies included in this work are those identified as influential in the adoption of innovations by diffusion scholars. Literature on the perceived attributes of innovations (Rogers, 2003; Ryan & Gross, 1950) highlights the role of the innovation's characteristics over adoption. Literature exploring adopter characteristics identifies how values (Schultz et al., 2005), environmental concerns (Diaz-Rainey & Ashton, 2015), and environmental knowledge (Sonenshein et al., 2014) influences the adoption of eco-innovations. Finally, literature on background factors depicts the positive and negative influences of age, gender, education, socioeconomic factors, and contextual factors over adoption. The studies reviewed in this section were within the scope of green or eco-innovations to fit the domain of this work.

Covering all preceding domains, previous studies on the adoption of innovations with preventive qualities are introduced. These studies present factors that influence the adoption of innovations with preventive qualities within multiple domains, including pollution prevention (Deltas et al., 2014), food waste prevention (Martin-Rios et al., 2018), cyber-attack prevention (Mirtsch et al., 2021; Wynn et al., 2013), business risk mitigation (Köhler & Som, 2014), and a variety of healthcare applications including vaccinations (Bertrand, 2009) and substance abuse prevention (Lachance, 2021). In this section, the term preventive innovations, as proposed by Rogers (1983, p. 171), is included, as it was utilized in some articles that make up this work. While this review presents multiple empirical studies that explore the adoption of innovations with preventive qualities, these publications have not incorporated the preventive quality into the innovation construct. Furthermore, adoption studies have not considered the influence of the characteristics of the unwanted event over adoption. These are research opportunities addressed through the remaining part of this work.

3 METHODOLOGY

3.1 Research approach

Social sciences are most appropriately interpreted when the audience understands philosophical principles and theory assumptions (Moon & Blackman, 2014). This section will evaluate the philosophical beliefs behind this research.

Ontological assumptions concern ideas about the existence and relationship between people, society, and the world (Eriksson & Kovalainen, 2008, p. 13). An ontological assumption for qualitative research is that reality is understood as subjective, meaning that reality may be different for every person, depending on their past experiences, time, and context. On the other side, objectivism is an ontological assumption for quantitative research that assumes the social world is independent of people and their actions.

A main premise of this research is that prevention is centered around an unwanted event, which has certain attributes, such as probability and severity. The probability and severity of the unwanted event can somehow be quantified; however, subjective perceptions affect both (Rees & Wambach, 2008). The subjective reality element is also relevant when discussing climate change mitigation technologies, as the perception of climate change mitigation efforts varies between individuals. Therefore, the assumption that reality is subjective is a central element of this work.

On the other side, epistemological assumptions define how knowledge can be produced and argued for (Eriksson & Kovalainen, 2008, p.13). In epistemology, there is also an objectivist and a subjectivist view; in the objectivist view, there is a possibility for a theory-neutral world to exist, whereas, in the subjectivist opinion, there is no access to the external world beyond our interpretations and perceptions (Moon & Blackman, 2014).

Within epistemology, this research takes a critical realism direction, meaning there is an assumption of the existence of an observable human world, yet it is also socially constructed (Johnson & Gray, 2015). When conducting survey studies, various respondents yield distributions of subjectivity which help uncover the truth. This research assumes truth exists and is socially constructed and subjective, but there is a better view when many respondents are aggregated. Using questions, the researcher can find truth through distributions of subjectivity.

Another epistemological assumption is the role given to the researcher: can the researcher be a detached and autonomous member, or is the researcher part of the knowledge production process? (Eriksson & Kovalainen, 2008, p.15). In this work, the researcher acts as an independent, autonomous member seeking to identify the influence of the preventive quality of innovations in their adoption or adoption intention, yet not directly involved with the subjects of study.

This study was conducted using an exploratory mixed methods approach. Mixed methods research combines quantitative and qualitative research to provide rich insights into a phenomenon that cannot be fully understood using only one method (Venkatesh et al., 2013). There are few empirical findings describing the preventive quality of innovations, so there is no truth against which to compare this research; therefore, mixed methods research is a suitable methodology. Using mixed methods allows for developing varied insights into different research objects. Exploratory research investigates RQs that have not been studied in depth. Social science exploration is a systematic, broad-ranging undertaking that seeks to describe and understand an area of social life (Stebbins, 2001, p. 3).

This dissertation contains six empirical studies using qualitative and quantitative methods. Qualitative methods were used for Articles I and VI, and quantitative methods were used for Articles II to V. The methodology chosen for each publication is presented in Table 1.

Qualitative methods were used to explore how organizations perceived the preventive quality of innovations. Qualitative research allowed for understanding the meaning of the complex social problems (Creswell, 2013) in Articles I and VI. Qualitative methods were a good fit for these studies, as they dealt with unstructured problems (Eriksson & Kovalainen, 2008). The in-depth analysis provided by qualitative methods helped to identify the influence of the preventive quality of innovations in the adoption process.

Quantitative methods were used in Articles II to V to identify the traditional elements in diffusion studies, such as innovation attributes and adopter and background factors influencing adoption. Quantitative methods were applied when the RQs concerned the relationship between variables, such as the influence of innovation attributes on the intended adoption period. The statistical techniques implemented in quantitative methods help examine the relationship between variables (Hair et al., 2016).

Table 1. Data collection, data analysis, and the empirical context for each article.

Article	Data Collection	Data Analysis Method	Empirical Context
I	Semi-structured interviews Fall 2019-Fall 2020, 20 interviewees, 60-150 min.	Qualitative: switching path analysis technique in Atlas.ti	Organizational adoption of wood materials in public procurement processes
II	Online survey June-August 2021, 365 responses	Quantitative: multiple linear regression in SPSS	Individual adoption of photovoltaic systems
III	Online survey May-November 2020, 124 responses	Quantitative: multiple linear regression in SPSS	Household support toward the communal adoption of prevention products and services
IV	Online survey September-November 2021, 297 responses	Quantitative: multiple linear regression in SPSS	Adoption intention of renewable energy contracts
V	Online survey Same dataset as Article IV	Quantitative: partial least squares structural equation modeling in SmartPLS4	Adoption intention of photovoltaic systems through third-party ownership
VI	Semi-structured interviews Same dataset as Article I	Qualitative: narrative research in Atlas.ti	Organizational adoption of wood materials in public procurement processes

The predictors of the study settings in Articles II to V were derived from earlier research on the adoption of innovations, specifically eco-innovations and the preventive quality of these innovations (European Commission, 2011; IEA, 2021). This allowed the creation of a baseline theoretical model. The statistical technique used in Articles II to IV was multiple regression modeling to explore factors' influence on the dependent variable. While items were derived from existing scales on earlier research, the analysis was done for individual factors as the researchers sought to understand how each element performed and contributed to the dependent variable. Regression modeling is a commonly used statistical technique that identifies interactions among variables and their explanatory power toward the dependent variable—in this case, the adoption of innovations (Hair et al., 2016, p. 390). Multiple regression modeling has been previously implemented to study the adoption of innovations with preventive qualities, such as UV-specialized clothing (Sung & Slocum, 2004) and medical screenings (Ayodele, 2017; Lan, 2017).

Article V relied on Partial Least Squares Structural Equation Modelling, PLS-SEM (Dijkstra & Henseler, 2015) to identify the preventive quality of innovations over adoption intention seeking to conceptualize it as a construct of innovations. PLS-SEM seeks to confirm theories by determining how well a model can estimate a sample data matrix (Hair et al., 2014). PLS-SEM has been popularly utilized in multiple applications due to its ability to handle problematic modeling issues characteristic of social sciences. Relevant applications of the PLS-SEM include the adoption intention of green innovations (Hosseinikhah Choshaly, 2019; Yang et al., 2021) and the adoption of construction-sector technologies (Ji & Chan, 2019; Katebi et al., 2022). As shown in Table 1, the articles have different data collection, data analysis methods, and empirical contexts. The research context and the data collection and analysis will be explained in the following sections.

3.2 Research context

All cases presented in this dissertation belong to the construction and energy sectors. Articles I and VI focus on the adoption of wood as a building material in public school procurement processes. Article II studies the adoption intention of PV systems in households, and Article III analyzes household support for the adoption of communal products and services with preventive qualities. Article IV explores the adoption intention of renewable electricity contracts. Article V studies the adoption intention of photovoltaic systems through third-party ownership. The following sections will explain each innovation's underlying quality of climate change prevention and mitigation.

3.2.1 Adoption of wood materials in public procurement

Articles I and VI were empirical studies that analyzed recently completed school procurement processes in Finland; these publications studied the purchase process completed by municipalities. They focused on five public procurement cases in which wood was the preferred building material. For these publications, wood as a building material was considered to have preventive qualities concerning healthcare and environmental protection.

Regarding healthcare, using wood helps mitigate indoor moisture, which prevents bacterial growth (Muilu-mäkelä, 2015), affects indoor air quality, and improves thermal comfort (Virtanen et al., 2000). The improved air circulation of wood materials helps inhibit moisture degradation (Franzini et al., 2018) and lowers the risk of mold growth (Virtanen et al., 2000). Mold exposure, moisture, and bacteria have been associated with respiratory diseases (Palaty & Shum, 2012).

Regarding environmental protection, wood materials are considered environment-friendly (Rametsteiner, 1999) and low-carbon alternative materials for sustainable urban housing (Toppinen et al., 2019). They outperform concrete materials regarding greenhouse gas (GHG) emissions, carbon storage (Robertson et al., 2012), and carbon emissions. After their natural cycle, wood materials can be turned into biofuels (Robertson et al., 2012). However, wood needs to be responsibly sourced and forests replenished for wood to remain the renewable alternative.

While wood construction has been present for thousands of years, nineteenth-century technologies led to the widespread use of steel and reinforced concrete; this, alongside increased fire disasters, led to the decline of traditional wooden structures (Grabner et al., 2018). A consequence of the shift away from wood construction is the loss of knowledge except for the conservation of historic buildings.

Wood materials were studied as an innovation because of incumbents' widespread perception of newness when working with wood, particularly for multi-story buildings (Mahapatra & Gustavsson, 2008). In an innovation context, incumbency refers to whether an organization participated in a previous product generation; these studies considered municipalities as the incumbent organizations as they had participated in the last generation of buildings made from concrete. Overall, builders believe they have insufficient knowledge of wood buildings and unclear project management skills (Lindblad, 2019). There are also perceived difficulties related to wood building codes and a lack of knowledge related to such codes (Gosselin et al., 2017).

Studies of prevention in the construction sector are oriented toward the prevention of workplace accidents through efficient scheduling (Niskanen & Lauttalammi, 1989) and the use of technologies (Rey-Merchán et al., 2020), prevention of material waste (Formoso et al., 2002), and prevention of seismic damage through building design (Tremblay et al., 2008). However, the prevention benefits derived from building materials have yet to be explored.

Because of these health-related and environmental prevention capabilities and incumbents' general perceptions of newness, wood as a building material can be studied as an innovation with preventive qualities; wood helps prevent future respiratory diseases caused by poor indoor air quality, mold exposure, and dampness. Wood also deters climate change through its carbon storage properties and low carbon emissions in the construction sector, one of the most carbon-intensive sectors (Huang et al., 2018).

3.2.2 Adoption of photovoltaic systems

Article II explored the influence of the preventive nature of innovations on the intent to adopt PV systems in central Finland. This article studied the adoption of PV systems considering their preventive qualities of climate change mitigation and prevention and dependence on prices and supply from fossil fuel markets.

A PV system converts light into electricity. A PV system's main components are interconnected PV cells to create a PV module, a mounting structure for the module, an inverter, a storage battery, and a charge controller (Issaadi, 2018, p. 4). PV systems help lower GHG emissions (Wolske et al., 2017), thus helping prevent and mitigate climate change and its consequences. PV systems also help protect users from the consequences of volatile electricity prices and lower dependence on unreliable fossil fuel markets (Ciucci, 2021). Thanks to these underlying prevention goals, PV systems were identified to display preventive qualities in this study.

3.2.3 Household support toward the communal adoption of prevention products and services

Article III analyzed household support for the communal adoption of products and services with preventive qualities. The context of this article was Finnish apartment buildings and the companies that manage these buildings. This publication studied the factors that contribute to supporting communal housing projects to improve the environmental friendliness of buildings through the adoption of innovations.

Many apartment buildings in Finland are run by housing companies, which oversee the maintenance, operations, and finances of the tenants of the building. A well-established regulatory framework runs housing companies. While apartment owners may participate in decision-making for significant investments, the board of the housing company has the last say (Murto et al., 2019). Each household pays a fee to the housing company, which covers general expenses throughout the year.

Article III focused on household support toward investments in housing companies that will improve the environmental friendliness of buildings. These investments include insulation, heat recovery, ground source heat pumps, solar PV systems, and window replacement (Isännöintiliitto, 2021). This publication studied the individuals living in the building.

For the study, the investments were classified as preventive, as they serve underlying qualities related to climate change prevention and mitigation. For example, insulation systems prevent heat loss, PV systems lower dependence on unreliable fossil fuel markets (Ciucci, 2021), and renewable electricity sources, such as solar and wind, contribute to climate change prevention and mitigation.

3.2.4 Adoption intention of renewable energy contracts

Article IV explored the influence of the preventive nature of innovations on the intent to adopt renewable electricity contracts in central Finland. Specifically, the study analyzed a case in which a consumer pays a fixed monthly fee plus a consumption fee for electricity generated from solar panels.

Solar energy significantly contributes to the global capacity for sustainable electricity generation. However, purchase costs are the main barrier to individual adoption of PV systems (Arroyo & Carrete, 2019). One solution to address this financial barrier has been the creation of solar PV parks. Utility companies can procure electricity from solar parks, or consumers can purchase electricity from these renewable sources. By subscribing to an electricity contract in which all energy is procured from renewable sources, consumers have the power to contribute to a more sustainable future (Tabi et al., 2014).

For Article IV, the preventive quality of renewable electricity contracts was studied as these services served individual and supplier prevention goals. At the individual level, there is a reduction in GHG emissions. At the supplier level, voltage swell and dip events are prevented through dynamic grid support and frequency support functions (Hernández et al., 2017).

3.2.5 Adoption intention of photovoltaic systems through third-party ownership

Article V explored the influence of the preventive quality of innovations on the intent to adopt photovoltaic systems through third-party ownership (TPO) in Finland. Solar PV system ownership can be either direct or third-party ownership. In direct ownership, the homeowner owns and finances the equipment with or without government support. However, buyers have shifted towards TPO in the last decade (Rai et al., 2016). In TPO, commercial companies own and operate the PV system in the customer's household or solar parks. Customers can then decide whether to lease the system or enter a power purchase agreement (Rai et al., 2016). These two modes were the forms of TPO analyzed in this study.

Among TPO's advantages are reduced technology risk, complexity, and cost savings within the first month, unlike the order of decades of direct ownership (Drury et al., 2012). For this article, the TPO of PV systems was studied based on the preventive quality of PV systems regarding emission reduction and climate change prevention (European Commission, 2011).

3.3 Data collection and analysis

The articles included in this dissertation relied on diverse methodologies for data collection and analysis. Articles I and VI were created from the same dataset, Articles II and III were designed from different datasets, and Articles IV and V belonged to the same dataset.

Articles I and VI resulted from a multiple case study of public school selection procedures. The researchers sought to identify the factors that influence the selection of wood materials in Finland; these articles depict organizational-level aspects of innovation adoption. Article I sought to investigate the existing decision-making dynamics and factors behind the adoption of wood materials which were further analyzed in Article VI through preventive qualities.

The primary data source for Articles I and VI was a series of semi-structured retrospective interviews carried out from Fall 2019 to Fall 2020 that sought to identify the events and decisions that led to the selection of wood materials. Other data sources included news outlets, municipalities' websites, and official procurement documents. The interviewees were those professionals responsible for city administration, project management, municipal services, and education services. Interviews helped capture the tacit knowledge and experiences of those involved in the procurement process, which cannot be found in official procurement documents. Twenty people in critical roles in these procurement processes were interviewed. The interviews were conducted in English and Finnish, and the researcher participated in the interviews in English. Fifteen interviews were conducted face-to-face, and the rest were conducted remotely through video calls, lasting between 60 and 150 minutes.

For Article I, the data were analyzed using the switching path analysis technique (SPAT; Roos, 1999). SPAT was chosen for this publication because of its ability to depict actual events and the factors that influence decision-making. SPAT is a variation of the critical incident technique (CIT) introduced by Flanagan (1954). The CIT and its variations identify the most frequent quality determinants through traditional content analysis. SPAT seeks to describe the path leading from an intentional switching decision to a behavioral change (Roos, 1999).

In SPAT, a relationship is divided into a trigger, an initial stage, a process, and a consequence. A trigger is a catalyst that makes the decision-maker inclined to act; it fuels and steers the process (Roos, 1999). The process is illustrated by determinants, which guide the decision-maker toward or away from the action. For Article I, SPAT was used as the basis for data coding, analysis, and presentation of the results. Coding was conducted in Atlas.ti, a qualitative data analysis software.

Articles II to V were created through survey research, a method regarded as inherently quantitative (De Vaus et al., 2013); these publications depict individual-level aspects of innovation adoption. In survey research, respondents are selected from a population, and the researcher administers a standardized questionnaire in a face-to-face interview or through remote methods, such as by telephone or online. Survey research was selected for Articles II to V because the researchers sought to identify the factors that influence the adoption intention of products and services with preventive qualities. The researchers collected standardized data through surveys and systematically compared respondents on the same variables (De Vaus et al., 2013).

For these articles, the surveys were administered through online questionnaires, which were distributed with the help of organizations involved in research projects along with Tampere University. Four researchers created, translated, tested, and implemented surveys. For Article II, the data were generated through a survey distributed on the website of a local electricity company in central Finland from June 2021 to August 2021; this survey yielded 365 responses. The data for Article III were collected using a survey distributed via email by nine housing companies in central Finland from May 2020 to November 2020; this survey provided 124 responses. The data for Articles IV and V were collected through a survey distributed by a local electricity company in central Finland from September 2021 to November 2021; this survey yielded 297 responses. All these data were compiled by the authors who contributed to the publications.

Article II measured adoption intention through background factors of gender, age, income, housing characteristics, and the five perceived attributes of innovations. The preventive quality of PV systems was measured through four questions designed by the researcher group. These questions sought to identify the use of PV systems to prevent electricity price increases, climate change, and dependence on energy producers.

Article III measured adoption intention through adopter characteristics and background factors. Adopter characteristics included values, environmental concerns, environmental self-assets, and willingness to sacrifice for the environment. Background factors measured included gender, age, education, occupation, income, and housing characteristics.

Articles IV and V measured adoption intention through background factors of gender, age, income, housing characteristics, and the five perceived attributes of innovations. In this case, the preventive quality of PV systems was measured through two questions designed by the researcher group that sought to identify the use of PV systems as mechanisms to prevent greenhouse gas emissions and climate change. The difference between these two articles is that Article IV focuses on willingness to pay for solar electricity contracts, and data is analyzed through multiple regression modeling; Article V studies the adoption intention of PV systems through two modes of third-party ownership and carries out a PLS-SEM analysis.

To analyze the survey data for Articles II to V, the researchers used SPSS software, SmartPLS4 software, and statistical techniques to determine whether there was a statistically significant association between the dependent and independent variables (Hair et al., 2016). The dependent variables identified either the time lapse in which the respondent was willing to adopt the innovation (Articles II and IV), whether the respondent supported the adoption of the innovation (Article III), or if the respondent had intentions to adopt the innovation (Article V). The independent variables sought to identify the influence of demographic factors, innovation attributes, and prevention elements. For the analysis of Articles II to IV, the researchers relied on multiple linear regression to determine the variables that were significant contributors to each article's dependent variable. Once a relationship between variables was identified, its direction was interpreted (positive or negative) along with its meaning concerning the dependent variable. For the analysis of Article V, the researchers relied on partial least squares structural equation modeling to identify the influence of the preventive quality over adoption intention and conceptualize preventiveness as a construct of innovations.

For Article VI, the interview data were analyzed through a narrative approach (Eriksson & Kovalainen, 2008) to examine the anecdotes told by the interviewees. These narratives helped illustrate incumbent paths in adopting wood as a building material. By studying the interview data, the researcher sought to identify *what* and *why* incumbents do what they do and how these factors relate to the attributes of the innovation with preventive qualities. Mainly, this article explored the attributes of the unwanted event (probability and severity) over adoption decisions. The researcher also incorporated the extended time-lapse to see the benefits inherent to products of prevention into the analysis (Allander & Lindahl, 1997). These elements (what, why, probability, severity, and time-lapse to see benefits) were placed in a matrix for data analysis and result presentation. For example, *what* and *probability* described whether the probability of the unwanted event affected what incumbents do. This matrix arrangement provided a view of the relationship between incumbent decisions and the elements of the innovation with preventive qualities.

4 RESULTS

This chapter presents the findings of each publication. The results for each article are introduced separately, and their contributions within the context of each case are provided. A discussion of the key findings is presented in the following section.

4.1 Article I: Wood material selection in building procurement – A multi-case analysis in Finnish municipalities

A frequently discussed way to reduce carbon dioxide emissions in the construction sector is the use of sustainable building materials; other strategies include extending the lifetime of buildings (Huuhka & Vestergaard, 2020) and promoting energy efficiency in construction processes (Huang et al., 2018). In discussions of sustainable building materials, the use of wood has been highlighted, as this material is a low-carbon alternative that can help achieve climate change mitigation objectives.

In many parts of the world, the public sector is increasingly adopting green procurement practices in construction projects, such as by specifying its preferred building materials in public procurement tendering (European Commission, 2018). However, previous research lacks empirical evidence of how wood is introduced in public building procurement projects.

This article explored the factors behind wood material selection in public procurement tendering. The study examined how wood selection was initiated in public procurement processes and the types of factors that facilitate or hinder the adoption of wood materials. This paper reported the results of an interview study on procuring school buildings in Finland.

This paper's key contribution was identifying triggers and determinants of incorporating wood into construction projects. Following SPAT vocabulary, triggers are those factors that make the decision-maker inclined to act, and determinants are those factors that steer the decision-making toward or away from the action (Roos, 1999). The identified triggers and determinants were classified into financial, environmental, strategic, and political issues and construction-related elements.

Regarding triggers, a permissive budget was identified as a financial factor that allowed wood to be considered in the construction project. Environmental elements depicted how municipalities incorporated into the project to reach sustainability goals. Strategic elements identified decision-making mechanisms, either top-down decisions or decisions that were part of municipal strategies. Construction elements determined the technical issues that affected the incorporation of wood into the project, such as land plot size and shape and the number of building stories. Other relevant triggers included the use of wood materials in response to problems with the previous building, particularly indoor air quality issues that led to health problems.

Regarding determinants, financial elements depicted the additional cost of wood as a potential hindrance to the selection process. Environmental issues identified that the carbon sequestration capabilities of wooden buildings made them more attractive options. Strategic and political issues showed that wood strengthens local businesses, as it is an important export product of Finland. Construction elements covered the technical aspects of wood that could steer decision-makers toward its incorporation, such as the good look, feel, and smell of wood buildings. On the other hand, relevant determinants that could drive decision-makers away from the incorporation of wood into the project included problems with acoustics, fire safety concerns, and a significant perceived lack of experience and capabilities for working with wood.

This study unveiled the triggers and determinants of public wood construction procurement and identified the dynamics behind the setting of building material requirements in public tendering processes. The findings are valuable for green public procurement and sustainable construction research. An important result of the article is the widespread perceived lack of experience and capabilities in working with wood. An avenue for future research based on this paper is the analysis of wood, considering its preventive qualities in which wood is used to prevent unwanted future health consequences or environmental consequences associated with traditional building materials, such as concrete.

4.2 Article II: Influence of innovation attributes with preventive nature of innovation on intent to adopt: The case of photovoltaic systems in mass markets

Diffusion studies have classified innovations based on their degree of innovativeness or innovation characteristics. However, few studies in the diffusion tradition have covered the preventive quality of innovations, which is relevant to multiple contemporary problems. This study highlighted the need to conceptualize preventiveness as part of building up the construct of innovations.

This study aimed to evaluate whether the preventive nature of innovations has a positive or negative influence on the intent to adopt. The paper introduced the attributes of innovations that can be classified as preventive, as discussed in existing diffusion studies. This paper depicted the results of a survey study that analyzed the individual adoption of PV systems. These systems were considered to have preventive qualities, as they serve various underlying prevention goals, including the reduction of GHG emissions, protection against volatile electricity prices, and decreasing people's dependence on unreliable fossil fuel markets (Ciucci, 2021).

The key contribution of this paper was a linear regression model that identified the variables influencing the intended period for the adoption of PV systems in mass markets. The model suggested that personal forms of relative advantage and compatibility with existing decision-making mechanisms and technical requirements contribute to the intended period of adoption. Independent variables contributing to the dependent variable, along with their unstandardized coefficients and p-values, are shown in Figure 1.

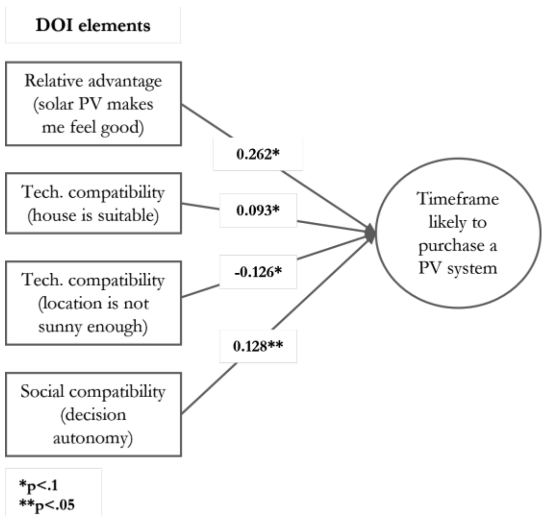

Figure 1. Significant variables that contribute to the timeframe to purchase a PV system.

Regarding relative advantage, a variable describing personal forms of advantage significantly contributed to the intended adoption period. Specifically, this variable described a *good feeling* provided by the PV system. The remaining significant variables belonged to compatibility. Two variables described technical compatibility, identifying whether the respondent's house was suitable for installing a PV system and whether the location was sunny enough to produce electricity. The last variable described social compatibility, identifying whether the respondent had decision-making autonomy regarding whether to install the PV system.

Traditionally, innovations with preventive qualities are regarded to have a low relative advantage, as their benefits are delayed in time and difficult to observe. Furthermore, these innovations are not considered fully compatible with individuals' values, attitudes, and lifestyles. This study identified that personal forms of relative advantage and compatibility with existing decision-making mechanisms and technical requirements contribute to the intention to adopt and can contribute to the intended period for the adoption of PV systems.

The chosen model did not report any significance among the individual prevention variables for this technology. A look at the responses from those who had already adopted PV systems showed that prevention-specific attributes had a higher presence than potential adopters. However, the researchers could not build a regression model out of these responses, as the sample size was too small and not normally distributed. The main barrier to the individual adoption of PV systems is purchase cost (Arroyo & Carrete, 2019), which could have influenced adopter behavior across this study focusing on PV purchase. Furthermore, this publication studied various preventive qualities of PV systems (preventing electricity price increases, climate change, and dependence on energy producers), for which researchers decided to focus on only one aspect of prevention for future study settings.

Thus, this study opens the way for a different approach to identify the influence of prevention-specific attributes, namely by limiting the scope of the preventive quality of the innovation. Another future research setting stemming from this study was the focus on an adoption mode that requires less commitment from the adopter, such as third-party ownership (Drury et al., 2012). This contribution creates grounds for future studies that can facilitate an understanding of the preventive quality of innovations.

4.3 Article III: Household support to adopt preventive innovations to mitigate climate change: A case of Finnish apartment buildings

Among the strategies to decarbonize and achieve sustainability goals are energy efficiency, behavioral changes, and renewables (IEA, 2021). Reaching sustainability goals requires individuals, governments, and organizations adopting these strategies. Previous efforts have identified pro-environmental behavior and knowledge of environmental issues as determinants of the diffusion of environmental technologies (Chen & Zheng, 2016; Saari et al., 2020).

This study aimed to identify the factors that support the adoption of products and services with preventive qualities of environmental protection. The paper relied on the concept of preventive innovations to describe environmental technologies that seek to deter climate change or its consequences. The results were obtained from a survey study that analyzed household support for the adoption of innovations by housing companies.

Specifically, the respondents were asked whether they would support projects related to geothermal energy, heating systems and heat recovery, and solar panels, which would improve the environmental friendliness of buildings. The innovations studied sought to improve the environmental friendliness of buildings and have underlying qualities of environmental protection, so they were categorized as preventive. For example, insulation systems prevent heat loss in buildings, PV systems reduce GHG emissions, and the use of renewable electricity sources contributes to climate change mitigation.

The key contribution of this paper was the development of a linear regression model that identified the variables affecting household support for projects that improve the environmental friendliness of buildings. The model suggested that demographic variables and variables related to environmental assets contribute to the dependent variable. Independent variables contributing to the dependent variable, along with their unstandardized coefficients and p-values, are shown in Figure 2.

Regarding demographic variables, support for communal housing projects was more significant among female respondents and more educated individuals. Regarding environmental assets, individuals who were more knowledgeable about environmental issues showed greater support for housing projects.

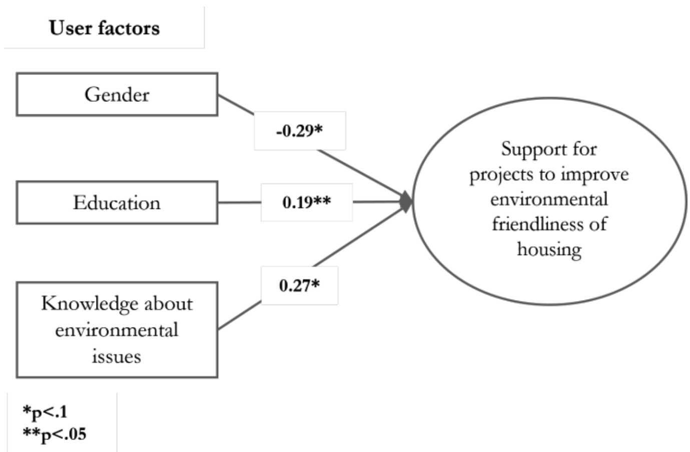

Figure 2. Significant variables that contribute to the support of communal housing projects that improve the environmental friendliness of housing.

This study provided a path for evaluating the preventive quality of innovations as a construct and identifying the factors leading to their adoption more systematically. The selected model depicted the characteristics of individuals who can potentially support the adoption of innovations with preventive qualities, which were not covered in previous studies, mainly focusing on the characteristics of innovation. The results presented in this paper belonged to a context in which the investment was made collectively with people from the same building, which could represent fewer risks. Furthermore, seeking to keep the focus simple and on a small number of factors poses a limitation on this study as other elements could be potentially relevant.

4.4 Article IV: Adoption of a service with preventive innovation characteristics

Solar and wind energy significantly contribute to the world's sustainable electricity generation capacity. As technologies improve and policies on fossil fuel use become more stringent, renewable methods for electricity generation will be adopted more widely.

Seeking to address the barrier of the purchase cost (Arroyo & Carrete, 2019) in the individual adoption of PV systems, governments, and other organizations have established solar PV parks (Burke et al., 2019). These parks are large areas of land in which many PV systems are installed; utility companies can procure their electricity from the parks, or consumers themselves can rent a panel whose production is credited to their electricity bill.

Previous efforts have examined the adoption of electricity contracts procuring electricity from renewable sources (Vecchiato & Tempesta, 2015). Still, the focus has been on the selection of renewable energy sources (wind, solar, and geothermal). There has been little focus on understanding the factors that influence the adoption of electricity contracts. Furthermore, the adoption of innovations in renewable electricity sources has not been studied from the point of view of prevention.

Therefore, the purpose of this study was to identify factors that influence the adoption intention of a sustainability-oriented innovation, specifically the service of a renewable electricity contract. The paper reported the results of a survey study, where the time lapse in which the respondents were planning to subscribe to renewable electricity contracts was analyzed. Specifically, the researchers sought to identify the demographic factors, innovation attributes, and prevention factors that lead to the adoption of renewable electricity contracts, which are studied through their preventive qualities. This paper considered renewable electricity contracts to have individual and supplier-level preventive qualities, including reducing GHG emissions and preventing voltage swell and dip events through dynamic grid support functions (Hernández et al., 2017).

The key contribution of this study was a linear regression model that identified the variables influencing the intended period for the adoption of renewable electricity contracts. The model suggests that demographic variables, innovation attribute variables, and prevention variables are significant contributors to the intended period for adoption. Independent variables contributing to the dependent variable, along with their unstandardized coefficients and p-values, are shown in Figure 3.

Regarding demographic variables, gender was a significant contributor in which female respondents depicted greater intentions for adoption. The remaining significant variables were related to relative advantage, compatibility, complexity, and prevention, in which a closer look at coefficients and their effects on the dependent variable offered interesting insights.

Variables with negative coefficient values represented a reduction in the time the respondents were likely to take a solar PV contract. In contrast, those with positive coefficient values represented an increase in the time the respondents were likely to take a solar PV contract. A feel-good feeling derived from adoption, the opportunity to save natural resources and reduce greenhouse gas emissions, and decision-making autonomy were all variables with negative coefficients.

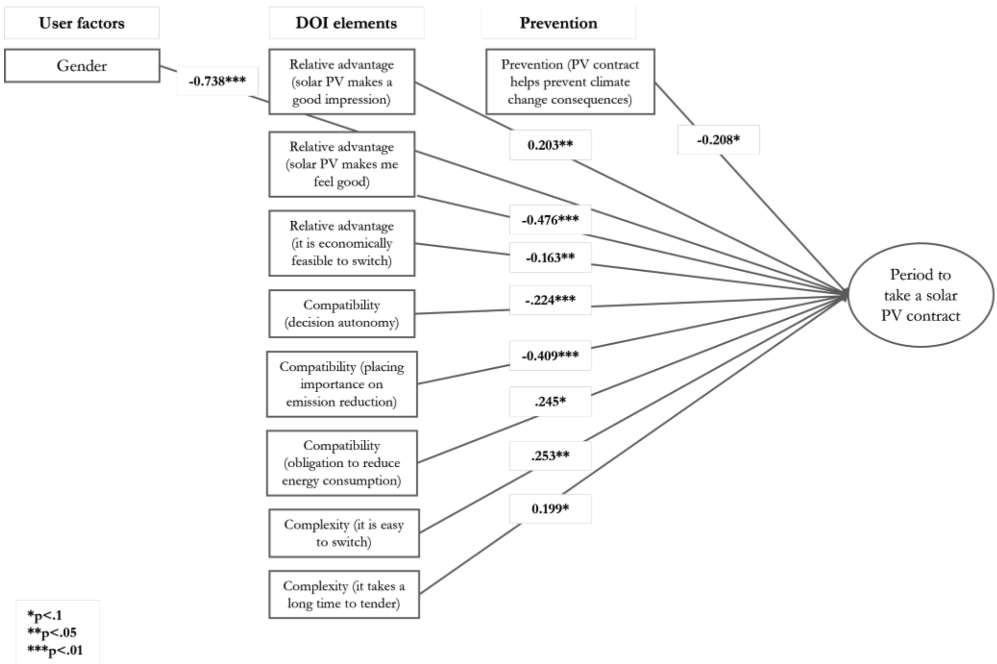

Figure 3. Significant variables that contribute to the period to take a solar PV contract.

On the other hand, a solar electricity contract making a good impression on other people was a variable with a positive coefficient. This suggests that the respondents were not interested in the reputational benefits derived from the adoption of a renewable electricity contract. This finding aligns with the fact that the renewable electricity contract represents an additional expense compared to other electricity purchase alternatives in Finland.

This study expanded innovation studies through empirical evidence of a service with preventive qualities and by identifying the factors that lead to its adoption. The main future research avenue is to study the preventive quality of innovations as a construct to understand their role in the adoption process. As with other publications in this work, a closer look at individuals who have already rented a solar panel could offer insights into what adopters consider valuable.

4.5 Article V: Recognizing the preventive quality in the adoption of innovations: the case of Third-Party Ownership of Photovoltaic Systems in Finland

The study of the adoption of innovations has not considered the preventive quality of innovations outside of health applications. This paper evaluates the preventive quality of innovations on their adoption intention, particularly seeking to conceptualize preventiveness as a construct of innovations. The empirical setting of the article was the adoption of photovoltaic (PV) systems through third-party ownership (TPO). The study relies on survey data collected in central Finland, where adoption intention was measured.

The researchers created and tested hypotheses theoretically grounded on the preventive quality of innovations and in the Diffusion of Innovations theory through PLS-SEM with SmartPLS. A key contribution of this study was a structural model that displays the relationship between DOI elements, prevention elements, and demographic elements regarding the adoption intention of TPO PV systems. The model with total effects and R^2 is shown in Figure 4.

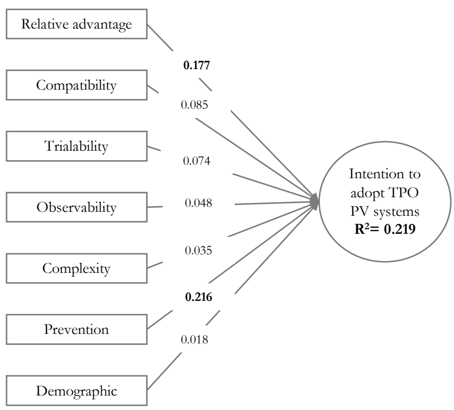

Figure 4. PLS-SEM Model.

Results from the PLS-SEM suggest that the constructs of prevention and relative advantage significantly and positively influence adoption intention. Prevention was found to be a standalone construct with a significant impact on adoption intention, with a stronger influence than all other studied constructs.

This study provided empirical evidence on the role of the preventive quality of innovations on adoption intention. These results suggest technology suppliers and practitioners to consider the innovation's preventive quality as it could provide new insights to promote adoption. An important avenue for future research is replicating this study with other innovations with preventive qualities.

4.6 Article VI: Incumbent actions in adopting preventive innovations: Cases in the Finnish construction sector

Adopting innovations to reduce and prevent environmental impact in the construction sector could yield impactful steps toward sustainability goals (Huang et al., 2018). However, incumbent organizations in the construction sector can struggle in the face of innovations, as this sector is known for its risk aversion and path dependency (Mahapatra & Gustavsson, 2008). This paper studies incumbents in the construction sector. Here, the term "incumbents" was used to refer to organizations and municipalities that had participated in the last generation of buildings made from concrete.

One of the solutions to reduce the environmental impact of the construction sector is to use sustainable building materials; wood is one of the most discussed alternatives, as it is an environment-friendly (Rametsteiner, 1999), low-carbon alternative and a sustainable urban housing solution (Toppinen et al., 2019). A few studies have considered wood an innovative building material, as it is perceived as new in established concrete and steel markets. Furthermore, the prevention benefits derived from building materials are yet to be explored.

This article aimed to explore incumbent decisions in the adoption of wood materials, which were studied through their preventive quality. This study introduced wood building materials as innovations with underlying qualities of health and climate change mitigation and prevention. The paper reported the results of an interview study in which the procurement of school buildings was analyzed through narratives illustrating the path of incumbents in the adoption of wood materials. In this study, the researcher explored the role of the probability and the severity of the unwanted event over adoption decisions. Furthermore, the researcher incorporated the extended time-lapse to see the benefits inherent to products of prevention (Allander & Lindahl, 1997) into the analysis.

This study's key contribution was identifying what and why incumbent organizations are selecting wood materials and how these choices relate to the time lapse to perceive the benefits of the innovation and to the unwanted event's probability and severity (Table 2). In short, the probability and severity of an unwanted event made incumbents more likely to select wood materials, and future-oriented benefits were not identified as deterrents to adoption. Still, they were instead often used to argue potentially more significant investments.

Table 2. Synthesized findings Article VI.

	What?	**Why?**
Probability -of the unwanted event	With a highly probable unwanted event, organizations are more likely to adopt the innovation.	Seeking to avoid reoccurrence, organizations are willing to adopt, even if unfamiliar with the innovation.
Severity - of the unwanted event	Severe issues lead to develop a strong attitude against the previous alternative.	Severity of health issues led to poor reputation, which organizations seek to avoid.
Time lapse - to perceive benefits	Incumbents expect benefits on the long run.	School buildings are to last decades, for which future-oriented benefits are sought.

Regarding probability, the researcher identified that the perception of a high probability of an unwanted event made incumbent organizations more likely to adopt the innovation, even if the organization was not familiar with it. To reduce the uncertainty associated with the innovation, incumbents would seek to learn from peers or select a purchasing model to minimize liability.

Regarding severity, the researcher identified that an unwanted event perceived as highly severe led to prioritizing solutions that would avoid the poor reputation associated with the unwanted event. Additionally, incumbents strongly opposed the previous solution with severe unintended consequences.

Regarding the time-lapse to see the benefits of the innovation, the researcher found that incumbents sought long-term benefits as schools are expected to last decades. Unlike commonly portrayed in diffusion studies, the extended time lapse was not considered a deterrent to adoption.

An important element worth highlighting is that the study depicted the influence of the probability and severity of an unwanted event on the decision to adopt an innovation with preventive qualities *after* the unwanted event was experienced. Across all cases, municipalities previously experienced issues with indoor air quality from concrete buildings and faced external pressure from environmental regulations. Therefore, the main area highlighted for future research was the willingness to adopt an innovation with preventive qualities in cases where the unwanted event has not been experienced.

This study provided an overview of prevention-related benefits derived from building materials and highlighted what construction sector incumbents ponder when adopting innovations. The findings depicted the influence that the perceived probability and severity of an unwanted event have on the adoption of an innovation, as well as the role of the extended time lapse in perceiving benefits.

4.7 Discussion of the key findings

The previous section identified the key findings of this dissertation's six articles. This section synthesizes these findings and determines which parts of this dissertation they contribute to. The scope of this research includes the innovation and its attributes, the preventive quality of the innovation, and the innovation's adopter characteristics and background factors.

4.7.1 The innovation and its attributes

As identified previously, innovations can be described by five characteristics as perceived by individuals—relative advantage, trialability, observability, compatibility, and complexity—also known as the perceived attributes of innovations. The findings of the six articles in this dissertation identify mixed conclusions concerning previous studies yet provide new insights regarding the adoption intention of innovations with preventive qualities.

Relative advantage. Across the studies on the factors influencing the adoption of innovations included in this dissertation, intangible forms of relative advantage were significant, particularly a *feel-good* emotion that could be realized from adoption. In the case of wood materials, the interviewees brought up the good look, feel, and smell of wood buildings as decision-making drivers. Regarding PV system purchases, communal housing projects, and solar electricity contracts, the independent variable identifying that the technology that will make the respondent feel good was statistically significant to the dependent variable. There were other identified forms of relative advantage, but these were not present across all cases; for example, reputational benefits from the adoption of wood materials were brought up by multiple municipalities, yet in the adoption of solar PV contracts, reputational gains negatively contributed to adoption intention.

Rogers (2002) identified that innovations with preventive qualities have a low relative advantage, as rewards are often delayed and nearly intangible. However, empirical findings have determined that the relative advantage of innovations with preventive qualities is a significant contributor to the intention to adopt, as reported by D'Souza et al. (2013) and Kuhn et al. (2014). The findings of this work build on these empirical settings (D'Souza et al., 2013; Kuhn et al., 2014; Lamm et al., 2017; Sung & Slocum, 2004) by highlighting the significant and positive role of personal benefits in the adoption intention of innovations with preventive qualities for climate change mitigation. Findings in this dissertation suggest that innovations with preventive qualities might not necessarily have a low relative advantage but that these might be present through subjective elements.

The time-lapse to see benefits is considered a sub-element of relative advantage (Rogers, 2003, p. 234). It is usually long for innovations with preventive qualities due to the inherent long-term orientation of prevention (Allander & Lindahl, 1997). This work explored the time-lapse element in the last article and found that a more extended time lapse to see benefits is a good fit for sectors with long-term projects, such as it was for the construction sector. The long-term benefits of wood materials were used as an argument to justify significant investments.

Diffusion studies commonly report that a more extended time lapse to see benefits deter adoption (Rogers, 2002). This was true in an empirical setting by Cohen and Head (2013), who found that non-adopters were less likely to adopt a healthcare innovation because there was no immediate benefit. On the other hand, Pine et al. (2011) identified a time lag between adoption and perception of benefits, yet the time lag did not represent an obstacle to adoption. They highlighted that this time lag should be considered when determining the success of a dissemination program. Similar findings were also presented by D'Souza et al. (2013), who identified long-term benefits as advantageous. This work found that the time-lapse to see benefits is not necessarily a deterrent to adoption but can be a better fit for those looking for long-term benefits.

Trialability and observability. Trialability and observability were not identified as significant in this work. However, in the case of the adoption of wood materials, all incumbents already experienced the unwanted consequences that the innovation sought to prevent, which influenced the adoption decision. This finding indicates that experiencing the unwanted event can give potential adopters a better view of the benefits of prevention (trialability and observability) and could influence the decision in favor of adoption, as it did with wood materials.

These findings align with those reported in other fields, such as insurance adoption, in which individuals are more likely to purchase insurance policies after experiencing losses (Aditya et al., 2018). According to Rogers (2002), innovations with preventive qualities have limited trialability, observability, and divisibility. The empirical findings of Sung and Slocum (2004) identified trialability as the most important predictor of the intent to adopt innovations with preventive qualities, in which an innovation perceived as easy to try without a commitment is more likely to be adopted. Similarly, trialability has been identified as a critical step in the adoption of mHealth apps (Lin & Bautista, 2017). Regarding observability, previous studies on the diffusion of innovations with preventive qualities (Bollinger & Gillingham, 2012) found that the visibility of the innovation contributes to peer effects, which in turn influence adoption in a community. Peer influence was also identified in the empirical setting presented by D'Souza et al. (2013).

Compatibility. Compatibility had a significant presence in this work. In the case of wood materials, there was an apparent lack of compatibility between existing skills and practices and those required to work with wood. The use of wood was incompatible with existing capabilities and construction traditions. In other cases, compatibility positively influenced the adoption intention of products (PV systems) and services (solar electricity contracts) with preventive qualities. On the other hand, in Articles II and IV, innovations were identified as compatible with existing decision-making mechanisms and energy-saving behaviors and attitudes. The mixed results across this work, the existing literature, and previous empirical studies suggest that compatibility is not necessarily challenged for innovations with preventive qualities, but it might be context specific.

Rogers (2002) identified that innovations with preventive qualities have low compatibility with existing values, attitudes, and lifestyles; empirical findings support and challenge this proposition. Pine et al. (2011) identified incompatibility as an obstacle to the adoption of improved biomass stoves, which they classified as preventive. On the contrary, Kuhn et al. (2014) found compatibility with values and needs to positively influence the intention to use a smartphone app targeted at prolonged exposure therapy. Roßnagel (2006) found strong technical compatibility between existing mechanisms and innovations for safe banking transactions.

Complexity. Complexity was not present across all cases in this work, but it influenced adoption similarly to that depicted in previous studies. The adoption of wood materials was perceived as more complex than the adoption of traditional materials, such as concrete. However, incumbents relied on their peers' experiences to overcome this challenge. In the adoption of a solar electricity contract, two variables related to complexity were identified as negatively influencing the period in which the adopter was willing to take a solar contract, as it was not "easy" or that it would "take a long time" to tender the contract.

These findings build on previous studies to support that cause-and-effect relationships present in innovations with preventive qualities can be complex. Previous literature identified that these innovations have complex cause-and-effect relationships (Rogers, 2002). Similarly, Cohen and Head (2013) and D'Souza et al. (2013) identified that complexity regarding HPV influenced the adoption rate of the HPV vaccine.

4.7.2 The preventive quality of the innovation

While several studies have relied on the use of social and behavioral theories to explain the adoption of innovations with preventive qualities, most commonly, the Theory of Planned Behavior —TPB— (Ajzen, 1985) and the Protection Motivation Theory —PMT — (Prentice-Dunn & Rogers, 1986), these have not widely considered the role of prevention over adoption intention. The TPB seeks to predict and explain human behavior through the constructs of attitude, subjective norm, and perceived behavioral control (Ajzen, 1985). The TPB has been used widely to predict preventive behavior across disciplines, including health screenings (Amin et al., 2019; Orbell et al., 1997), safe sex practices (Ayodele, 2017; Montanaro & Bryan, 2014), and environmental behavior (Harland et al., 1999; Oreg & Katz-Gerro, 2006). On the other side, the PMT (Prentice-Dunn & Rogers, 1986) was created to understand the individual response to fear appeals, and it partially covers prevention in the constructs of threat appraisal and coping appraisal; however, these constructs explain the individual response to a situation that could involve risk. Thus, neither the TPB nor the PMT covers the preventive quality of the innovation per se.

This dissertation sought to explore the role of the preventive quality of innovations over adoption and adoption intention. Findings across Articles II, IV, V, and VI show the positive and influential role of the preventive quality of innovations. While Article II found no significance from prevention variables, this study explored the purchase of PV systems. The main barrier to the individual adoption of PV systems is purchase cost (Arroyo & Carrete, 2019). Furthermore, this publication studied various preventive qualities of PV systems (preventing electricity price increases, climate change, and dependence on energy producers), for which researchers decided to focus on only one aspect of prevention for future study settings.

Therefore, the researcher explored the role of prevention for other types of ownership of PV systems for Articles IV and V, focusing only on the preventive quality related to climate change prevention. In Article IV, one variable of prevention was found to be a positive contributor to the dependent variable. This variable measured whether the solar electricity contract was perceived as a mechanism to save natural resources and reduce greenhouse gas emissions, highlighting the preventive quality of PV systems regarding climate change mitigation.

Also exploring third-party ownership of PV systems, Article V sought to explore the role of the preventive quality of innovations to their adoption intention, seeking to conceptualize preventiveness as a construct of innovations. This publication found prevention to be a standalone construct with a positive impact on adoption intention, yielding a greater impact than the other constructs, which were the perceived attributes of innovation and background factors. These findings highlight the positive role of the preventive quality of PV systems (regarding climate change mitigation) over adoption intention.

On the other side, this dissertation dealt with the attributes of the unwanted event in an exploratory fashion through Article VI. In insurance economics (Rees & Wambach, 2008), utility functions depend on the probability of an unwanted event with certain loss sizes; this work considered that the unwanted event could be described by its probability and severity. The influence of probability and severity was found to be relevant to decision-making. For the adoption of wood materials, the perception of a high probability of an unwanted event made incumbent organizations more likely to adopt the innovation, even if the organization was unfamiliar with it. When an unwanted event was perceived as highly severe, incumbent organizations prioritized solutions that would avoid reoccurrence. Additionally, incumbents developed a strong attitude against the previous solution with severe unintended consequences. An important research avenue is the further exploration of these attributes of the unwanted event.

4.7.3 Adopter characteristics and background factors

Preventive behavior is challenging to foster because it requires individuals to be future-oriented and motivated toward an underlying goal in prevention (Werle, 2011). Articles II to V sought to identify the adopter characteristics and background factors that could influence individual adoption.

Gender. The findings of Articles III and IV depicted gender as a highly significant variable in the intent to adopt or support the adoption of an innovation with preventive qualities. In both cases, female respondents were identified as more likely to adopt innovation. The role of gender in environmental behavior and decision-making has been identified in previous studies (Dietz et al., 2002; Mertens et al., 2021; Xiao & Hong, 2010). Similar to the findings of this work, female respondents showed more positive attitudes and environmental concerns than male respondents. A possible explanation is that traditionally female figures have a caregiver role, making them more concerned with nature (Blocker & Eckberg, 1997).

Knowledge about environmental issues. Another significant factor related to adopters was knowledge of environmental issues, classified as environmental self-assets in Article III. Environmental self-assets have previously been identified as determinants of pro-environmental behaviors and eco-behavioral intentions (Saari et al., 2020; Sonenshein et al., 2014). In Article III, environmental self-assets were identified to have a significant influence on the support of the adoption of products and services with preventive qualities. This finding could suggest that awareness of the unwanted event that the innovation seeks to avoid could promote its adoption.

Education. The findings in Article III also highlighted education as a significant factor in supporting the adoption of innovations. In this case, individuals with higher education levels were more likely to support communal housing projects with a preventive quality. This finding aligns with previous empirical settings in which higher levels of education are reflected in higher environmental knowledge and greater environmental concern (Blocker & Eckberg, 1997; Xiao & Hong, 2010; Xiao & McCright, 2015).

An important element to highlight relates to the context of all empirical studies—they were all carried out in Finland. According to Hofstede's cultural dimensions, Finland has a high level of uncertainty avoidance (Hofstede, 1993). Societies with high uncertainty avoidance adopt strict rules to minimize uncertainty and are risk-averse (Dinev et al., 2006). Therefore, the results may be different across cultures that are more risk-tolerant.

This study also identified the influence of prevention on adopters. Across these cases, the prevention of an unwanted event influenced adopter behavior. For example, incumbents in the construction sector developed strong attitudes toward materials that had previously caused health problems. Previous studies (Cohen & Head, 2013; D'Souza et al., 2013; Sherlaw & Raude, 2013) have identified that specific behaviors are necessary to promote the adoption of innovations with preventive qualities.

Perception influences risk attitudes, which guide behavioral intentions (Hillson & Murray-Webster, 2007, p. 8) and influence actions (Ajzen, 1991). Therefore, perceptions of the unwanted event the innovation seeks to avoid yield certain risk attitudes, which might influence the decision to adopt.

This study briefly analyzed how regulations regarding prevention influenced adopters and their behaviors. In the case of wood materials, upcoming regulations regarding carbon neutrality influenced incumbents' decisions in favor of the selection of wood. However, regulations reflect the influence of prevention and the type of innovation-decision, which can be optional, collective, or authoritative (Rogers, 2003, p. 24).

5 CONCLUSIONS

5.1 Key contributions

There is a challenging relationship between action and delayed benefits afflicting innovations with preventive qualities, which this dissertation sought to understand better. This work studied the preventive quality of innovations, seeking to build the construct further and explore factors influencing their adoption. Particularly, the researcher sought to understand how the preventive quality and perceived attributes of innovations influence adoption and intent to adopt and explore the influence of user and background factors. This final chapter highlights the key contributions by answering the proposed RQs, identifies theoretical and practical implications, assesses the reliability and validity of the study, and depicts the limitations and future study opportunities.

The different conceptualizations of prevention utilized throughout these chapters and the publications that make this dissertation are worth mentioning. Most articles in this work relied on the concept of preventive innovation introduced by Rogers (1983, p. 171); this term seeks to create a different category for innovations that prevent unwanted future events. The term preventive innovation has been used across diffusion studies to analyze the adoption of innovations with preventive qualities, such as vaccinations (Cohen & Head, 2013; D'Souza et al., 2013; Head & Cohen, 2012), climate change mitigation technologies (Pine et al., 2011), and information security behaviors (Mirtsch et al., 2021). However, these studies have paid little attention to further developing the concept of preventive innovation and identifying if the preventive element is a category of innovations or a dimension in their adoption.

The previous chapters in this dissertation and Article V refer to the preventive quality of innovations, not the concept of preventive innovations. This naming was incorporated as this work progressed, and it became more apparent that the 'preventive' quality may be a dimension influencing adoption. While there might be innovations purely created for prevention, there are other innovations where prevention is not the primary purpose. The contribution of this work lies in the latter, towards conceptualizing prevention as a construct of innovation influencing how these innovations are perceived.

RQ1*: How do the preventive quality and perceived attributes of innovations influence individual and organizational adoption and intent to adopt?*

Empirical evidence in this study identified the preventive quality of innovations to have a positive and influential role in the intent to adopt the innovation. The preventive quality of innovations is a distinctive attribute of innovation that is directed towards avoiding a future, possibly harmful event. In this study, the ability of PV systems to contribute toward climate change mitigation was a predictor of the intent to adopt the innovation.

The five attributes of innovations can describe innovations with preventive qualities. Innovations with preventive qualities can provide personal forms of *relative advantage*, such as a feel-good emotion. On the other hand, *trialability* and *observability* were not identified as significant in promoting or hindering the adoption intention of innovations in these studies. However, these attributes are commonly identified as challenging for innovations with preventive qualities due to the long-term orientation of prevention (Allander & Lindahl, 1997). In many situations, an adopter does not want to see the benefits of the innovation; for example, one does not want to test the efficiency of a seatbelt in an accident or make an insurance claim for illness. Therefore, how can one see the advantage of something one does not want to experience, try out, or observe? This was also identified across this work; for example, adopters of PV systems expected no electricity shortages, which should not occur with the purchase of PV systems. These examples illustrate how preventive quality can influence other attributes of innovations.

Compatibility might be challenged in the case in which the innovation does not match existing practices and capabilities. However, mixed results across existing studies and this work suggest that compatibility is not necessarily challenged for innovations with preventive qualities, but it can be context specific. Moreover, preventive behavior requires individuals to be future-oriented and motivated toward an underlying goal in prevention (Werle, 2011). Preventive behavior results from specific risk attitudes and is, therefore, not compatible with all behaviors and attitudes. Therefore, prevention creates a filter in compatibility, in which individuals with certain risk attitudes or a future orientation are better matched with innovations with preventive qualities. Future-oriented behavior seemed to be present across this work; for example, adopters of wood materials expected future-oriented benefits from wood constructions, which served to justify the significant investments.

Previous empirical settings have also identified risk attitudes as a hindrance to adopting innovations with preventive qualities. For example, Cohen and Head (2013) identified that non-adopters lack of a perceived personal risk of contracting HPV had explanatory power in the unwillingness to vaccinate. These examples illustrate how compatibility can be challenging to foster for innovations with preventive qualities compared to innovations that do not require individuals to be future-oriented or to have certain attitudes toward risk.

Previous studies and the empirical settings in this dissertation highlight a perceived *complexity* in using the innovation. It could be argued that innovations with preventive qualities can be difficult to understand and use. Additionally, the motivations behind prevention can be complex and difficult to communicate. For example, an inadequate understanding of how HPV is transmitted and how it could be avoided was identified as a deterrent to adopting the HPV vaccine (Cohen & Head, 2013). In the case of the adoption of wood materials, incumbents initially had difficulties understanding how wood could prevent future indoor air quality issues. Still, through seminars and external consultants, they understood the role of wood in preventing future unwanted events.

Finally, it is worth highlighting the findings from the exploratory analysis of the attributes (probability and severity) of the unwanted event that the innovation seeks to avoid. Probability and severity were first incorporated into the discussion as these elements are used in the insurance economics literature (Rees & Wambach, 2008). Because this work is studying the preventive quality of the innovation, the nature of the unwanted event in the analysis of innovations with preventive qualities seemed relevant. Empirical findings show the influence of perceptions of probability and severity on the adoption decision process. The unwanted event's greater probability and severity led to a greater interest in adopting the innovation. Previous findings on the adoption of insurance (Aditya et al., 2018) suggest that when an unwanted event has a high probability of occurrence, benefits can be experienced; this contributes to trialability and observability. This was observed in the case of wood materials, in which municipalities that experienced problems with indoor air quality in several instances were more willing to adopt innovations.

RQ2: *How can adopter characteristics and background factors influence the adoption and intent to adopt innovations with preventive qualities?*

The theoretical background of this dissertation identified a series of personal characteristics and background factors that can influence the adoption of innovations. The empirical settings across these publications sought to measure the role of adopter characteristics and background factors in the individual adoption of innovations with preventive qualities. Adopter characteristics included values, environmental attitudes and concerns, environmental knowledge, and willingness to sacrifice for the environment. Background factors included age, gender, education, income levels, contextual factors, and peer behavior.

Findings depicted that *gender*, *education*, and *knowledge about environmental issues* were influential in the adoption intention of innovations with preventive qualities. Particularly, those respondents who identified as female, highly educated, and knowledgeable about environmental issues were more likely to adopt or support the adoption of innovations. Previous studies on pro-environmental behavior and behavioral intentions have presented similar findings regarding gender (Dietz et al., 2002; Mertens et al., 2021; Xiao & Hong, 2010), education (Blocker & Eckberg, 1997; Xiao & Hong, 2010; Xiao & McCright, 2015), and knowledge about environmental issues (Saari et al., 2020; Sonenshein et al., 2014).

Regarding organizational level findings, corresponding to qualitative study settings in Articles I and VI, factors that influence the adoption of innovations were classified into financial, environmental, strategic/political, and construction related. No common denominators were identified describing adopter characteristics and background factors between individual and organizational adopters.

5.2 Theoretical and practical implications

This dissertation studied innovations from the construction and energy sectors with underlying qualities of health and climate change prevention and mitigation. This work included qualitative and quantitative empirical studies, providing a rich picture of the factors influencing the adoption of innovations with preventive qualities and paving the way for building the construct of prevention in the adoption of innovations.

The main contribution of this work is theoretical in the domain of diffusion studies, in which the preventive quality of innovations has seldom been covered when studying adoption and adoption intention. Previous studies have also paid little attention to building up the construct of prevention in the adoption of innovations, which this work seeks to contribute towards.

For the researcher, this study provides a macro-level view of factors that influence the adoption of innovations with preventive qualities. The findings provide a picture of how the factors influencing adoption are present for innovations with underlying qualities of climate change protection and mitigation. For example, the feel-good emotion derived from adoption was identified as a form of relative advantage, and environmental self-assets and education levels were identified to be influential in the expected period for adoption. This work also depicts prevention as a standalone construct with significant and positive influence over adoption intention. The potential interrelationships of prevention over other constructs must also be examined.

At the same time, this work makes a theoretical contribution by exploring the attributes of the event to be avoided by studying the role of probability and severity in the adoption of innovations with preventive qualities. These two elements have not been covered in diffusion studies but are relevant when evaluating unwanted events. This dissertation identified that the perceived probability and severity of the unwanted event that the innovation sought to avoid influenced adoption intentions, thus warranting future in-depth study settings. Overall, these findings provide valuable insights for future researchers to explore the adoption of innovations with preventive qualities and further examine the interrelationships between constructs.

For the practitioner, this study provides insights into factors that influence the adoption of innovations with preventive qualities; this could be particularly valuable for suppliers of products and services with underlying prevention qualities, such as preventive healthcare technology, green technologies, and business risk mitigation offerings, among others. Understanding the role of prevention can help practitioners appeal to buyers keen on preventing an unwanted event; more buyers could follow due to peer influence. However, it is important to understand that 'prevention' might not appeal to all buyers, and economic incentives usually have a stronger influence over other factors (Cheung et al., 2017), for which benefits from prevention can also be quantified in the form of time and money savings. Also worth highlighting is that the more radical the innovation with preventive qualities, the less likely there will be any pre-established norms and attitudes, so it is the job of the practitioner to develop such attitudes so the innovation is better accepted.

Moreover, the identified influence that subjective perceptions of probability and severity may have on adoption could be valuable for those supplying prevention products and services, in which strategies to lower these subjective perceptions could influence adopter behavior. The perceived probability and severity of risk have been identified as significant contributors to the intention to purchase insurance policies across insurance studies (Aditya et al., 2018; Lefebvre et al., 2014; Palm, 1995). Overall, these findings offer insights and provide guidance for suppliers of products and services of innovations with preventive qualities that can guide production or promotion decisions.

5.3 Reliability and validity assessment

This section focuses on the reliability and validity assessment of the measurements used in this dissertation. Measurement is the process of linking abstract concepts to empirical indicators; it involves both empirical and theoretical considerations (Carmines & Zeller, 1979, p. 9). There is an observable response from the empirical side, whereas, from the theoretical side, the focus is on underlying unobservable concepts. When the relationship between empirically grounded indicators and underlying unobservable concepts is strong, inferences can be made about the relationships between concepts (Carmines & Zeller, 1979, p. 11). Social scientists seek to determine the extent to which an empirical indicator can accurately represent a theoretical concept; they rely on two basic properties of empirical measurements: reliability and validity.

Reliability is the extent to which a measuring procedure can yield the same results on repeated trials (Carmines & Zeller, 1979, p. 11). With less variation in repeated measurements of an attribute, reliability will be higher (Polit & Hungler, 1992). Reliability can be assessed in different ways for quantitative and qualitative research. In qualitative research, reliability lies in consistency (Leung, 2015). Among the approaches used to establish qualitative data reliability is constant data comparison, which involves researchers verifying data through continuous comparison, either alone or with peers, as a form of triangulation (Leung, 2015). Articles I and VI used qualitative data analysis (semi-structured interviews and data coding). Notes on coding were cross-checked and agreed upon among the researchers to ensure the reliability of the data analysis. Weekly discussions with the authorial team helped ensure that the data interpretations were consistent. Regarding data collection, the knowledgeability of the informants was sought by selecting them based on official documentation; these informants played key roles in procurement processes.

Reliability can be assessed in quantitative research in different ways, including the retest method for stability, inter-item reliability for internal consistency, and parallel scale for equivalence. This study evaluated quantitative data reliability through inter-item reliability for internal consistency. Internal consistency assesses how different items measure the same characteristic (Bannigan & Watson, 2009). Inter-item reliability for internal consistency can depend on a single test administration, and it yields coefficients that measure internal consistency (Carmines & Zeller, 1979, p. 44).

Among the most common coefficients measuring internal consistency is Cronbach's alpha, formulated from the average inter-item correlation and the number of items on a scale. For Articles II to IV, where multiple regression was the primary data analysis method, Cronbach's alpha was used through SPSS software as the first step before other statistical analyses. Across all cases, there were Cronbach's α values all above 0.6. To assess internal consistency reliability, for Article V, Rho_A(ϱA) was selected following more recent guidelines (Sarstedt et al., 2022), highlighting ϱA as a new and consistent reliability coefficient for PLS (Dijkstra & Henseler, 2015). Following Hair et al. (2019), all values were within acceptable minimum levels of 0.60. Reliability in quantitative publications was also enhanced by triangulation among researchers, in which four researchers were involved in survey creation, translation, testing, and implementation, lowering the possibility of random errors.

Validity helps identify whether what is being measured is what the researcher wants to measure; it is concerned with the meaning and interpretation of a scale (Bannigan & Watson, 2009). Validity depicts the appropriateness of tools, processes, and data (Leung, 2015). The three most basic types of validity are criterion-related validity, content validity, and construct validity (Carmines & Zeller, 1979, p. 17). Criterion-related validity is relevant when the purpose is to use an instrument to estimate a form of behavior. Content validity depends on how well an empirical measurement reflects a content domain. Construct validity identifies how much a measure relates to other measures consistent with theoretically derived hypotheses concerning the measured concepts.

Various steps were taken to ensure that the validity of the present study was as high as possible. For data extraction and analysis, validity was enhanced through triangulation among researchers, an audit trail of materials and processes, and respondent verification (Leung, 2015). This was particularly relevant to Articles I and VI, which relied on qualitative data analysis.

To analyze the validity of Articles II to IV, the researchers relied on Pearson Product Moment Correlations using SPSS. This test is done by correlating each item in the questionnaire with the total score. Items significantly correlated with the total score indicate validity (Puth et al., 2014). In this step, researchers removed items with validity issues ($p>0.1$), where less than 20% of all variables were removed.

For Article V, which relied on PLS-SEM, construct validity was measured with the average variance extracted (AVE), where all values were above 0.5 (Hair et al., 2019). Discriminant validity was assessed with the Heterotrait-monotrait (HTMT) ratio (Henseler et al., 2015) with a cutoff value of 0.90. Here, the HTMT between the two items was above 1; however, an analysis of the Fornell & Larcker criterion (Fornell & Larcker, 1981) confirmed no validity issue. Another measure taken to reduce criterion-related validity issues was the use of variables grounded in previous empirical research on the adoption of innovations and eco-innovations (Chen et al., 2020; Islam, 2014).

Common method bias, the variance attributable to the measurement method, was also evaluated throughout these publications with Harman's single factor test using SPSS. Across Articles II to V, the test revealed that the total variance extracted by one factor was well below the recommended threshold value of 50% (25% on average). This result demonstrates that common method bias was not an issue in this study.

Selection bias is the one that occurs during the identification of the study population (Pannucci et al., 2010), and it is a problem in social research when the investigator does not observe a random sample of a population (Winship & Mare, 1992). For the three datasets of Articles II, III, and IV-V, selection bias was avoided by random sampling, in which respondents would voluntarily complete the survey on the website of a local electricity company (Articles II, IV, and V) or were distributed to tenants of apartment buildings (Article III). Researchers also compared the sample's demographics to the country's average and reported cases with significant over– or under– representations. For the dataset utilized for Articles I and VI, purposive sampling (Martínez-Mesa et al., 2016) was conducted as researchers sought first-hand accounts from experts involved in the procurement process to identify decision-making paths in the adoption of wood materials. To minimize selection bias in purposive sampling, researchers interviewed representatives in diverse roles — ranging from the city's mayor to education specialists— in each case and sought to reach a saturation point, where no new insights were brought from interviews (Martínez-Mesa et al., 2016).

5.4 Limitations and future studies

This dissertation and the publications included in it are not without limitations. A significant limitation is that the findings cannot be generalized, as they belong to the context of the construction and energy sectors in Finland. The Finnish culture is characterized by high uncertainty avoidance (Hofstede, 1993), which could drive individuals toward risk-averse decision-making; the findings might differ for more risk-tolerant cultures.

The empirical settings included in this dissertation studied the individual and organizational adoption of innovations with preventive qualities. While these diverse adopter groups provided a rich view of the adoption of innovations, they were limited to the same economic sectors—the construction and energy sectors. Focusing on a limited number of industries allowed comparison across findings, but at the same time, it limited the ability to generalize the results.

Across empirical studies, the researcher was able to focus on only one type of adopter at a time. For Articles I and VI, the focus was on adopters who had already selected wood materials. In contrast, Articles II to V focused on those who would potentially adopt innovations. This meant that the researcher could not obtain a view of the factors influencing different adopter groups for the same innovation. Furthermore, in quantitative settings, the researcher focused on a few factors influencing adoption, DOI characteristics for Articles II, IV, and V, and personal and background factors for Article III, which also limits identifying elements that influence the adoption as those highlighted in other behavioral theories such as the Technology Acceptance Model, TAM (Davis et al., 1989), the Theory of Planned Behavior, TPB, (Ajzen, 1991) or the Unified Theory of Acceptance and Use of Technology, UTAUT (Venkatesh et al., 2003), which merit further investigation. This limited scope also resulted from seeking to comply with conference page limits.

Finally, acknowledging that preventive actions are not only in the form of innovation adoption is important. For example, curtailment behaviors around energy usage can mitigate climate change, and prophylaxis can prevent disease. Therefore, this dissertation is limited to the adoption of innovations as one way to take preventive action, recognizing that other forms of prevention exist.

These limitations pave the way for future study settings. First, research should delve deeper into the preventive quality, which has now been measured as an influence over adoption; however, could it also be a mediator to other characteristics of innovations? Future studies investigate whether the preventive aspect can be a categorization or a dimension of innovations.

Other avenues for future research include studying the factors behind the adoption of innovations with preventive qualities in cross-cultural settings. This could illustrate the role of uncertainty avoidance in the adoption of innovations. Additionally, researchers could focus on the adoption of other types of innovations across different sectors, such as the industrial, agricultural, and transportation sectors, which are all strong contributors to global emissions.

An important research avenue is the further exploration of the characteristics of the unwanted event (probability and severity) and the role these play in the adoption. In this work, the characteristics of the unwanted event were incorporated in an exploratory fashion, mostly in Article VI, where the unwanted event was found influential over adoption. Determining the influence of the features of the unwanted event on the intent to adopt can provide valuable insights into building the construct of innovations with preventive qualities.

Despite these limitations, the results of this dissertation provide additional steps to unveiling the elements that influence the adoption of innovations with preventive qualities. Future work should identify evidence that supports the construct within applications of prevention products, services, and ideas.

Prevention might be difficult to foster, consequently, innovations with preventive qualities can be perceived as difficult to adopt and diffuse. The limited existing theoretical base on the topic constrains research efforts and output. This work highlights the need to conceptualize preventiveness as a construct of innovation and provides a theoretical base from which to start.

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ARTICLE
I

Wood material selection in school building procurement – A multi-case analysis in Finnish municipalities

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Wood material selection in school building procurement – A multi-case analysis in Finnish municipalities

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ABSTRACT

Municipalities are increasingly adopting green public procurement practices in construction projects; one example is the specification of preferred building materials in public procurement tenders. Before tendering documents, different stakeholders and their ambitions influence the framing of material requirements. In this paper we explore factors initiating wood material selection in five public procurement cases, where the initiation phase of the procurement resulted in wood material use requirements specified in the public procurement tenders. Based on the cases, we constructed potential paths leading to building material requirements to be set in the tender documents. We also identified triggers initiating construction projects and offer a discussion of the role of different determinants related to building material use. These identified paths, triggers, and determinants unveiled the dynamics behind building material requirements in public procurement tenders and more specifically, the actions and underlying values for doing so.

1. Introduction

The transition toward sustainability involves technological changes as well as changes in practices, culture, networks, regulation, and infrastructure (de Oliveira et al., 2013; Morone, 2018). The construction sector has the potential to significantly contribute to the transition, as it is one of the most significant carbon-intensive sectors. Annually, its practitioners are responsible for more than 20% of the carbon dioxide emissions originating from global economic activities (Huang et al., 2018). Additionally, the sector is also one of the main contributors to energy consumption, other greenhouse gas emissions, material extraction, and water consumption (e.g., European Commission, 2011; Bohari et al., 2017; Bohari et al., 2020; D'Amico et al., 2021).

Using low-carbon building materials is one way to reduce carbon dioxide emissions; other methods include extending the lifecycle of existing buildings (Huuhka and Vestergaard, 2019) and promoting the energy efficiency and renewable energy use of machines in new construction (Huang et al., 2018). In discussions of building materials, wooden materials have generally been considered as low-carbon, suggesting that their use would lower the environmental impact of new buildings (Viholainen et al., 2021). Additional benefits include wood's abilities to be a restorative material, balance indoor moisture, prevent bacterial growth, and provide a warm atmosphere (Alapieti et al., 2020). Such benefits are, however, difficult to express in monetary terms and thus easily considered as having no market value (Hurmekoski et al., 2015).

Wood material use may help in achieving climate change mitigation targets and supporting users' well-being. Such benefits do not directly benefit the building procurer by providing cost savings; instead, the benefits are partly indirect and actualized in the long-term. Moreover, despite the perceived benefits, the adoption of new building solutions can be challenging in the construction sector, as it is particularly risk-averse (Arora et al., 2014) and technological changes can take several decades to be realized (Reichstein et al., 2005; Mahapatra and Gustavsson, 2008). Reasons behind this have been referred to as liabilities: the liability of immobility of the product and the liability of unanticipated demand (referring to how demand is uncertain, complex, involves several stakeholders, and depends on fixed capital investments [Reichstein et al., 2005]). Furthermore, path dependency of an established construction system could also deter the diffusion of new practices in the

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sector (Mahapatra and Gustavsson, 2008), with path dependency referring to previous events or decisions affecting the present. New initiatives are needed to step outside these paths to promote sustainable building material use. This research sheds light on such initiatives and forerunner practices for sustainability in the public sector.

In this paper we examine wood material selection in public building procurement, as municipalities are increasingly promoting the use of sustainable building materials. Such initiatives include adopting green practices by, for example, specifying preferred building materials in public procurement tenders. One suggested driver for municipalities' eagerness to promote wood material is linked to their responsibilities for furthering residents' well-being in an economically feasible manner (Jäntti, 2016). However, empirical investigations are lacking with regard to how different stakeholders' levels of commitment, awareness, knowledge sharing, and technical competencies drive greener building projects (Bohari et al., 2020).

Existing research has not adequately covered how wood is introduced in public building procurement projects. Neither it is known what factors facilitate or hinder the selection of wood in public procurement. Thus, we pursued these specific Research Questions (RQs):

RQ1: How is wood material selection initiated in public building procurement processes?
RQ2: What kinds of factors facilitate or hinder the selection of wood material during the procurement process?

In this paper we address these questions by examining recently completed school procurement processes in Finland. The results show how wood material requirements become incorporated into public procurement tenders. To uncover the incorporation mechanisms and value expectations during the procurement process, we first analyzed the procurement processes and then explored discussions as to how and by whom they are connected to wood material selection (cf. Ritala et al., 2021). We used the Switching Path Analysis Technique (SPAT) to identify the *initiating, facilitating,* and *hindering* factors for wood selection in public school procurement processes. In the SPAT vocabulary, the initiators are framed as *triggers* and they can be *situational, reactional,* or *influential*. The facilitating or hindering factors are framed as *determinants*. After identifying the triggers and determinants in each procurement process, we explain how they are linked to the influence and involvement of different stakeholders. Our analysis offers a detailed account of how wood has become specified in public procurement tenders.

The rest of the paper is structured as follows: The next section explains public procurement and the role of requirement specification in the procurement procedure. We then discuss the benefits and obstacles of using wood as a building material. Next, we present SPAT as our method for understanding the paths leading to wood material requirement specification in school building procurement. We present our findings and discuss them using SPAT vocabulary. We end the paper by offering implications for both literature and practice.

2. Existing analytical lenses

2.1. Procedural view on green public procurement

Municipalities are increasingly promoting sustainability in the construction sector. One example is the specification of green criteria in public tenders (Andrecka, 2017; Kristensen et al., 2021), e.g., by preferring greener building materials (de Oliveira et al., 2013; Bohari et al., 2017; Francart et al., 2019) and emphasizing circularity (Sönnichsen and Clement, 2020). Prior researchers have labeled such procurement practices and decisions as "green public procurement" (Bohari et al., 2017, 2020; Cheng et al., 2018), and the approach has gained a foothold in achieving the transition toward sustainability (Sönnichsen and Clement, 2020). In general terms, green public procurement has been defined as "a process whereby public authorities seek to procure goods, services, and works with a reduced environmental impact throughout their life cycle when compared to goods, services, and works with the same primary function that would otherwise be procured" (European Commission, 2016).

In many parts of the world, municipalities as public entities are subject to strict regulations on procurement when promoting green criteria. In this study, public procurement was acknowledged as being regulated by European Union (EU) directives (European Commission, 2018). At the time of the study, EU regulations allowed eight tendering procedures for public procurement; however, choosing the tendering process is not the only condition for attaining green procurement. Also, the winning tender must be selected, which ultimately decides whether the outcome of the process will be 'green' or not. Indeed, according to European Commission regulations, contracting authorities must choose the best tender following certain award criteria. Alongside selection criteria, award criteria must be set in advance and published in procurement documents. Typically utilized award criteria include the most economically advantageous tender (MEAT), the lowest price approach, and best price-quality ratio approach.

MEAT is a method of assessment where the contracting party can award a contract based on various aspects of the tender submission, other than just price. In a MEAT assessment, various criteria can be weighed in, including quality, price, aesthetic and functional characteristics, technical merit, environmental and characteristics, delivery conditions, among others. In the lowest price or price-only approach, price is the only factor that is considered; the tender with the lowest price wins the contract. Finally, in the best price-quality ratio approach, the selected tender is the one that offers the best value for money, assessed through criteria linked to the subject of the public contract, and may include qualitative, environmental, and social aspects. Typically, the award criteria will be scored using a system that assigns weightings to the different criteria (European Commission, 2018).

Even though formal procedures help structure decision making and interaction in public procurement, the mechanisms within their "real-life" context are more complex. Prior literature on urban development projects shows that decision-making processes proceed via various networks of public and private actors that also interact informally (Klijn, 2008). Less often, processes proceed purely within the context of formal and bureaucratic structures operating at one policy level (Block and Paredis, 2013). Interactions and dialogue require further research, as they are not yet thoroughly understood in the context of sustainable procurement practices (Sönnichsen and Clement, 2020).

The complex, multi-actor, and multilevel nature of the procurement process is also present in our school building procurement cases. School buildings are large investments for municipalities and the impacts of procurement are long-lasting, as the buildings are intended to be used for several decades. Moreover, they are procured rather rarely in one municipality. These characteristics mean that the procurement process and related requirements specifications are crucial, resource-intensive efforts for the municipalities, thus necessitating the involvement of several actors and viewpoints. In this vein, Murtagh et al. (2020) mentioned school buildings as an example of a building product requiring holistic perspectives on sustainability. As procurement objects, they also represent the softer values and societal aspects of sustainability; these have been overshadowed by the "hard" science of sustainable construction, e.g., waste, materials, and energy management (Udomsap and Hallinger, 2020).

2.2. Environmental, financial, and well-being related benefits encourage wood material selection

The use of renewable building materials has gained wider attention in response to increasing pressure to support sustainable urban development. Particularly, the use of wood for construction has gained attention in this trend. Wood use is justified mainly for three reasons:

environmental sustainability, financial benefits, and well-being impacts.

First, wood material use is considered to be a way to reduce the carbon footprint of the building throughout its life cycle (Peñaloza et al., 2016; Hildebrandt et al., 2017). Environmental impact studies show that wood-framed buildings are carbon-neutral (Ritter et al., 2011), have lower environmental impact than steel or concrete structures (Robertson et al., 2012), and can act as carbon stores (Börjesson and Gustavsson, 2000).

These environmental aspects seem to fit well with municipalities' strategic aims in the Finnish context, as almost half the population lives in a municipality that aims to be carbon-neutral by 2030. Increasing the amount of wood in construction projects is seen as an efficient way to reduce carbon footprints and achieve climate targets (Finnish Ministry of the Environment, n.d.). Promoting wood construction is part of Finland's objectives within the strategic theme of carbon neutrality and biodiversity of the current administration. Alongside strategies to promote the use of wood in the construction sector, Finland's support for the cause is reflected in a series of legislative changes where regulations for load-bearing structures and fire safety requirements have been loosened, now allowing wooden constructions of up to eight stories (Puuinfo, 2020). Similar political ambitions to decrease the environmental impact of construction have been reported in other Nordic countries; in Sweden, political support was reported to be a driving force for timber construction (see e.g., Lindgren and Emmitt, 2017).

Second, wood is a useful and versatile building material (Miller et al., 2004, p. 163) and it offers various financial benefits to construction projects (Mahapatra and Gustavsson, 2008; Ritter et al., 2011; Grable, 2018). Production of a wooden building is less complex than concrete buildings, which leads to faster project delivery (Mahapatra and Gustavsson, 2008). In the case of prefabricated wooden building projects, analyses have depicted that costs are the same or less in comparison to concrete constructions (Grable, 2018), and there is potential for more savings through improved logistics and increased prefabrication (Mahapatra and Gustavsson, 2008). Furthermore, aesthetic differentiation from non-wood counterparts allows project owners to capture higher rental rates (Grable, 2018). Finally, the use of wood supports the economic development of forest areas and contributes to national income (Ritter et al., 2011).

Third, wood offers benefits related to well-being. Wood material is considered a restorative material that affects the psychological well-being of occupants (Burnard and Kutnar, 2019; Demattè et al., 2018). By using wood, it is possible to create pleasantness and coziness and improve the atmosphere of indoor spaces or urban environments (Karjalainen, 2002, Demattè et al., 2018; Poirier et al., 2019). Moreover, wood can moderate indoor humidity and has antibacterial properties, which affect the perception of indoor air quality, thermal comfort, and energy efficiency (Virtanen et al., 2000; Rametsteir et al., 2007; Nore et al., 2017; Vainio-Kaila et al., 2017). Some tree species are naturally resistant to decay, which can be exploited in construction (Rametsteir et al., 2007) Such attitudes are partly country-specific, as the use of building materials varies between countries due to traditions and culture, which can be the result of the availability of materials (Høibø et al., 2015).

2.3. *What discourages wood material selection in construction?*

Despite myriad benefits, there are barriers that discourage the selection of wood for new building construction. First, there are characteristics inherent to the construction sector (see the six *liabilities* identified by Reichstein et al., 2005), in which immobility and unanticipated demand have been identified as deterrents to the diffusion of technologies in the construction sector. For example, shifting to wood as a main building material for multi-story buildings would require changes in products, processes, and organizations (Hurmekoski et al., 2015).

In the Finnish context, industry stakeholders consider wood-related regulations to be excessive and cost-burdensome. For wood multi-story construction (WMC), national building codes regarding fire regulation are perceived as relatively strict, as they require installing automatic sprinklers and encapsulating the structural frame, which can create significant additional costs (Hurmekoski et al., 2018). However, these concerns have been noted by the current administration and steps have been taken toward harmonizing building supervision.

As a result of industrialized concrete construction, the experience and education of construction professionals is centered around bricks and concrete. Therefore, wood can even be considered an old-fashion material (Høibø et al., 2015). Having no experience with wood construction, builders consider they have insufficient knowledge of wood buildings and unclear project management skills for the process (Lindblad, 2019). Furthermore, difficulties related to wood building codes and lack of knowledge related to those codes are important obstacles to the adoption of wood (Gosselin et al., 2016). Thus, the transition toward wood construction requires education and marketing efforts, both of which are costly (Lindblad, 2019). In the Finnish wood-frame markets, suppliers and contractors have created alliances to share risks and costs of development (Hurmekoski et al., 2018).

On the other side, costs also pose an important barrier to the adoption of wood as a structural material, where capital, material, construction, and long-term maintenance costs are mentioned. As identified previously, analyses have shown that costs are the same or less in comparison to concrete construction, when it comes to prefabricated wooden building projects (Grable, 2018). Additionally, there are cost savings through shorter construction times, improved quality control, lighter foundation work, and reduced transportation (Hurmekoski et al., 2015). This might compensate for 25% costlier material, additional fire safety costs, and façade maintenance costs that occur every 10–20 years (Hurmekoski et al., 2015). Furthermore, municipal resources might to be too scarce for environmental consideration (Francart et al., 2019).

Consumers have concerns and prejudices about wood buildings' technical characteristics, perceiving them as more expensive to maintain, less fire-resistant, less durable, and less resistant to decay and insects than other materials (Rametsteir et al., 2007; Lähtinen et al., 2019). There are likewise negative perceptions that forest product companies engage in unsustainable practices (Eastin et al., 2001). Altogether, path dependency (Mahapatra and Gustavsson, 2008; Hemström et al., 2017) and tradition (Høibø et al., 2015) create barriers to the use of wood in construction projects. Path dependency refers to how a decision that is made today is affected by past decisions. The main sources of path dependency are beliefs, perceptions, norms, and rules that guide decisions and activities along certain trajectories (Geels, 2004). Path dependency hampers the willingness of construction professionals to select a material that has a lower degree of standardization than other alternatives, especially one with which they have little expertise (Mahapatra and Gustavsson, 2008).

2.4. *Identifying paths behind building materials requirements*

We chose the Switching Path Analysis Technique (SPAT [Roos, 2002]) for analyzing the procurement processes, due to its ability to capture the actual events and influencing factors in decision-making. SPAT assumes a procedural view of decision making, as it approaches decision making from a historical perspective.

SPAT is a variation of the widely recognized Critical Incident Technique (CIT, originating from the work of Flanagan, 1954). CIT offers a method for analyzing incidents and describing their criticality, as it involves a set of procedures for collecting direct observations of human behavior affected by broader factors. A critical incident is one in which the objective of an individual's act is widely evident for the observer and consequences are sufficiently evident regarding its effects (Flanagan, 1954). Researchers utilize the technique in content analyses to identify the most frequent quality determinants (Roos, 2002). Compared to other CITs, the SPAT acknowledges the disparities and dynamic nature of critical incidents (Roos, 1999). It is based on the consequence of a critical incident (Roos, 2002) and provides a broad view of decision-making processes (Selos et al., 2013). In SPAT, an incident has a trigger, an initial stage, a process, and a consequence (Roos, 2002).

Triggers are catalysts that make the decision maker inclined to act; they fuel and steer the process without being visible (Roos, 2002). There are three different types: situational, influential, and reactional. Situational triggers originate from changes within an organization outside of the process (Roos, 2002; Selos et al., 2013). Influential triggers originate from market changes which affect the competitiveness of organizations (Selos et al., 2013). Reactional triggers arise from individuals' (or organizations') immediate responses when they are dissatisfied with a chosen solution.

The decision-making process is illustrated by *determinants* (Roos, 2002); there are three types: pushing, swayer, and pulling determinants. Pushing determinants give the decision maker reasons to act; they *push* toward change. Swayer determinants can accelerate (positive swayer) or delay (negative swayer) the action, but they do not cause the action per se. Finally, pulling determinants bring the decision maker back to the original solution.

Decision-making paths and their triggers and determinants are highly case-specific; what is considered a trigger in one case, could be a determinant in another. The difference between triggers and determinants lies on when they occur in each decision-making process (Roos, 2002). The trigger appears at the beginning of the process and it reveals how the process starts whereas the determinant is part of the decision process itself.

SPAT was first applied to study consumer decision making in insurance, retail, public administration, and retail banking (Roos, 1999, 2002). The technique was later extended to organizational decision-making processes. It was applied in business-to-business supplier switching processes by Selos et al. (2013) when they studied businesses with service elements that had an important role in supplier selection. Furthermore, Saukkonen et al. (2017) demonstrated the applicability of SPAT to explain companies' investment decisions relevant to the adoption of environmental technology.

For this study we utilized SPAT in understanding public procurement processes. As decision-making entities, public organizations vary greatly from consumer-based and private organizations. While private sector organizations seek to maximize wealth for shareholders, public service organizations seek to satisfy the needs of the community (Nutt, 2006) through multiple and sometimes conflicting goals (Rainey, 2003, p. 149), while attaining value for the monies exchanged (Lindholm et al., 2019). These differences are also reflected in public investment decisions, where the overall economic impact of different options is considered given that the most economically advantageous tender must be selected (Lindholm et al., 2019; Walsh et al., 2011, p. 32).

3. Materials and methods

In this paper, we present multiple case studies on school selection procedures. We applied a qualitative research approach suitable for studying complex problems that cannot be explored in isolation from their human and social contexts (Creswell, 2013). Requirement specifications in municipal school building procurement are examples of such a problem. The use of multiple studies enabled us to make comparisons across cases (Fig. 1).

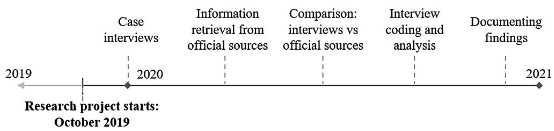

Fig. 1. Research process timeline As shown in Fig. 1, our research consisted of five main stages where multiple data sources were employed.

- First, we conducted semi-structured retrospective interviews (Decker et al., 2020), which served as a primary data source.
- Second, we retrieved information from news outlets, municipalities' websites, and official procurement documents such as contract notices and contract award notices available at EU Tenders Electronic Daily (TED).
- Third, we compared data from interviews to information from official sources to identify if there was any information missing or that required clarification.
- Fourth, we coded and analyzed the interviews using SPAT vocabulary in Atlas.ti, a qualitative data analysis software.
- Finally, we documented our findings.

Through the interviews we were able to capture tacit practices and experiences of the people involved in procurement processes; such knowledge could not be seen from official documents which tend to anonymize the motivations and practices of the actors involved (Decker et al., 2020). Interviewees included professionals responsible for project management, city administration, urban services, and education. As noted by Kumar et al. (1993), multiple informant reports are needed to achieve correspondence between the reports and the studied concepts at the collective level. The informants were identified based on official project documentation and "snowballing." We interviewed 20 people in key roles in each of the five cases. All agreed to follow-up interviews for clarification purposes if needed. Some shared confidential internal documentation related to purchasing decision preparations.

The interviews were analyzed through Atlas.ti. Notes on coding were cross-checked among authors of the paper. The researchers agreed on two main coding families based on SPAT vocabulary: first, triggers (situational, reactional, and influential triggers) initiating the procurement projects, then determinants (pushing, positive swayer, negative swayer and pulling determinants) moving the process toward requiring the use of wood in the tendering phase. Other coding groups emerged as the coding progressed; these include stakeholders (officials and politicians e.g.,"stakeholders_politicians_mayor" or "stakeholders_officials_project engineer") and made decisions (official and unofficial). Weekly discussions within the authorial team (Cresswell, 2000) helped ensure that interpretations of data were not idiosyncratic.

Because our data was collected from a Nordic country that has a history of wood industry, similar findings could be limited to contexts adequately comparable to ours. However, in terms of accumulating scientific knowledge, we can claim that our study provides new knowledge about green procurement practices in general as well. Moreover, our research process itself could well be replicated but the findings in other context might differ from ours, thus contributing to the accumulation of scientific knowledge based on findings in other socioeconomic contexts (in other countries and regions) in which ecologic sustainability is sought for through public procurement.

4. Findings

4.1. Overall context of the procurement cases

We selected five public procurement cases from the construction sector; each concerned school buildings that listed wood as the preferred building material. Cases were first selected based on their recent history, which ensured the availability of key informants and their ability to recall critical points in the process as well as justifications of procurement requirements. All cases were based in Finland, meaning that all the municipalities operated under the same national context following EU regulations on public procurement procedures (Public Procurement Directive, 2014/24/EU). They were all from the same region, having forerunner status in promoting wood construction. The region has the second-largest wood construction share from new building construction in the country. Finally, the cases were representative of the variety of school procurement processes, as they differed in terms of chosen procurement procedure, how wood use was specified in the award criteria, and the actual wood use in the winning tender (Table 1).

4.2. Wood material selection within the school procurement processes

School buildings are rather large and rare investments for a municipality. The investments have direct impacts on the municipality's financials. For return, the municipality may aim for achieving several positive impacts, such as promoting well-being and achieving operational efficiency of different user groups. Naturally, the groups have different requirements for the school building, with material requirements being one. Municipalities may differ in terms of how they engage user groups or other stakeholders in the procurement process. Therefore, procurement processes may differ in terms of how the wishes of school staff, students, and evening users are considered. Due to its rareness, municipal officers may also hire external experts and consultants for taking the process forward. On a general level, the process may engage different municipal officers, vendors, consultants, and user groups in different stages of the process.

In the studied cases, wood material was incorporated to the building material requirements before tendering, selecting the supplier, and contracting (Fig. 2). This indicates that wood becomes considered through other paths than those suggested by bidding vendors. To better understand these mechanisms, we identified the elements initiating the wood material selection in each case.

As shown in Fig. 2, the incorporation of wood into selection criteria does not appear in the same manner across cases. Furthermore, the way criteria related to wood material selection are incorporated in the tendering phase varies; for example, for school 1, tendering documents called for a "mainly wooden" structure, whereas in school 2, requirements specified that "most of the facades, partitions and claddings should be made of wood". Other cases did not have specifications for wood incorporation in tendering criteria but did call for the inclusion of bio-based materials and solutions (school 4) or had award criteria such as "environmental sustainability" and "energy efficiency", which could have supported the incorporation of wood into the project.

4.3. Situational, reactional, and influential triggers

In each procurement case, all three triggers were present. All cases featured major situational triggers, which depict the constantly evolving and multi-actor network environment, typical of the public sector. Drivers for situational changes can be divided into four categories: financial, environmental, strategic and political, and construction related.

- Financial issues established a permissive or restrictive limit on the municipality's budget for the construction project.
- Environmental issues such as carbon-neutrality and sustainable development goals made the municipalities more inclined toward environmentally conscious decisions.
- Strategic and political issues triggered the consideration of wood materials in various ways, either through top-down decisions that mandated their incorporation; through municipality-wide strategies to have more buildings made from wood; or through the desire to increase the municipality's attractiveness, as illustrated by an urban services director's quote, *"Some municipalities that have these wood schools, they use as, it's sort of a way to attract new citizens or inhabitants to the municipality for instance"* (23.09.2020).
- Construction issues encapsulated technical elements that affected the incorporation of wood such as land plot size and shape, the number of stories in the building, and requirements for space versatility.

Reactional triggers were also clearly present in the cases. In most, the consideration of wood materials started as a response to indoor air quality problems in buildings made from "traditional," hard materials such as concrete, as brought up by a construction manager: *"There were indoor air problems, or people suffering from indoor air problems. So that, of course, kicked this issue [school procurement process] forward"* (09.11.2020). The related health problems created a feeling of urgency to react, as described by a technical director: "*There have been such serious health problems and threats that they [schools] have had to be closed down and procured with great urgency*" (29.11.2019).

Influential triggers were mostly present through peer learning, self-learning, cross-municipality competition, and the quest for a positive reputation. Peer learning was identified by a municipality's willingness to learn from another municipality's successful wooden school project as well as their willingness to learn from their drawbacks in the process. Self-learning was present in municipalities that had previously carried out a wooden building project, which gave enough experience and confidence for a larger endeavor, as stated by a structural expert: *"When [new project] was decided it [previous project] was already a good experience"* (15.11.2019).

In this case, influential triggers affect the competitive situation of municipalities. In this study, a desire to stand out from other municipalities and be more competitive in terms of citizen attraction was identified as a driver toward incorporating wood, as directly highlighted by a project manager: *"So if in X [other municipality] is something happening [our] people think we have to be a little bit better and we have to have at least one more wood-framed school"* (28.08.2020). Finally, the

Table 1
An overview of the school procurement cases.

	School 1	School 2	School 3	School 4	School 5
Municipality size*	Large Suburban	Medium Town	Small Rural	Small Rural	Small Rural
Municipality has a wood construction strategy?	Yes	Yes	Yes	No	No
Type of procurement procedure	Open procedure	Open procedure	Competitive dialogue	Competitive dialogue	Competitive dialogue
Amount of wood use specified in the procurement criteria	Yes	Yes	No	No	No
Operative model of the building	Building contract	Turn-key contract	Building contract	Public-private partnership	Turn-key contract
Wood use in the chosen building	Mainly cross-laminated timber (CLT), wood façade	Concrete structure, wood façade	Concrete structure, log façade	Concrete structure and wooden elements	Mainly wooden logs
Number of floors	2	3	2	2	2
Award criteria	Lowest price	MEAT	MEAT	Price-quality	Price-quality
Total value of the procurement	10.0 Me	12.6 Me	16.7 Me	15.4 Me	6.5 Me
In use	2022	2021	2021	2019	2017

*Municipality sizes: Small <10,000 inhabitants; Medium = 10,000 to 100,000; Large >100,000.
Me = Million Euros.

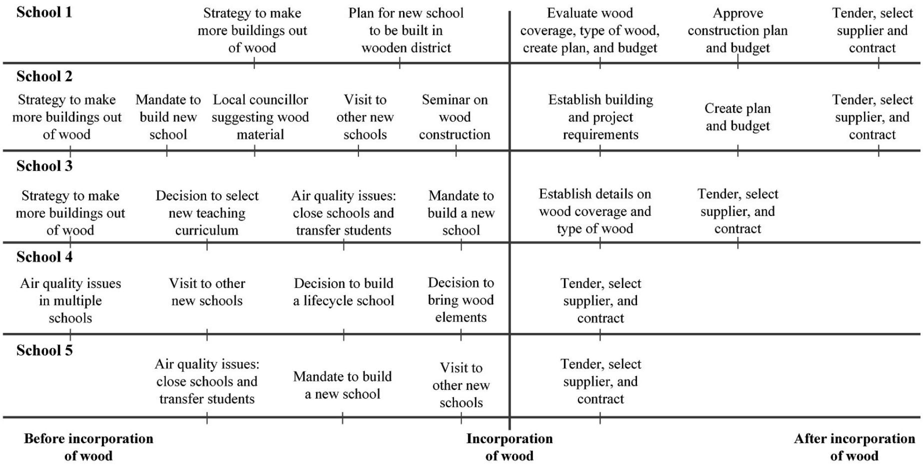

Fig. 2. School procurement process timelines and timing of wood material selection.

quest for a good reputation came primarily from positive media coverage that other municipalities were receiving with regard to their wooden schools; this was captured by a construction manager who said, *"The big school [name omitted] that was being made […] got quite a lot of publicity at the time. So, we also decided that it could be like this"* (09.11.2020). Table 2 summarizes the situational, reactional, and influential triggers initiating wood selection in each case.

4.4. Determinants driving and hindering wood selection in the school procurement process

Determinants brought up by these cases (Table 3) helped us assess which factors move the process toward incorporating wood material requirements into procurement tenders and which factors curtail this progress. In all cases, pushing and swayer determinants were present, where pushing determinants and positive swayer determinants are considered drivers for the wood selection process and negative swayer determinants were identified as hinderances in the process. Pulling determinants were not detected, thus were excluded from Table 3. As with situational changes, pushing and swayer determinants can be pooled into four categories: financial, environmental, strategic and political, and construction related. Interestingly, there were no monetary issues considered as pushing determinants; neither were there any environmental issues as part of negative swayers.

As for pushing determinants, environmental issues included identifying wood as the renewable option thanks to the wooden building's carbon sequestration capabilities, bringing up A-class energy efficiency and future recycling opportunities. The idea that wood construction strengthens local business was identified as a strategic and political issue. Construction issues covered technical elements such as building flexibility, good acoustics, and the possibility of prefabricating buildings, as well as more subjective elements such as a good look, feel, and smell in wood buildings, as brought up by an education manager: *"That warmth and, coziness […] creates such an atmosphere which must be very suitable for such good schooling"* (15.09.2020).

Swayer determinants were mostly negative, meaning that those factors may have slowed down the incorporation of wood in the construction project, but were not concerning enough to halt the process. Financial issues were strongly present across all cases, where the main concern was the higher price of wood in relation to other building materials. Construction issues revealed wooden buildings' poor sound insulation, fire safety concerns, and more pressingly, the perceived lack of experience with and capabilities for working with wood. This was evident from the point of creating the project budget to carrying out the project, as expressed by a project manager: *"What is making it, let's say impossible or difficult to construct buildings in timber is that we don't have that much construction companies or developers who really have, enough competence or knowledge about it"* (28.08.2020). Consequently, small municipalities are not ready to be pioneers in a field where they have little knowledge or experience; this was captured by a construction manager who said, *"Not so much was known about log construction; there is not that knowledge in Finland anyway. And one always doubts whether such a small municipality should become a test project"* (09.11.2020).

4.5. The role of individual actors initiating wood selection

Typical for the building procurement process, all the procurement phases were usually made in interactive groups or committees comprised of politicians, representatives from city council, experts from the technical board, and representatives from the education sector.

Interviewees referred to both strategic-level influence and stakeholder influence when reflecting on the reasons behind selecting wood in the procurement process. As identified in Fig. 2, one of the first events in the process is the decision to build a new school. However, close data analysis shows that between the decision to build a new school and the incorporation of wood, there are typically both political strategy- and influential stakeholder-related elements steering the process toward the selection of wood. This inclination to follow a political strategy can be seen as top-down initiative in Schools 3, 4, and 5, while the influence of active stakeholders was more present in Schools 1 and 2.

As an example of the influence of political strategy, the deciding committee of School 3 was inclined to incorporate wood, as it would cater to the municipal strategy of having more buildings made from the material. This was highlighted by a city manager who said, *"We [politicians] have spoken a lot for wooden materials and use of wood in construction, […] So I believe that that's also been motive when, they did the decision"* (02.09.2020).

As an example of stakeholder influence, a few active municipal civil servants suggested the incorporation of wood into procurement requirements for School 2, as brought up by a local councilor who mentioned *"Hey, we can build it from wood"* (26.08.2020) during a project evaluation seminar. And, even though the suggestion was initially received with skepticism, as highlighted by the interviewee, *"And well, then there wasn't much enthusiasm for it, and I heard a little bit of a laugh about the suggestion,"* it became an item to consider and eventually gained enough support to become a collectively agreed-upon goal.

Table 2
Situational, reactional, and influential triggers initiating wood selection.

School	Situational triggers	Reactional triggers	Influential triggers
School 1: Large Suburban	**Monetary issues:** - Extensive budget available **Environmental issues:** - Bioeconomy and eco-efficiency became a priority for the city - New carbon-neutrality goals2030-2035 - Future constructions will require carbon assessment **Strategic/political issues:** - New city-wide target to have multi-story buildings made from timber - New land plots reserved for wood construction - New legislation affecting building materials	- Recent problems with indoor air quality in concrete buildings	- Good image that other wooden schools received - Competing with neighboring municipalities to attract citizens - Release of official statistics on wood construction positioning the city above others - Webinars on carbon neutrality strategies - Internal learning from recent wooden construction projects
School 2: Medium Town	**Environmental issues:** - New sustainable development goals **Strategic/political issues:** - Recent municipal target to have more buildings made from wood - Municipality's population growth **Construction issues:** - Availability of long land plot; allowed building horizontally - Trend of learning-space versatility - Changing legislation regarding wood building limitations	- Problems with indoor air quality in previous schools	- Visiting and learning from other wooden schools - Finnish Sawmill Entrepreneurs' petition to include wood as an option in public construction projects
School 3: Small Rural	**Strategic/political issues:** - New municipal strategy target to build as much as possible with wood - Curriculum reform warranting co-teaching and flexible learning spaces	- Problems with indoor air quality in old building; school shut down and students transferred - Recent moisture issues with concrete structures	- Internal learning from recent wooden construction projects - Visiting and learning from other wooden schools
School 4: Small Rural	**Monetary issues:** - Limited budget available **Strategic/political issues:** - Curriculum reform warranting co-teaching and flexible learning spaces **Construction issues:** - Large-sized school decision - Trend for increased liability for the tendered over the building lifecycle (lifecycle model)	- Recent problems with indoor air quality in old buildings	- Visiting and learning from other wooden schools that implemented competitive negotiation procedures
School 5: Small Rural	**Strategic/political issues:** - Recent decision to build a unified school with special education **Construction issues:** - Municipality did not want insulation in new construction - The deteriorating condition of the old building - Trend to build with wood - Recent discussion of wood as the solution for indoor air issues	- Problems with indoor air quality in previous school; students partially evacuated and temporarily transferred	- Good image that other wooden schools received - Visiting and learning from other wooden schools

This illustrates how a single suggestion from an influential member of a council group might spark a discussion regarding the incorporation of wood.

A closer look at single influential individuals illustrates that they may have a special preference for and connection to the promotion of wood. For example, the interviewee who said *"Hey, we can build it from wood"* was raised in a family whose members worked in the construction sector and referred to wood as *"an element that has always felt so pleasant and it has somehow had a very positive connotation."* This finding is in line with that of Francart et al. (2019) who suggested that single municipal politicians can remarkably contribute to wood construction, due to their personal motivation and engagement. Altogether, these findings suggest that actively engaged individuals need to be present in the process in order to operationalize the municipalities' strategic goals to promote wood construction.

5. Discussion

5.1. Wood material selection in public building procurement processes

This article contributes to the green public procurement literature with identification and analysis of actual procurement processes in which green criteria have been used (Andrecka, 2017; Kristensen et al.,

Table 3
Synthesis of the determinants in each school procurement case.[a]

School	Drivers (pushing determinants)	Hindrances (swayer determinants)
School 1: Large Suburban	**Environmental issues:** - CO_2 sequestration in wood buildings - Fewer CO_2 emissions - Easy recycling of wooden buildings **Strategic/political issues:** - Positive image **Construction issues:** - Possibility of prefabricating buildings - CLT as a flexible solution - No moisture or humidity problems - Good working environment; nice look, feel, and smell - High fire safety: mandatory sprinklers for multistory buildings - Good acoustics	**Financial issues:** - More expensive than concrete (negative) **Construction issues:** - Small land plot; need to build upward (negative) - Lack of experience with and knowledge about wood construction (negative) - Stricter fire protection measures (negative) - Poor sound insulation (negative) - Thicker midsole required (negative)
School 2: Medium Town	**Environmental issues:** - CO_2 sequestration in wood buildings - A-class energy efficiency - Renewable option **Strategic/political issues:** - Positive image - Image/idea that wood is healthier than concrete - Positive press coverage - Domestic material **Construction issues:** - Good indoor air in wooden buildings - Creates a "good atmosphere" for learning - Good acoustics	**Financial issues:** - Estimated to be more expensive than concrete (negative) - Three-story building; too expensive to be fully wooden (negative) **Strategic/political issues:** - Initial backlash from fire potential and mold accumulation (negative) - Inaccurate information about wooden construction during initial stages (negative) **Construction issues:** - Higher maintenance requirements (negative) - Lack of experience with and knowledge about wood construction (negative) - Poor sound insulation (negative) - Higher heat consumption (negative)
School 3: Small Rural	**Environmental issues:** - Good environmental choice **Strategic/political issues:** - Good reputation and image - Strengthens local business **Construction issues:** - Healthy living option	**Financial issues:** - More expensive than other materials (negative) **Strategic/political issues:** - Small local fire department (negative) **Construction issues:** - Durability of wood not acknowledged by everyone (negative) - Big building with two floors; wooden frame doesn't support it (negative) - Lack of experience with and knowledge about wood construction (negative)
School 4: Small Rural	**Strategic/political issues:** - Wooden constructions are safe and healthy - Good market value **Construction issues:** - Good look and feel	**Financial issues:** - More expensive than concrete (negative) **Construction issues:** - Bidders experienced with concrete (negative) - No experience building with logs in big projects (negative) - Bidders seek to remove risk and uncertainty in a lifecycle project (negative) - Fire safety issues (negative) - Concrete offers better temperature control (negative) - Adhesive used for wood buildings can bring challenges in the long run (negative)
School 5: Small Rural	**Strategic/political issues:** - Good reputation from log buildings **Construction issues:** - Perceived as a solution for indoor air problems	**Construction issues:** - Fire safety issues (negative) - Lack of experience and knowledge with wood construction (negative)

[a] Pulling determinants were not detected, i.e., determinants that would have cancelled a decision already made to use wood as a building material, and then opt for another construction material.

2021). By studying five school procurement cases and using SPAT, we identified procurement process timelines, triggers, and determinants that together unveiled the dynamics behind building material requirements in these cases. Regarding RQ1, as a key contribution, *our findings provide a rich account of the factors initiating, facilitating, and hindering greener material selection during a procurement process* (building on e.g., de Oliveira et al., 2013; Bohari et al., 2017; and Francart et al., 2019). Particularly, our analysis revealed that:

- Wood selection was often initiated by a situational change (financial, environmental, strategic, or construction related) that paved the way for incorporating material requirements into the selection criteria.
- Indoor air quality issues in a former school building created the urgent need for a new building. This situation represented an opportunity for the municipalities to promote wood material use.
- Analyses of the actors involved in the procurement process revealed that wood use is not only the result of an accumulation of triggers, but also influenced by individual stakeholders. Stakeholder influence bridged the decisions of building a new school and incorporating wood materials into the selection criteria, thus revealing that actively engaged individuals play an important role in operationalizing municipal strategies.
- Moreover, a municipality's tradition of working with the wood industry appeared to influence the incorporation of wood in the selection criteria. Municipalities that had a long-standing tradition with wood or a local wood industry had also set strategy-level goals for increasing the amount of wooden construction. This finding appears to be in line with that of Høibø et al. (2015) in which tradition, culture, and the availability of materials were identified as influencing building material preferences.

5.2. Elements facilitating and hindering wood material selection

Identified triggers were categorized into situational, reactional, and influential. Previous researchers (Gosselin et al., 2016; Franzini et al., 2018; Toppinen et al., 2018) have found similar factors affecting wood material selection, framing them as motivators, contributors, or drivers. However, this study is among the first to unveil the dynamics of these issues in the actual procurement processes over time.

Regarding RQ2, uniquely, we identified the reactional triggers for wood construction in response to the issues with indoor air quality in concrete buildings. This finding complements those of earlier studies, in which wooden interiors were identified as helping mitigate indoor moisture, preventing bacterial growth (Muilu-Mäkelä et al., 2014), and inhibiting moisture degradation through improved air circulation (Franzini et al., 2018). Furthermore, the finding is in line with that of Hurmekoski et al. (2018), who reported that the "quality of construction and indoor air quality issues" possibly affected the construction market.

Essentially, by unveiling the dynamics of the procurement process, this study offers a depiction of the presence of path dependency (Mahapatra and Gustavsson, 2008; Hemström et al., 2017) as a barrier in the use of wood materials in construction projects. In each of our five cases, construction professionals were less willing to select a building material with which they had little experience and capabilities due to past beliefs, perceptions, norms, and rules.

Interviews related to these cases engaged a variety of municipal civil servants who provided us with an in-depth understanding of their procurement processes. Therefore, our work supports and deepens the work of Franzini et al. (2018) and Toppinen et al. (2018) regarding WMC. Particularly, the identified pushing determinants in the Finnish context have similarities with the supporting attitudes identified by Franzini et al. (2018) and Lähtinen et al. (2019) and internal and external factors found by Toppinen et al. (2018). However, instead of focusing on intentions and attitudes (Franzini et al., 2018) or Delphi techniques (Toppinen et al., 2018) regarding wooden buildings in general, our study reveals the actual procurement processes leading to building procurement and wood material selection.

Lastly, our study broadens the use of the SPAT method from consumer and business decision-making contexts to those relating to public procurement. For this methodological contribution, we briefly commented on the applicability of SPAT in public procurement context. Altogether, SPAT showed its ability to provide useful, in-depth understanding in the studied context. However, the idea of pulling determinants seemed to not be applicable in the context of school procurement. School procurement is an example of a large and irreversible investment. Therefore, the idea of pulling determinants cannot be applied in a straightforward manner. It is natural, then, that such elements were not detected in the interviews.

5.3. Conclusions and recommendations

We explored the paths, triggers, and determinants of public wood construction procurement, and thus unveiled the dynamics behind building material requirements in public procurement tenders. In general, we have shown how utilizing detailed interviews (Cheng et al., 2018) helps better cover the details of green public procurement processes. These findings have implications for both research and practice. The findings on wooden school procurement hold implications to the key areas of green public procurement and sustainable construction research. They also provide understanding of the dynamics related to introducing new practices in public building procurement. In practice, the findings may be especially valuable for municipalities that specify wood use in public procurement for the first time.

The identified triggers and determinants in the public procurement cases also hold practical relevance. As illustrated by our cases, municipal civil servants are increasingly interested in incorporating sustainability related aims to their selection criteria. Specifying wood use in the criteria carries the message that several benefits other than the lowest price are being sought, as illustrated by the list of pushing determinants.

These findings also introduce avenues for future research. The transferability of the results to other sustainable public procurement contexts should be tested. In general, future researchers may require longitudinal, multi-actor perspectives. In particular, the findings from our study suggest that green public procurement and green building material selection result from a multi-stakeholder negotiation of objectives and values. Thus, our research encourages further research on wood construction from a narrative viewpoint, as "narratives of wood use." Such future studies could focus on different user group perspectives or on public discussion, as media also creates and sustains wood construction-related narratives. Furthermore, future studies could evaluate role of wood as a form of preventive innovation in procurement, where wood is utilized to prevent unwanted future health consequences or unwanted environmental consequences associated with traditional building materials.

We have several stakeholders that will benefit from our research. First, based on our findings, policymakers could make sure that there is enough reference information available about wooden buildings. This would support municipalities avoid the feeling that they have to do pioneering work, in the case they wish to avoid risks. For example, a public archive of public wood buildings with details such as costs and benefits could make wood construction more "business as usual" for municipalities. Second, for municipalities to aspire their 'green' goals, our findings provide encouragement to include wood-related criteria to calls for tenders. In the case a call for tender favours a different construction material (such as concrete), it is unlikely that wood is selected – and vice versa. This issue might seem self-evident, but it is not, in practice. Rather, it is not automatic that all officials have the skills to write calls for tenders that favour wood. If this is the case, we recommend using procurement consultants to support 'green' tender writing. Third, and finally, our findings encourage tenderers to argument that wood does not equal more costly. In the long term, with indirect benefits, wood might become less expensive, e.g., if residents do not become ill due to poor indoor air quality, thus saving costs in healthcare for the municipality. Moreover, the life cycle costs of wooden buildings are competitive. While the idea of indirect benefits is not new (e.g., Lindholm et al., 2019), we see that it applies to the wood construction sector as well.

CRediT authorship contribution statement

Deborah Kuperstein Blasco: Formal analysis, Visualization, Writing – original draft. **Natalia Saukkonen:** Funding acquisition, Conceptualization, Writing – original draft. **Tuomas Korhonen:** Project administration, Investigation, Writing – original draft. **Teemu Laine:** Writing – review & editing, Supervision. **Riina Muilu-Mäkelä:** Project administration, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ARTICLE
II

Influence of innovation attributes with preventive nature of innovation on intent to adopt: The case of photovoltaic systems in mass markets

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Influence of innovation attributes with preventive nature of innovation on intent to adopt: the case of photovoltaic systems in mass markets

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Abstract*— Diffusion studies have focused on multiple areas of innovation, and innovations have been given various classifications. However, a type of innovation that is not widely covered in diffusion studies yet and which is relevant for multiple contemporary applications is preventive innovation. Preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future or to mitigate the severity of the consequences of an unwanted event. In this study, we explored if the preventive nature of innovations influenced the intent to adopt the innovation with a survey study. In our study, photovoltaic (PV) systems were identified as preventive innovations as they serve various underlying goals of prevention. The dependent variable, intent to adopt was identified as the "period when the respondent is planning to purchase a photovoltaic system" and independent variables were either demographic, household-related, or based on diffusion of innovations theory. We ran a statistical analysis with our survey responses, and it yielded three linear regression models, out of which one (Model 2) was selected as the best fit. The selected model identifies four significant variables associated with the intended period of PV system adoption: one related to relative advantage, one to social compatibility, and two to technical compatibility. Our results do not confirm that the preventive nature of innovations would be important to mainstream customers; hence, we derive that prevention-specific attributes merit further investigation with other adoption groups.

***Keywords*— preventive innovation, photovoltaic systems, diffusion of innovations**

I. INTRODUCTION

An innovation is an idea, practice, or object that is perceived as new by a unit of adoption, be it an individual, a group of individuals, or an organization [1]. The newness of the idea depends on the potential adopters' perceptions, therefore, whether the idea is objectively 'new' or not does not matter. Furthermore, newness not only denotes knowledge about the innovation but can also be identified in terms of the decision to adopt it [1].

The diffusion of an innovation refers to the process by which an innovation is communicated to a social system, over time, through certain channels [1]. Thousands of diffusion studies have focused on various areas of innovation, including technology, agricultural practices, policies, and educational and health promotion programs [2]. Furthermore, innovations have been given various classifications depending on the type of innovation (product vs. process) or newness of the technology (radical vs. incremental) [1].

However, there is another type of innovation that is not widely covered in diffusion studies yet is relevant to multiple contemporary problems: preventive innovation. Preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future [1] or to mitigate the severity of the consequences of the unwanted event.

Nowadays, prevention seems timelier than ever. Preventive behavior is needed in various aspects of our lives such as health decisions, sustainability choices, and business decisions. Preventive behavior is difficult to foster because it requires individuals to be future-oriented and motivated toward an underlying goal in prevention [3].

While preventive behavior has been studied widely, the focus of research has mostly been on public health, and only a few studies (e.g. [4]–[6]) in the innovation diffusion tradition have studied the preventive innovation. Hence, this paper highlights the need to conceptualize preventiveness as a part of the construction of innovation conceptualization. We report results from a survey research that analyzes a series of concepts that make up the construct of preventive innovation. This contribution is expected to build grounds for further studies that can facilitate the understanding of the concept.

The purpose of this study is to explore if the preventive nature of innovations, present in attributes of innovations, has a positive or negative influence over the intent to adopt. There are two objectives in this study. First, this study highlights the attributes of innovations that can be classified as preventive as discussed in diffusion studies. Second, this study seeks to identify the influence of preventive attributes on the intent to adopt photovoltaic systems (identified as preventive innovations) by mass markets.

The remainder of this paper is organized as follows. The next section sets a theoretical ground for this study and highlights the main attributes of preventive innovations as identified in diffusion studies theory. We then discuss the methodology for data gathering and analysis utilized in the study and report the results of our analysis by identifying predictors in the intent to adopt PV systems. Next, we discuss the limitations of our study and finalize this paper by identifying future research opportunities and implications for literature and practice.

II. Theoretical Background

A. Definitions and Interpretations

According to Rogers, "A preventive innovation is a new idea that an individual adopts now to lower the probability of some unwanted future event"[1]. The concept was first introduced by Rogers in 1983 in the 3rd edition of *Diffusion of Innovations* and further elaborated in the 4th edition in 1995. In this paper, we argue that preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future [1] or to mitigate the severity of the consequences of the unwanted event as some unwanted events are unavoidable, for example, natural disasters.

Two important elements that should be highlighted yet aren't commonly discussed in diffusion studies are the probability and severity of the unwanted event. Probability refers to the extent to which an unwanted event is likely to occur; in nontechnical contexts, the probability of an unwanted event that may or may not occur is referred to as 'risk' [8]. In insurance economics, the probability is associated with a loss of a certain size [9], which we identify to as severity, referring to how harmful the event and its consequences might be. The measures of probability and severity are frequently utilized when modeling expected loss [10].

Probability and severity can be affected by potential adopters' subjective perceptions. While there might be standard scales to determine the severity of certain unwanted events, such as scales to determine the magnitude of natural disasters, individuals might still have different perceptions of how severe an event can be. Furthermore, an unwanted event may have an impact on various domains, for which it is difficult to assess severity objectively. Furthermore, the probability of an unwanted event can be estimated at times; individuals know whether they are cautious or careless drivers, or whether they lead healthy lifestyles or not [9] and thus can be expecting or denying the possibility of an unwanted event. Alongside, probability and severity influence potential adopters' attitudes toward prevention.

B. The Innovation

Preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future [1, p. 234] or to mitigate the severity of the consequences of the unwanted event. According to diffusion studies, innovations can be identified as 'preventive' by focusing on two of the four elements in the diffusion of innovations: the innovation and time. Particularly, the preventive nature of the innovation is evident when analyzing five attributes of the innovation: relative advantage, compatibility, complexity, trialability, and observability.

1) Relative advantage

Relative advantage is the degree to which an innovation is considered better than the previous idea [1, p. 15] and it is considered the strongest predictor of the adoption of innovations [1, p.

232]. Existing literature identifies that preventive innovations have low relative advantage as benefits are delayed in time and difficult to observe [6]. This idea can be further explored by incorporating subdimensions of relative advantage [1, p. 232] such as economic profitability, social prestige, decrease in discomfort, and time and effort savings.

The degree of relative advantage is commonly expressed as economic profitability; economic motivators are assumed as the main triggers for an individual's adoption of an innovation [11, p. 115]. For preventive innovations, economic profitability is challenged when compared to non-prevention, for example, paying for a health screening versus getting no screening.

Social prestige from adopting an innovation is another important factor [11, p. 115]; for certain innovations, such as fashionable clothing, social prestige may be the sole benefit received. However, preventive innovations might hinder social prestige, as is the case for wearing protective equipment in extreme sports where, despite the obvious advantages, the use of safety equipment is poor as it is still regarded as unfashionable and portrays inexperience [12, p. 174].

A decrease in discomfort may also be an important motivator to adopt an innovation, particularly for potential adopters that are less profit-oriented [11, p. 233]. Many preventive actions are commonly associated with discomfort when compared to non-adoption. Preventive efforts are known to have a direct impact on the adopter's daily life such as controlling sugar and fat consumption to prevent health issues, a behavior associated with negative emotions [3].

Finally, an innovation that can provide time and effort saving yields a greater relative advantage. Time and effort savings might not be achievable for preventive innovations when compared to non-adoption and evaluating present-time savings. Preventive innovations such as prophylaxis require continuous effort to prevent future negative consequences [4].

2) Compatibility

Compatibility is the degree to which an innovation is perceived as being consistent with existing values, past experiences, and needs of potential adopters [1, p. 15]. Preventive innovations are often not very compatible with individuals' values, attitudes, or lifestyles [13]. Low compatibility can be identified in the slow adoption rate of various preventive innovations, such as seatbelts, which took decades of public campaigns to get most of the population to adopt, [1, p. 235], use of contraceptive methods in countries where religious beliefs discourage family planning [1, p. 15] or the diffusion of HPV vaccine among young women, affected by their attitudes toward the vaccine [14].

According to Rogers [1, p. 15], the adoption of an innovation with low compatibility often requires the adoption of a new value system, which is a fairly slow process. However, external factors such as social influence can expedite the adoption of a new value system. For example, when peers within a social system have adopted a preventive innovation, individuals might feel compelled to adjust their value system and adopt the innovation, as it happened with solar water heaters in neighborhood clusters in California [1, p. 16].

3) Trialability and Observability

Trialability is the degree to which an innovation might be experimented on a limited basis [1, p. 15]. Preventive innovations are often characterized by their difficult or impossible trialability [13]. These innovations seek to reduce the probability of an unwanted or to mitigate the severity of the consequences of the unwanted event; therefore, how to try out what adopters hope to avoid?

Another aspect of trialability refers to divisibility, referring to trying out innovations on a limited basis [1, p. 15]. While it might be impossible to experience the trialability of some preventive innovations (for example, one cannot wear a seatbelt halfway nor get a small dose of a vaccine), it is possible to experience other preventive innovations on a limited basis, for example, opting for a 30-day free trial of antivirus software.

Similarly, observability is the degree to which the results of an innovation are visible to others [1, p. 16]. As the results of a preventive innovation are delayed, they are not very observable [13] and some preventive innovations might have non-observable benefits until implemented, such as insurance policies or contingency plans [4]. However, the preventive innovation itself can be visible and stimulate peer discussion in a social system. For example, solar water heaters can be found in neighborhood clusters in California, where there are various adopters within the same block, while there can be areas of the city with no such heaters [1, p. 16].

When an unwanted event has a high probability of happening trialability and observability of preventive innovations can be experienced. Examples of unwanted events with high occurrence include earthquakes in seismic hazard zones, flooding in high-risk areas, or crashing in an elite cycling race. Once the unwanted event has been experienced, the preventive innovation can be sampled, and its benefits observed, the adopter can decide whether to keep the innovation or make a change. This was the case with crop insurance adoption in India, where there was a higher probability of adoption for farmers who had already experienced crop loss [15].

4) Complexity

Finally, complexity refers to the degree to which an innovation is perceived as difficult to understand and use [1, p. 16]. While preventive innovations are not necessarily more complex to understand and use than other innovations, the cause-and-effect relationships involved are complex [13]. Therefore, it might be difficult for potential adopters to understand the reasons behind prevention. This is commonly the case for the diffusion of vaccines, such as the HPV vaccine, where low vaccination rates can be explained by a lack of understanding regarding the transmission of the human papilloma virus and its role in cervical cancer [16].

III. METHODS

A. Photovoltaic Systems

A photovoltaic system converts light directly into electricity; its main components are various kinds of photovoltaic cells interconnected to create a photovoltaic module, a mounting structure for the module, an inverter, a storage battery, and a charge controller [17, p. 4]. For this study, we consider PV systems preventive in nature as they serve various underlying goals of prevention, including reduction of greenhouse gas emissions, protection against volatile electricity prices, and lowering dependence on unreliable fossil fuel markets [18]. While PV systems are not new in the market, the newness of the technology depends on the potential adopters' perceptions, therefore, whether the idea is objectively 'new', or not, does not matter.

B. Data Collection

Our data was generated through an online survey, distributed through the website of a local electricity company in central Finland during 22.6. – 16.8.2021. Out of the 365 responses altogether respondents with missing values and individuals who had already purchased a PV system were excluded from the study as their intention to adopt cannot be compared with those who are in earlier stages of the adoption-decision process. Furthermore, factors that provide value after the adoption of technology may differ from factors that provide value before adoption.

When developing the survey, we were guided by theory-based survey items and by the practical experience in survey design of members of our research team. Survey questions sought to measure variables from a diffusion of innovations (DOI) theory, which could contribute to the adoption of PV systems. Survey items included various types of questions: demographic questions to gather demographic data, multiple choice questions to assess household characteristics, and 5-point Likert scale questions (from 5= strongly agree to 1= strongly disagree with an additional option to specify don't want to say) for other variables related to the intent to adopt. We will now discuss the DOI variables that were utilized in survey items.

Relative advantage. Relative advantage is considered the strongest predictor of the adoption of innovations [1, p. 232]. Four questions on the survey measured the perceived relative advantage of PV based on the subdimensions of relative advantage, including economic profitability, decrease in discomfort, and conveyed social prestige.

Trialability and observability. Innovations are more likely to be adopted if they can be experimented out on a limited basis, and if they can observe the results of the technology [1, p. 16]. Three questions assessed trialability and observability, by considering peer experience, social influence, and availability of information.

Compatibility. Innovations that are compatible with existing values, experiences, and needs of potential adopters are more likely to be adopted [1, p. 15]. For our study, we assessed technical compatibility with two variables (compatibility with technical aspects of PV) and social compatibility with five variables (social system's compatibility with the use of PV in terms of values and norms).

Complexity. Complexity identifies the degree to which an innovation is perceived as difficult to understand and use [1, p. 16], and innovations with higher complexity are less likely to be adopted. We sought to measure complexity through four questions that assessed the difficulty of utilizing PV systems from accessing information about the systems to installing them.

Preventiveness. For this study, we consider PV systems preventive in nature as they serve various underlying goals of prevention, including reduction of greenhouse gas emissions, protection against volatile electricity prices, and lowering dependence on unreliable fossil fuel markets [18]. Therefore, we included four questions that measured each of these aspects of prevention.

Control variables. We included a series of socio-demographic and household-specific items to measure characteristics that could affect the dependent variable: the period when the respondent is planning to purchase a PV system. Socio-demographic questions assess decision-maker characteristics; these include gender, age, and income levels. Household-specific questions identify household characteristics including type and size of the dwelling, and type of household management (self-owned, renting, subletting, etc.)

Dependent variable. We used one main measure to identify the intent to adopt PV technologies: the period when the respondent is planning to purchase a PV system. This variable measures behavioral intention, with an underlying belief, that intentions are predictors of behavior [19]. The scale included plans to adopt a PV system within a year, within two years, within five years, after a long time, and no intention to adopt. Those who already had installed a PV system were excluded since their intention to adopt was not considered comparable to those still deciding. The factors seen as most important after the adoption and use of technology can be different from those perceived and valued before adoption.

C. *Data analysis*

We ran our statistical analysis on SPSS. The dependent variable met the normality assumption per acceptable skewness and kurtosis values, which allowed for linear regression analysis. We ran three linear regression models. Model 1 included only demographic control variables. Model 2 included only the variables associated with relative advantage, compatibility, trialability, observability, complexity, and preventiveness. All variables from models 1 and 2 were included in model 3. Removing answers with missing values yielded 239 responses accounting for all variables in regression model 3. Regression models 2 and 3 with smaller subsets of variables included 243 and 239 responses respectively. Multicollinearity issues were not detected as only one variance inflation factor (VIF) exceeded 3 but remained below 3,3 in models 2 and 3 for the "I feel an obligation to reduce the negative consequences of my energy consumption" variable.

IV. Results

A. *Descriptive Statistics and Regression Analysis*

In Table 1 we present descriptive statistics and correlations for all measures in the regression analysis. Table 2 displays the results of the performed regression analysis with non-standardized coefficients and their standard errors.

Model 1 with demographic control variables reveals household income, size of the dwelling, and the type of household management as significantly associated ($p < 0,05$) with the intended period of PV system adoption. These results suggest that higher-income respondents with larger living spaces are considering adopting a PV system within a shorter timeframe. However, we interpret model 2 since its adjusted R2 value is the same as for model 3, yet the F-value for model 2 is better and none of the demographic variables in model 3 are significant ($p < 0,05$). In model 2 variables that are associated with compatibility are significant predictors of adoption: Living quarters well suited for fitting a PV system and a sunny location predict a shorter timeframe for adoption from the technical compatibility side. Regarding social compatibility, being able to freely choose to adopt a PV system is a very significant ($p < 0,001$) predictor of faster adoption. This suggests that those who are free to do so are more likely to have active plans for installing a PV system. Out of variables concerning relative advantage, a good mood is the only significant one, signifying that those who have plans for installing a PV system hope to derive emotional benefits from it for themselves. In model 3 the social compatibility variable and the mood advantage remain significant predictors.

B. *Intent to adopt Photovoltaic Systems*

Our results suggest that PV systems, which can be classified as preventive innovations, provide non-financial forms of relative advantage and are compatible with existing decision-making mechanisms and with technical energy requirements. These two attributes are traditionally considered "low" for preventive innovations.

Through four variables we measured the role of PV systems in the reduction of greenhouse gas emissions, protection against volatile electricity prices, and lowering dependence on unreliable fossil fuel markets [18]. As depicted in Table 2, neither of these variables is strongly correlated with the intended period of PV system adoption. Therefore, it appears that prevention-specific attributes are not significant in the intent to adopt PV systems in mass markets.

However, factors that provide value after the adoption of a technology may differ from factors that provide value before adoption; therefore, we went through the responses of participants that had already installed a PV system. We noticed that prevention-specific attributes had a higher presence for respondents that had already purchased a PV system. This finding suggests that adopters of PV systems find attributes of prevention more important than individuals who are still in the adoption-decision process. However, we could not build a regression model from respondents who had already purchased a PV system as their intention to adopt was not considered comparable to those still deciding. Furthermore, the sample size for those who had already purchased a PV system was small and not normally distributed.

V. Discussion and Conclusions

Our study sought to explore if the preventive nature of innovations, present in attributes of innovations, has a positive or negative influence over the intent to adopt.

Preventive innovations are considered to have low relative advantage as benefits are delayed in time and difficult to observe [6]. Previous studies on residential photovoltaics (RPV) [20] have identified elements of relative advantage (economic profitability) as negative attributes that directly reduce the intention to buy. However, our study indicates that PV systems can provide non-financial forms of relative advantage.

Furthermore, preventive innovations are identified as not very compatible with individuals' values, attitudes, or lifestyles [13]. Previous studies on solar technologies through the lens of DOI by Labay & Kinnear [21] have identified solar systems as compatible with the personal values of the general population in the state of Maine in the United States. Our findings reveal that PV systems are compatible with existing decision-making mechanisms and technical requirements for energy systems. Thus, our findings complement previous studies on this attribute of innovations.

Moreover, preventive innovations are considered to have low trialability and observability. Previous studies on observability in the diffusion of photovoltaic panels have found that the visibility of solar panels enhances peer effects, which are found to increase the amount and size of installations over a zip code [22]. Studies on trialability [21] indicate that even a small trial of solar systems represents a major financial commitment, for which these systems don't have a real possibility for a low-risk trial. While our study did measure trialability and observability variables, we did not detect any significant influence over intent to adopt.

Finally, preventive innovations are believed to have high complexity due to the cause-and-effect relationships involved and ease of use. Previous studies evaluating the complexity of renewable energy systems have found solar systems as less complex than other sources of energy [21], and have identified that perceived ease of use does not affect the purchase intention of renewable energy [23]. Our study did not detect any significant

TABLE 1. DESCRIPTIVE STATISTICS AND CORRELATION OF VARIABLES

		Mean	SD	N	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
(1)	Dependent variable	2.07	0.86	239	1.00																												
(2)	Reladv_1	3.68	0.84	239	0,16**	1.00																											
(3)	Reladv_2	3.95	0.88	239	0,35**	0,59**	1.00																										
(4)	Reladv_3	4.06	0.83	239	0.04	-0.04	-0.05	1.00																									
(5)	Reladv_4	3.26	0.99	239	-0.09	-0.11	-0,11*	0,13*	1.00																								
(6)	Observ_1	3.07	1.50	239	0,19**	0.07	0.06	0.01	-0.02	1.00																							
(7)	Trial_1	3.84	0.99	239	0.08	0.06	0,17**	0,11*	0.04	0,17**	1.00																						
(8)	Trial_2	3.07	1.39	239	0,20**	-0.01	-0.02	0.06	-0,13*	0,30**	-0,19**	1.00																					
(9)	CompTech_1	3.61	1.16	239	0,25**	-0.02	0.08	0,12*	0.00	0,12*	0,11*	0,19**	1.00																				
(10)	CompTech_2	3.04	1.11	239	-0,21**	-0.03	-0,13*	0.06	0,19**	0.07	0.07	-0.09	0.01	1.00																			
(11)	CompSoc_1	3.07	1.08	239	0,32**	0.10	0,27**	0.01	-0.01	0,35**	0,23**	0,23**	0,20**	0.04	1.00																		
(12)	CompSoc_2	2.51	1.60	239	0,33**	-0.08	-0.07	0,26**	-0.04	0,30**	-0.07	0,40**	0,27**	-0.08	0,21**	1.00																	
(13)	CompSoc_3	4.34	0.96	239	0.09	0,15*	0,24**	-0.05	-0.01	-0.04	0.02	0.03	0,12*	-0,12*	0.08	-0,12*	1.00																
(14)	CompSoc_4	4.30	0.80	239	0,21**	0,34**	0,46**	0.04	-0.09	-0.02	0,19**	0.03	0.07	-0,12*	0,15*	-0.07	0,42**	1.00															
(15)	CompSoc_5	3.83	1.06	239	0,21**	0,38**	0,45**	-0,11*	-0.07	-0.01	0.09	0.00	0.04	-0.10	0,16**	-0.08	0,51**	0,61**	1.00														
(16)	Complex_1	3.44	0.76	239	0,27**	0,18**	0,17**	0,22**	-0.08	0,21**	0.02	0,31**	0,23**	-0.07	0,21**	0,32**	-0.09	0,15**	0.02	1.00													
(17)	Complex_2	3.23	0.81	239	-0.08	0.05	0.00	-0,12*	0,32**	0.06	-0.01	-0.05	0.04	0,12*	0.10	-0.08	0.09	-0.03	0.02	-0.10	1.00												
(18)	Complex_3	3.19	0.92	239	0,13*	-0.06	0.01	0.07	-0.09	0,26**	0.00	0,22**	0.09	0.09	0,11*	0,19**	-0.01	-0.06	-0.02	0,21**	0.00	1.00											
(19)	Complex_4	3.79	0.73	239	0,14*	0.07	0,15**	0,17**	-0,16**	0.07	-0.02	0,26**	0,12*	-0,17**	0.08	0,16**	0,14*	0,22**	0.07	0,40**	-0,16**	0,20**	1.00										
(20)	Prevent_1	4.05	0.77	239	0,18**	0,25**	0,42**	0,15*	-0,12*	-0,13*	0,15*	-0,12*	0.10	-0.07	0,13*	-0.07	0,15**	0,22**	0,16**	0.06	-0.10	0.00	0.10	1.00									
(21)	Prevent_2	4.20	0.98	239	0,27**	0,39**	0,58**	-0.05	-0,14*	0.01	0,22**	-0.02	0.09	-0,14*	0,28**	-0.09	0,44**	0,56**	0,57**	0.08	-0.02	0.10	0,16**	0,44**	1.00								
(22)	Prevent_3	4.07	0.77	239	0.04	0,17**	0,34**	0,11*	-0.02	0.01	0,24**	-0.06	0.01	0.04	0.08	-0,15**	0,26**	0,33**	0,18**	0.03	-0.01	0.00	0.05	0,47**	0,39**	1.00							
(23)	Prevent_4	3.84	1.05	239	0,20**	0,39**	0,45**	-0.09	-0.08	0.02	0,15**	0.03	0,13*	-0,15*	0,20**	-0.05	0,46**	0,58**	0,78**	0.08	0.04	-0.04	0.05	0,18**	0,56**	0,20**	1.00						
(24)	Demographics_gender	1.35	0.48	239	0.10	-0,11*	-0,19**	0,20**	-0.07	0.03	-0,20**	0,34**	0.09	-0,13*	-0.06	0,22**	-0,15**	-0,11*	-0,26**	0,17**	-0.03	0,12*	0,24**	-0,17**	-0,18**	-0,22**	-0,23**	1.00					
(25)	Demographics_age	3.83	1.39	239	-0.05	0.02	-0,16**	-0.08	0.00	0,13*	-0,15*	0.07	0,16**	0.10	-0.05	0.08	-0.07	-0,14*	-0.08	0.07	-0.01	-0.01	-0.01	-0.04	-0,16**	-0.05	-0.07	0,13*	1.00				
(26)	Demographics_income	3.14	1.84	239	0,23**	-0.04	0.08	0.08	-0,12*	0.08	0.07	0,16**	0,14*	-0,13*	0,20**	0,24**	-0.04	0.10	0.03	0,12*	-0.05	0.05	0,11*	0.10	0,15**	0.01	0.10	0,15*	-0.02	1.00			
(27)	Household_type	1.83	1.02	239	0,14*	-0.04	0.05	0,19**	0.00	0.06	-0.01	0.10	0,17**	-0,12*	0.05	0,21**	-0.04	-0,14*	-0.07	0,19**	-0.01	0.02	0.04	-0.04	-0.07	-0.03	-0.04	0,17**	0,12*	0,12*	1.00		
(28)	Household_size	99.71	63.26	239	0,29**	-0.07	-0.05	0,23**	0.02	0,17*	-0,17**	0,27**	0,19**	-0,20**	0.08	0,51**	-0,14*	-0.01	-0.05	0,32**	-0,11*	-0.03	0,16**	-0.06	-0.08	-0,16**	-0.03	0,22**	0,14*	0,29**	0,23**	1.00	
(29)	Household_mngmt	1.46	0.68	239	-0,23**	0.10	0.10	-0,21**	0.01	-0.07	0.08	-0,17**	-0,26**	0.07	-0.09	-0,40**	0.09	0.02	0.07	-0,14*	0,15*	-0.06	-0.03	-0.01	0.06	0,15**	0.05	-0,11*	-0,17**	-0,17**	-0,25**	-0,45**	

*p < .05
**p < .01

TABLE 2. REGRESSION ANALYSIS RESULTS

Variable	*Model 1 B (Std. Err)*	*Model 2 B (Std. Err)*	*Model 3 B (Std. Err)*
(Constant)	2,054 (0,297)**	0,239 (0,578)	0,007 (0,649)
Demographics_gender: Gender_num	0,057 (0,115)		0,210 (0,122)
Demogrphcs_age: Age_group_num	-0,070 (0,039)		-0,036 (0,038)
Demographics_income What is your household's total gross income (income before tax) per year_num	0,061 (0,030)*		0,018 (0,029)
Household_type: What is the house type of your dwelling_num	0,032 (0,054)		0,003 (0,053)
Household_size: What is the floor area of your dwelling?	0,002 (0,001)*		0,002 (0,001)
Household_mngmt: What is the type of management of your dwelling_num	-0,187 (0,087)*		-0,098 (0,086)
Reladv_1: [The introduction of a solar power system makes a good impression on other people.]		-0,049 (0,074)	-0,030 (0,076)
Reladv_2: [Solar PV makes me feel good.]		0,262 (0,081)*	0,265 (0,085)*
Reladv_3: [Solar photovoltaic systems have high purchase costs.]		-0,035 (0,065)	-0,092 (0,069)
Reladv_4: [Solar photovoltaic systems have high operating costs.]		0,016 (0,054)	0,013 (0,054)
Observ_1: [I know more than one person who has a photovoltaic system.]		0,032 (0,038)	0,032 (0,039)
Trial_1: [Before purchasing a photovoltaic system, I would like to talk to someone who has a photovoltaic system.]		0,008 (0,055)	0,033 (0,057)
Trial_2: [I have enough information about photovoltaic systems to make a decision about purchasing one.]		0,003 (0,041)	-0,013 (0,043)
CompTech_1: [My house is suitable for installing a PV system (no shadows from trees, chimneys, other buildings, or historic building).]		0,093 (0,045)*	0,075 (0,047)
CompTech_2:[My location is not sunny enough for solar panels to produce well.]		-0,126 (0,046)*	-0,088 (0,048)
CompSoc_1: [Many people who are important to me think it would be good if I installed a solar PV system.]		0,102 (0,053)	0,100 (0,053)
CompSoc_2: [It is entirely up to me to decide whether or not to install a solar PV system.]		0,128 (0,037)**	0,088 (0,040)*
CompSoc_3: [It is important for me to protect nature.]		0,002 (0,063)	0,029 (0,064)
CompSoc_4: [It is important to use renewable energy to reduce emissions.]		0,058 (0,086)	0,021 (0,089)
CompSoc_5: [I feel an obligation to reduce the negative consequences of my energy consumption.]		0,089 (0,079)	0,109 (0,081)
Complex_1: [I find it easy to install a photovoltaic system.]		0,092 (0,076)	0,084 (0,079)
Complex_2: [I think it takes a lot of time to install a photovoltaic system.]		-0,069 (0,065)	-0,061 (0,066)
Complex_3: [I think that the support procedures for installing a photovoltaic system are clear.]		0,044 (0,056)	0,052 (0,058)
Complex_4: [I think it would be easy to learn how to use a PV system.]		-0,069 (0,076)	-0,083 (0,078)
Prevent_1: [I consider it important that installing a solar system helps to protect against future electricity price increases.]		0,073 (0,080)	0,092 (0,081)
Prevent_2: [I consider it important that installing a solar system will allow me to save natural resources and reduce greenhouse gas emissions.]		0,031 (0,0756)	0,009 (0,077)
Prevent_3: [I consider it important that the introduction of a solar system will allow me to be independent from energy producers.]		-0,089 (0,076)	-0,050 (0,078)
Prevent_4: [People like me should do everything possible to reduce emissions and prevent climate change.]		-0,076 (0,077)	-0,071 (0,078)
N	245	243	239
Adj. R^2	0,10**	0,28**	0,28**
F	5.64	5.31	4.37

*p < .05

**p < .01

relationship between complexity-related variables and intent to adopt, which aligns with previous studies.

The key finding from the analysis was that four variables: "Solar PV makes me feel good", "My house is suitable for installing a PV system (no shadows from trees, chimneys, other buildings, or historic building)", "My location is not sunny enough for solar panels to produce well", and "It is entirely up to me to decide whether to install a solar PV system" were associated with the intended period of PV system adoption. Furthermore, our research suggests that adopters of PV systems find attributes of prevention more important than individuals who are still in the adoption-decision process. However, statistical assumptions made between variables made it impossible to create a model for individuals who had already purchased a PV system.

Therefore, future studies should explore the preventive nature of innovations present in attributes of innovations, for actual adopters of preventive innovations. With this, we seek to understand if prevention is perceived and prioritized differently across adopter groups; this could shed light on different strategies to promote adoption. Additionally, future survey questions should be adjusted to directly measure the preventive nature of innovations, as our current survey setup seems to merely hint at a direction of preventiveness.

There were limitations in this study being the most evident, the fact that we could not create a model from respondents who had already purchased a PV system. Furthermore, this study was carried out in Finnish households, a culture with a high profile of uncertainty avoidance [24]; these societies adopt strict rules to minimize uncertainty and are risk averse [25]. Therefore, results may be different across cultures that are more risk-tolerant. Despite the limitations, the results of this study provide additional steps to unveiling the drivers for the adoption of preventive innovations.

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ARTICLE
III

Household support to adopt preventive innovations to mitigate climate change: A case of Finnish apartment buildings

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Household support to adopt preventive innovations to mitigate climate change: A case of Finnish apartment buildings

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Abstract*— Among the various practices required to achieve sustainability objectives and prevent climate change consequences are energy efficiency, behavioral changes, and the use of renewables. Innovations that seek to deter climate change can be considered preventive innovations. Preventive innovations are those that individuals adopt to reduce the probability of unwanted future events for which, innovations that seek to reduce or mitigate unwanted environmental events can be considered preventive. However, 'clean' technologies and practices are seldom described as preventive. In this study we explored factors that support the adoption of products and services of prevention in relation to environmental protection. The context of our study was within Finnish apartment buildings, where we identified factors that lead to the support of communal housing projects to improve environmental friendliness through the adoption of preventive innovations. In this case, we considered the investments of housing companies to serve various underlying goals of prevention in relation to environmental protection. The dependent variable was "In general, I am in favor of housing association projects (geothermal, air heating, solar panels, heat recovery, etc.) to improve environmental friendliness" whereas independent variables were based on background factors, willingness to sacrifice for the environment, and environmental assets. We ran a statistical analysis with our survey responses, and it yielded three linear regression models of which one (Model 3) was the best fit. With the chosen model we identified three significant variables that were associated with the support of housing associating projects that seek to improve environmental friendliness. Our findings are in line with previous studies on pro-environmental behavior, confirming that gender, education, and environmental assets are factors that lead to pro-environmental behavior and behavioral intentions. This study provides a path toward analyzing the preventive innovation construct as well as identifying factors that lead to adoption.

Keywords— preventive innovation, environmental protection, willingness to sacrifice, environmental assets

I. Introduction

Even though the number of countries pledging to reach net-zero emissions by 2050 is on the rise, so are global greenhouse emissions. Achieving a swift reduction of carbon dioxide emissions requires a series of technologies and policy approaches. Among the key pillars of decarbonization highlighted by the International Energy Agency, there are energy efficiency, behavioral changes, electrification, and the use of renewables [1].

Energy efficiency measures minimize energy demand, reduce energy use and emissions, and yield financial savings. Individual behavioral changes can be in the form of reducing energy use, switching transport modes, and creating demand for energy-efficient materials. Behavioral changes are pivotal to steering the energy system to a sustainable path, as most emission reductions require a mixture of low-carbon technologies and the active involvement of consumers. Furthermore, the use of low-emission electricity and renewable energy technologies are important drivers of emission reductions, as global electricity demand is expected to double between 2020 and 2050 [1].

Reaching sustainability goals requires the adoption of solutions by individuals, governments, and organizations. Environmental innovations that seek to deter climate change or its consequences can be considered preventive innovations. Preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future [2] or to mitigate the severity of the consequences of the unwanted event. Therefore, innovations that seek to reduce the probability of unwanted environmental future events can be considered preventive innovations [3]. However, 'clean' technologies and practices are seldom described as preventive. While preventive behavior has been studied widely, the focus of earlier research has mostly been within public health; only a few studies [3]–[5] in the innovation diffusion tradition have studied preventive innovations in the context of environmental protection.

In this paper, we report results from survey research that analyzes household support of adopting preventive innovations by their housing companies where these preventive innovations seek to improve the building's environmental friendliness. Our contribution is expected to build grounds for future research on the individual or group-wide adoption of preventive innovations, particularly within the environmental protection context.

The purpose of this study is to **identify factors that support the adoption of products or services of prevention in relation to environmental protection**. There are two objectives in this study. First, this study introduces the concept of preventive innovations to describe environmental technologies that seek to deter climate change or its consequences. Second, the study seeks to identify factors that lead to the support of communal housing projects that improve environmental friendliness through the adoption of preventive innovations.

The remainder of this paper is organized as follows. The following section sets the theoretical ground for this study by providing a definition of preventive innovations, analyzing environmental technologies through a lens of prevention, and reviewing factors that influence decision-making. We then discuss the methodology for data gathering and analysis utilized in this study and report the results of our analysis by identifying a series of factors that support the adoption of products or services of prevention in relation to environmental protection. We finalize this paper by identifying limitations and future research opportunities.

II. Theoretical Background

A. *Preventive innovations*

Preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future [2] or to mitigate the severity of the consequences of the unwanted event, as some events are unavoidable, such as natural disasters. There are two main elements that help describe an unwanted event: probability and severity. Probability refers to the extent to which an unwanted event is likely to occur, whereas severity refers to how harmful the event and its consequences might be.

Even though there are standard scales to determine the severity of some unwanted events (such as natural disasters), individuals have different perceptions of how severe these are. Similarly, probability can be estimated at times; for example, individuals know whether they are cautious or careless drivers [6] and can therefore expect or deny the possibility of an unwanted event. Both probability and severity are affected by subjective perception, and, at the same time, they influence attitudes toward prevention.

Literature on diffusion studies [2], [7] states that innovations can be classified as 'preventive' by focusing on two elements from the diffusion of innovations: the innovation and time. Regarding the innovation, the preventive nature becomes more evident when analyzing the five characteristics of the innovation: relative advantage, compatibility, trialability, observability, and complexity. Existing literature identifies that preventive innovations have low relative advantage as benefits are delayed in time and difficult to observe [7], are not very compatible with individuals' values, attitudes, or lifestyles [8], and have difficult or impossible trialability [8], have low observability [8] or might even be non-observable until implemented, [3] and cause-and-effect relationships involved are complex [8].

Regarding time, the lapse from the adoption of preventive innovations to beneficial consequences can be longer than for other types of innovations [2] or cannot be observed until implemented, as it happens with insurance policies [3]. Besides uncertainty, time is also dependent on subjective perceptions, which determine the meaning attributed to certain events within a social system, and in turn, affect individual and collective behaviors [9].

Climate change is a relevant example to illustrate the subjective perception of time. Climate change and its catastrophic consequences are highly severe and probable to occur. Therefore, preventive innovations seeking to mitigate the effects of climate change should have been easily adopted since the concept was first introduced in 1896 by Arrhenius [10]. However, little was made to address climate change until protocols (such as the Kyoto protocol) and climate change panels (such as the Intergovernmental Panel on Climate Change, IPCC) were created one hundred years later. [11]. When climate change was first recognized, its catastrophic consequences seemed too far in time, and its effects appeared abstract, so there was no sense of urgency to act. Nowadays, serious consequences have been observed and are expected to increase during the near term [12], for which there are much greater efforts to address climate change. The subjective perception of the future time when unwanted consequences will appear creates different levels of motivation to address the problem.

In this paper, we argue that the reasons for developing the innovation in the first place indicate if it is preventive. If an innovation was developed with an underlying goal of preventing an unwanted from happening, then it can be classified as a preventive innovation. For example, seat belts were created to prevent pilots from falling off their gliders, and are considered a classic example of preventive innovations [2]. Similarly, the human papillomavirus (HPV) vaccine was created to prevent infection by HPV [13] and is also widely recognized as a preventive innovation [14]–[16].

Certain environmental technologies that seek to deter climate change can be considered preventive innovations as they have underlying goals of prevention, and their benefits can be delayed in time and difficult to assess [3]. For example, improved biomass stoves were developed to decrease exposure to indoor air pollution, and reduce pollution of greenhouse gases and consumption of biomass fuels [17]; the underlying goals of these stoves are related to respiratory disease and harmful emission prevention. Other examples include electric vehicles, which started to be widely promoted to prevent large-scale environmental damage caused by traditional fossil fuel-operated vehicles [18] and pro-environmental behaviors (recycling and energy savings) that seek to prevent climate change and its consequences [3].

B. Factors influencing decision-making

Various factors can influence environmental behavior, including personal and background factors. While personal factors are related to individual values, attitudes, and concerns, background factors are related to an individual's characteristics and social environment.

i) Personal factors

Four human **values** are considered to underlie environmental beliefs and behaviors: biospheric, altruistic, egoistic, and hedonic values [19]. Biospheric values describe an individual's concern for the environment without any link to human beings. Altruistic values reflect concern for the fair treatment of others. Egoistic values reflect concern for personal resources, power, or achievement. Finally, hedonic values describe a focus on attaining positive feelings, and pleasure, and reducing effort. Biospheric and altruistic values are known as 'self-transcendence' values, and egoistic and hedonic values are known as 'self-enhancement' values. Self-transcendence values are positive predictors of environmental behavior, and self-enhancement values tend to be negatively correlated with environmental behavior [20].

On the other side, environmental **attitudes and concerns** have been recognized as determinants of environmentally friendly behavior. Diverse studies [21]–[23] have proven that concern for the environment and desire to protect the environment contribute to the time to purchase environmentally friendly solutions. However, these studies have also highlighted that the consumption of green solutions is conditioned by the economic capacity of consumers.

Furthermore, **environmental-self assets** [24] and **willingness to sacrifice for the environment** [25] are two characteristics of consumers that have proven to influence decision-making. Environmental self-assets refer to people's knowledge about environmental issues and their experience handling these issues [26]. Willingness to sacrifice for the environment is the extent to which individuals will first consider the well-being of the environment even at the expense of self-interest, effort, or costs [27]. Both willingness to sacrifice for the environment and environmental-self assets have been identified as important factors that contribute to pro-environment behavior [24], [28].

ii) Background factors

The role of background factors in environmental behavior has been discussed widely. The strength of **age** effects in pro-environmental behavior has been inconsistent. Stereotypes place young people as more likely to engage in pro-environmental behavior, and have been backed up in survey studies [29]. However, various studies have also identified a positive relationship between aging and pro-environmental behaviors where older people are more likely to engage with nature, avoid environmental harm [30], and participate in pro-environmental behaviors [31].

Studies by Xiao & Hong [32], Mertens et al. [33], and Dietz et al. [34] have found that **gender** plays a role in environmental behavior where women show more positive attitudes and stronger environmental concern than men, mostly attributed to women having a caregiver role which directs them to be more cooperative toward nature [35]. However, a study by Vicente-Molina et al. [36] found that female gender role stereotypes are not significant for everyday pro-environmental actions such as green purchasing and recycling, which are traditionally considered to be within domestic work. These findings suggest gender roles might be decreasing due to gender equality efforts.

On the other side, a higher level of **education** is usually connected with higher levels of environmental knowledge and pro-environmental behavior and concern [32], [35], [37]. However, Wang et al.,[31] present opposing findings through a multi-national study on pro-environmental behavior where people with the lowest level of education performed more actively in pro-environmental behavior.

Furthermore, **income** level has been identified as a significant predictor of environmentally friendly behaviors where high income groups are more likely to engage in pro-environmental behavior [35], [38]. This is particularly the case when analyzing green purchasing, as green products are often positioned as premium products [38]. However, individuals with a low personal income tend to avoid wastefulness and preserve more resources [31], which can also be classified as pro-environmental behavior.

The **type of house** where individuals reside has been studied along with pro-environmental behaviors, particularly when analyzing technologies such as solar photovoltaic (PV) systems. For PV systems, the type of house is a significant factor for adoption as apartment buildings that are stacked one above the other do not have access to panel systems.

III. METHODS

To identify factors that support the adoption of communal housing projects, which we identified as products and services of prevention, we built a survey study with which we constructed a series of multiple linear regression models enlisting the most significant variables.

A. *Research setting: Housing companies' energy investments*

The context of the research is housing companies, a common form of organizing maintenance, operation, and finance in Finnish apartment buildings. The Finnish housing company model is close to housing cooperatives elsewhere in Europe. All apartment owners own shares in the housing company, and there is a well-established regulatory framework. Apartment owners generally make decisions on major investments together, but the board with a limited number of people has the last say in decisions [39]. Members of the housing company usually pay a fee covering general expenses, which includes heating costs as a fixed proportion of the total expenses in the housing company. In Finland, 85% of apartment buildings are heated by district heating [40]; but electricity is paid for by every household.

The most common energy investments for housing companies are heat recovery systems, ground-source heat pumps, solar PV, insulation, and window replacement [41]. In general, energy investments in housing companies are relatively challenging, as decision-makers are typically not experts in the field. Also, investments often require the integration of different technologies which are planned and sold separately by suppliers with narrow solutions [39].

For this study, we consider the investments of housing companies to serve various underlying goals of prevention in relation to environmental protection. For example, insulation systems prevent heat loss, PV systems lower dependence on unreliable fossil fuel markets [42] and renewable electricity sources contribute toward climate change mitigation.

B. Data collection

We conducted a customer survey in collaboration with nine housing companies in Tampere, Finland. In total, 124 people responded to the survey. Approximately 13% of total households answered the survey, presuming that only one person per household participated. The survey was implemented online from May to November 2020 to which apartments from housing companies received an invitation.

When developing the survey, we were guided by theory-based survey items and by the practical experience in survey design of members of our research team. Our survey was piloted to ten people before its publication. Pilot survey respondents were selected by the research team and an effort was made to select individuals across age groups, educational backgrounds, and housing types. After piloting, a few questions were modified based on comments received but the overall response toward the survey was positive.

Survey questions sought to identify household support toward housing association projects to improve environmental friendliness. We included two main types of questions: multiple-choice for demographic questions and a 5-point Likert scale for other variables, where 1 indicates "strongly disagree", or "not at all willing" and 5 indicates "strongly agree" or "totally willing".

The dependent variable for this study "*In general, I support projects (geothermal, air heating, solar panels, heat recovery, etc.) to improve environmental friendliness of the housing association*" sought to explore respondent support toward housing association projects to improve environmental friendliness.

Independent variables were background factors, willingness to sacrifice for the environment, and environmental self-assets. Background factors were identified through a series of socio-demographic and household-specific questions. Socio-demographic questions assessed respondent characteristics through variables of gender, age, education, occupation, and income levels. Household-specific questions identified ownership of the household (either self-owned or rental) and the number of inhabitants in the household. Willingness to sacrifice for the environment is the extent to which individuals will first consider the well-being of the environment even at the expense of self-interest, effort, or costs [27]. Environmental self-assets refer to people's knowledge about environmental issues and the experience they have handling these issues [26]. All variables and their abbreviations can be found in Table 1, which also presents regression analysis results.

C. Data analysis

Answers with missing values were removed, yielding 122 responses to be analyzed. The sample was rather representative of the Finnish population, but certain characteristics were more highlighted than others. Respondents were either relatively young or old, as 79% of respondents were under 30 years old (50%) or over 50 years old (29%). They were also more educated than average people, as 73% of respondents had a Master's degree, compared to 30% of the general adult population [43]. Also, the number of tenants was overrepresented as 52% of respondents lived on rent, whereas in Finland, approximately 25% of the population lives in rental homes [44].

We ran our statistical analysis on SPSS software. The dependent variable met the normality assumption per acceptable skewness and kurtosis values. We constructed three models through multiple linear regression analyses. Model 1 only included background factors. Model 2 included variables associated with willingness to sacrifice for the environment and environmental assets. Model 3 included all variables.

IV. RESULTS

A. Descriptive statistics and correlations

In Table 2 (see Appendix 1), we present descriptive statistics and correlations for all measures in the regression analysis. The dependent variable correlates statistically significantly with all hypothesized variables associated with willingness to sacrifice for the environment and environmental assets, although their coefficients of correlation are rather low (ranging from 0.25 to 0.41). Similarly, we find that variables associated with willingness to sacrifice for the environment and environmental assets correlate significantly with one another. We also find that age correlates with job, income, and house ownership, which we consider natural cross-correlations. These findings raise concerns about potential multi-collinearity problems in modeling but, all VIF factors remained under cut-off value of 5 in our regression modeling.

Overall, these findings encourage us to further investigate the relationship between our dependent variable and independent variables as there seems to be some sort of relationship between support for communal housing projects and willingness to sacrifice for the environment and environmental assets and attitudes.

B. Support for housing association projects to improve environmental friendliness

Table 1 (Appendix 1) displays the results of the performed regression analysis with non-standardized coefficients and their standard errors. Model 1 with background factors reveals that education ($p<0.05$) and gender ($p<0.10$) are significantly associated with the support of projects to improve environmental friendliness of the building. Model 2 with variables corresponding to willingness to sacrifice for the environment and environmental assets depicts that knowledge about environmental issues ($p<0.10$), belonging to environmental assets, is a significant variable. Finally, model 3 with all variables reveals that gender ($p < 0,05$), education ($p<0.10$), and knowledge about environmental issues ($p<0.10$) are significant variables. By observing adjusted R2 values and F-values, we decided to interpret model 3 as its F-value is better than that from model 1.

By looking at the unstandardized coefficients' signs we can identify how the three significant variables from model 3 contribute to the support toward communal housing projects that improve environmental friendliness. The variable of "gender" has a negative coefficient. Inputs for this variable were (1=female, 2=male), meaning that as the input increases, the support for communal housing projects decreases, which suggests support is greater from female respondents. On the other side, both "education" and "knowledge about environmental issues" have positive coefficients, meaning that as individuals are more educated and knowledgeable about environmental issues, the more likely they are to support these communal housing projects.

V. DISCUSSION AND CONCLUSIONS

The purpose of this study was to identify factors that support the adoption of products or services of prevention in relation to environmental protection. Through a case survey we sought to identify what factors drive individuals living under the administration of housing associations to support communal projects that improve environmental friendliness. In this context we considered investments of housing companies to serve underlying goals of prevention related to environmental protection. Our chosen model (model 3) found that gender (women), education (higher education), and knowledge about environmental issues (higher knowledge) were significant contributors.

These findings are in line with previous studies on determinants of pro-environmental behaviors. Xiao & Hong [32], Mertens et al. [33], and Dietz et al. [34] found that women have more positive attitudes and stronger environmental concerns than men. Blocker [35] and Xiao [37] have identified that higher levels of education are reflected in higher environmental knowledge and therefore, greater environmental concerns. Sonenshein et al. [26] identified that individuals with high environmental assets are more supportive than those who self-doubt. These findings also match those by Pine et al.,[4] who studied the adoption of an environmental preventive innovation and identified that communities with higher levels of education were more likely to adopt the innovation.

Previous studies have identified background factors of gender [32], [33], education [35], [37] and environmental assets [26] to be determinants of pro-environmental behaviors and eco-behavioral intentions. In studies of preventive innovations [4] education has also been identified as a significant predictor. However, preventive innovation studies are limited for which gender and environmental assets have not been assessed. Overall, preventive innovation studies have focused on the characteristics of the innovation rather than those of potential adopters, which this study seeks to address.

This study is not without limitations. First, the sample size of 124 respondents is small and limited to one city/country, where the survey was held. This study was carried out on Finnish tenants belonging to a culture with a high uncertainty avoidance profile and known to be risk-averse [45]. Therefore, these results are not to be generalized as they might be different across other cultures, particularly those that are more risk-tolerant. In addition, the context of housing companies implies that the preventive innovation investments are made collectively with other people living in the housing company. This makes the process often more complex compared to single detached houses [39].

Therefore, future studies could focus on the factors driving individual adoption of preventive innovations, either in the form of products or services, either for environmental, business or health-related applications. Furthermore, the next steps include expanding the research context to other countries with different uncertainty avoidance indexes. The results also point to a direction of the environmentally conscious segment to be content with environmental benefits and aspects in their adoption behavior while other segments may be seeking other benefits as well like savings or reliability or the like. These differences between segments adoption behavior in relation to preventive innovations is important future research avenue.

This study provides a path toward more systematically evaluating and analyzing preventive innovation construct as well as identifying factors that lead to the adoption of preventive innovations, specifically by identifying characteristics of potential adopters. In this case, we unveiled factors that could support the adoption of preventive innovations related to environmental protection through housing associations and cooperatives.

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APPENDIX 1

TABLE 1. REGRESSION ANALYSIS RESULTS.

Variable	*Model 1* *B (Std. Err)*	*Model 2* *B (Std. Err)*	*Model 3* *B (Std. Err)*
(Constant)	4.24***	2.24***	2.48***
Gender: Gender_num	-0.29*		-0.29*
Age	-0.01		-0.02
Education	0.29**		0.19**
Occupation	-0.13		-0.14
Income: Net monthly household income	-0.05		0.00
House_own: Home ownership	0.00		0.00
No_of_resi: Number of inhabitants in the household	0.10		0.05
Mon_env_a: How willing would you be to pay much higher prices to protect the environment?		0.05	0.07
Mon_env_b: How willing would you be to pay much higher taxes to protect the environment?		0.05	0.01
Cond_env: How willing would you be to compromise your own standard of living to protect the environment?		0.02	0.04
Env_a: I know a lot about environmental issues.		0.26*	0.27*
Env_b: I keep up to date with environmental issues.		0.06	0.02
Env_c: I care a lot about environmental issues.		0.07	0.03
Env_d: I value environmental protection very much.		0.09	0.12
Dependent variable: In general, I support projects to improve environmental friendliness of the housing association.			
N	122	122	122
Adj. R^2	0.37	0.22	0.32
F	2.67	4.61	3.54
Sig	0.01	0.00	0.00

* p<0.10
** p<0.05
*** p<0.01

TABLE 2. DESCRIPTIVE STATISTICS AND CORRELATION OF VARIABLES.

Dependent variable: In general, I support projects (geothermal, air heating, solar panels, heat recovery, etc.) to improve the environmental friendliness of the housing association.

No	Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Support	4.45	0.95	1.00														
2	Mon_env_a	2.50	1.24	.28**	1.00													
3	Mon_env_b	2.64	1.28	.25***	.67***	1.00												
4	Cond_env	2.95	1.21	.27***	.62***	.60***	1.00											
5	Env_a	3.78	0.91	.41***	0.14	.21**	.29***	1.00										
6	Env_b	3.81	0.89	.39***	0.17*	.27***	.39***	.82***	1.00									
7	Env_c	4.01	0.93	.40***	.41***	.40***	.52***	.58***	.65***	1.00								
8	Env_d	4.25	1.01	.34***	.33***	.34***	.35***	.41***	.47***	.79***	1.00							
9	Gender	1.55	0.52	-0.16*	-0.04	0.00	-0.06	0.05	0.01	-0.04	-0.10	1.00						
10	Age	3.10	1.78	-0.13	0.06	-0.03	0.09	-0.07	-0.04	0.05	0.09	-0.02	1.00					
11	Edu	4.07	1.13	.26***	0.05	0.12	.18**	0.12	0.17*	0.17*	0.08	0.03	0.05	1.00				
12	Job	2.68	1.11	-.18**	0.05	-0.05	0.16*	-0.09	-0.07	0.02	0.05	0.01	.70***	0.06	1.00			
13	Income	3.26	1.64	-0.09	0.12	0.08	0.14	-0.13	-0.05	-0.03	-0.12	0.13	.39***	.28**	.53***	1.00		
14	House_own	1.52	0.58	-0.13	0.13	-0.01	0.05	-0.10	-0.04	-0.01	0.05	-0.05	.74***	-0.05	.62***	.47***	1.00	
15	No_of_resi	1.69	0.75	0.04	-0.02	0.06	-0.01	0.08	0.07	0.00	-0.02	0.14	0.04	0.13	0.10	.45***	.23**	1.00

* Correlation is significant at the 0.10 level (2-tailed).
** Correlation is significant at the 0.05 level (2-tailed).
*** Correlation is significant at the 0.01 level (2-tailed).

ARTICLE
IV

Adoption of a service with preventive innovation characteristics

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Adoption of a Service with Preventive Innovation Characteristics

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Abstract –**Our study investigates the adoption of a sustainability-oriented preventive innovation, namely a service of a renewable electricity contract. Through a survey study we investigate how the five attributes of innovation, demographic and preventive factors influence the intent to adopt the service. The dependent variable "In which period would you be willing to take up a Solar PV contract?" measured the time lapse in which the respondent was planning to subscribe to a renewable electricity contract whereas independent variables helped identify the influence of demographic factors, attributes of innovations, and prevention factors. We ran a statistical analysis with our survey responses, and it yielded three linear regression models out of which one (Model 3) was selected as the best fit. We find variables of gender, relative advantage, and compatibility to influence intent to adopt and identify potential adopters to have significant altruistic motives. Furthermore, our results suggest that reputational gains are not a motive for adoption. We discuss our findings further and provide future research opportunities.**

Keywords– **Preventive innovation, adoption of innovations, renewable energy contract, photovoltaic system**

I. INTRODUCTION

The purpose of this study is to study which factors influence the adoption intentions of a preventive innovation. We will introduce the concept of preventive innovations in the context of services. The research is settled around renewable energy and climate change prevention and mitigation. We identify the influence of the five attributes of innovation [1, p. 16] and related preventive attributes tied to the nature of prevention as variables influencing intent to adopt a service of renewable electricity contracts. Our study reveals the importance of preventive benefits gained from the innovation and its use together with the five attributes of innovation.

II. LITERATURE REVIEW

A. Probability, severity, and temporal lag to see benefits

Preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future [1, p. 234] or to mitigate the severity of the consequences of the unwanted event as some events are unavoidable, for example natural disasters. Preventive innovations have been studied mostly within health-related contexts [2], [3];only a few studies have extended this topic to environmental innovations and applications [4], [5].

The unwanted event that preventive innovations seek to prevent or mitigate can be described by two elements: probability and severity [6]. Probability refers to the likelihood of happening, whereas severity refers to how harmful the event and its consequences may be. While there are standard scales to determine the severity and probability of certain unwanted events, subjective perceptions can influence an adopter's view of these.

The innovation can be defined through the five attributes of innovations as proposed by Rogers [1, p. 16]; particularly, the factor of timelapse to see benefits (relative advantage) differentiates preventive innovations as the temporal lag between adoption and beneficial consequences is distant in time in comparison to non-preventive innovations [1, p. 234]. Hence, our analysis of the perceived attributes of innovations (relative advantage, compatibility, complexity, trialability and observability) can illustrate the characteristics of preventive innovations.

B. *Perceived attributes of innovations*

There are five characteristics of innovations as perceived by individuals, also known as the attributes of innovation. These five attributes have been shown in earlier studies ([7], [8]) to have high explanatory power in explaining the different rates of adoption of innovations.

Relative advantage refers to the degree to which an innovation is considered better than the idea it supersedes [1, p. 15] and can be measured in economic terms or subjective terms such as social prestige, convenience, and time savings. Preventive innovations are considered to have a lower relative advantage as their benefits are delayed in time and difficult to observe [9].

Compatibility is the degree to which an innovation matches existing values, experiences and needs of potential adopters [1, p. 15][10, p. 15]; preventive innovations are often not compatible with individuals' attitudes and lifestyles. For example, contraceptive methods are not widely adopted in countries where religious beliefs discourage family planning [1, p. 15] .

Complexity refers to how an innovation is perceived as difficult to understand and use [1, p. 15] whereas more complicated innovations are adopted more slowly. For preventive innovations, the cause-and-effect relationships involved are complex [7].

Trialability is the degree to which an innovation can be experimented on a limited basis [1, p. 15]. Innovations that can be tested are more likely to be adopted than those that are not divisible. Preventive innovations have difficult trialability, or even impossible like equipment to mitigate damages from earthquakes. But at the same time, some preventive innovations trialability is not impossible; for example, one can test an antivirus software during a 30-day free trial period.

Observability is the degree to which the results of the innovation are visible to others [1, p. 15]. Preventive innovations have low observability as they are usually delayed in time and there are some innovations that have non-observable benefits until they are implemented, such as insurance policies [4]. However, some preventive innovations are visible and can stimulate discussion among peers, such as the installation of solar panels. In addition, when an unwanted event has a high probability of occurring (e.g., flooding in high-risk areas), trialability and observability can be experienced with frequent witnessing of the results of an unwanted event occurring, potentially positively affecting the adopter's acceptance.

C. *Products, ideas, and services of prevention*

Preventive innovations have traditionally been studied with direct material referents (product, hardware, or equipment) [11]. For example, D'Souza et al. [8] studied the diffusion of the human papillomavirus (HPV) vaccine, Sung & Slocum [7] studied golfer's intention to adopt UV-specialized clothing and Kuperstein-Blasco et al. [12] studied the use of wood as a building material; these are preventive innovations with direct material referents.

Logical extensions allow to describe preventive innovations as ideas without direct material referents [11]. For example, Rogers [11] analyzed the diffusion of the idea of 'beyond war', which promoted war and nationalism as obsolete in the 80s to prevent pro-war thinking. Bertrand et al. [13], studied strategies for education and behavior changes to halt the HIV/AIDS pandemic. Empirical studies analyzed the diffusion of behavioral change programs for smoking cessation [14], diabetes prevention [15], etc.

Furthermore, preventive innovations without direct material referents could also be services. Mirtsch et al. [16] studied the implementation of an information security management system as a preventive innovation.

D. *Adoption of renewable energy contracts*

Solar and wind energy are strong contributors to the global sustainable electricity generation capacity. Renewable methods for electricity generation will be adopted more widely as technologies improve, capacity for intermittent electricity generation is enhanced, and policies become more stringent on fossil fuel use.

Among the barriers to the individual adoption of photovoltaic systems, purchase cost stands out as the most significant barrier [17]. A solution to address this barrier is the creation of solar photovoltaic (PV) parks, out of which utility companies can procure their electricity, or consumers can rent a panel whose production is credited to their electricity bill. Utility-scale solar PV plants can be easy to install, operate and maintain; they can be built within one year and can be expanded incrementally, as demand grows [18].

The adoption of electricity contracts where electricity is procured from renewable sources has been previously explored [19]; however, the focus of studies has been on renewable energy source preference. Other studies have analyzed renewable electricity purchase from similar approaches, such as utility-scale solar PV parks [18], subscriptions to green electricity tariffs [20] or through distributed electricity resources.

III. METHODS

To identify factors that support the adoption of renewable electricity contracts, we built a survey study to construct a series of multiple linear regression models enlisting the most significant variables. For this study, we describe the 'adoption of renewable electricity contracts' as the decision to choose an electricity contract where all energy is generated through renewable sources.

A. *Research setting*

The context of this research is the adoption of renewable electricity contracts. Specifically, we analyze the case where a consumer pays a basic monthly fee (approx. 4€/month) plus a consumption fee (fixed rate per kWh) for electricity generated from renewable sources. We consider renewable electricity contracts as preventive innovations as these services serve individual and supplier goals of prevention including the reduction of greenhouse gas emissions (individual), and preventing voltage swell and dip events through dynamic grid support and frequency support functions (supplier) [21].

B. *Data collection and variables*

Our data was collected through an online survey distributed by a local electricity company in central Finland in Sep-Nov 2021. Our final sample size was 297 responses.

Our dependent variable: "In which period would you be willing to take up a Solar PV contract?" measured the time lapse in which the respondent was planning to subscribe to a renewable electricity contract.

Independent variables were labeled as demographic variables, attributes of innovation variables, or prevention variables. Demographic questions were multiple-choice questions whereas remaining questions were 5-point Likert scale questions from 1= "strongly disagree" to 5= "strongly agree".

Demographic variables allowed us to identify if socio-demographic or household-specific elements had an influence over the intended period to adopt; these helped assess decision-maker characteristics, attributes of innovation, and preventive innovation variables assessed the respondent's perception towards the service's relative advantage, compatibility, complexity, observability, trialability and prevention.

C. *Data analysis*

We ran our analysis on SPSS software. We checked for the assumption of regression analysis and found no violations against them. Model 1 only included demographic variables, model 2 included innovation attributes and prevention variables and model 3 included all variables. Multicollinearity issues were not detected.

IV. RESULTS

In Table 1 we present descriptive statistics and correlations for all variables in the regression analysis. Table 2 displays the results of the regression analysis with non-standardized coefficients and their standard errors. Model 1 with demographic variables contains one variable significantly associated with the intended period of renewable electricity contract adoption ($p<.1$); adjusted R^2 and F-values are low in comparison to models 2 and 3. Model 2 low in with innovation attributes and prevention variables reveals seven innovation attributes variables as significantly associated with the dependent variable ($p<.1$, $p<.05$, $p<.01$) but no significance from prevention variables. Finally, model 3 with all variables depicts one demographic variable ($p<.01$), eight innovation attributes variables ($p<.1$, $p<.05$, and $p<.01$), and one prevention variable ($p<.1$) as significantly associated with intended period of adoption.

By observing adjusted R^2 values and F-values, we decided to interpret model 3 as its adjusted R^2 is better than model 2. Therefore, ten independent variables were statistically significantly associated with the preventive innovation service intended period adoption.

IV. DISCUSSION AND CONCLUSIONS

This study sought to explore if the preventive nature of innovations influences the intended period for the adoption of a preventive innovation service. With a survey we sought to identify demographic, innovation attributes and prevention factors that lead to the adoption of renewable energy contracts, identified as preventive as they serve underlying goals of prevention.

Our model included ten variables that were significantly associated with the intended period of adoption. By looking at the unstandardized coefficient's sign we can identify how these variables contribute to the period in which respondents would be willing to take up a renewable electricity contract.

Negative variables (Reladv_2&4, Compatibility_2&4, and Prevention_1) would reduce the time in which respondents are willing to take up a contract, for example, the "feel good feeling" from a solar electricity contract or the opportunity to save natural resources through a solar electricity contract would reduce time to adopt. While variable Complexity_2 *"I think it takes a long time to tender a solar contract"* has a positive coefficient, the question is reverse-coded, thus the positive coefficient represents a reduction in time to adopt. Furthermore, the gender variable identifies women willing to adopt the contract quicker than men.

On the other side, positive-coefficient variables would increase the time in which respondents are willing to take a solar PV contract. However, a closer look at these variables provides interesting insights about potential adopters and solar PV contracts as preventive innovations. Variable Reladv_1 *"Switching to a solar electricity contract will make a good impression on other people"* signals the fact that respondents are not interested in the reputational benefits of adopting renewable electricity contracts. This finding is in line with the fact that a solar electricity contract does not bring any financial benefits (but represents an expense). Variables Compatibilty_5: *"I feel an obligation to reduce the negative consequences of my energy consumption"* and Complexity_1: signal *"I find it easy to switch to a solar contract"* could signal the fact that potential adopters don't see a solar PV contract as a means to fulfill the obligation to reduce the negative consequences of their energy consumption.

TABLE 1. COEFFICIENT CORRELATION

	Mean	SD	N	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
(1) (Constant)	3.13	1.53	297	1.00																							
(2) Demographics_gender	1.37	0.53	297	-.11*	1.00																						
(3) Demographics_age	4.25	1.39	297	0.01	0.20**	1.00																					
(4) Demographics_income	4.24	1.93	297	-0.06	-0.01	-0.01	1.00																				
(5) Household_type	2.19	1.01	297	-0.01	-0.27**	-0.01	-0.20**	1.00																			
(6) Household_size	92.55	62.59	297	-0.02	0.27**	0.11*	0.23**	-0.67**	1.00																		
(7) Household_mngmt	1.43	0.59	297	0.01	-0.22**	-0.17**	-0.21**	0.47**	-0.44**	1.00																	
(8) Reladv_1	3.10	1.10	297	-0.20**	-0.06	0.03	-0.12*	0.03	-0.04	0.06	1.00																
(9) Reladv_2	3.40	1.14	297	-0.34**	-0.26**	-0.08	-0.05	0.00	-0.01	0.04	0.67**	1.00															
(10) Reladv_3	3.57	0.93	297	0.15**	0.21**	-0.09	0.03	-0.27**	0.24**	-0.15**	-0.25**	-0.34**	1.00														
(11) Reladv_4	3.15	1.18	297	-0.25**	0.08	0.02	0.18**	0.07	0.03	-0.16**	0.15**	0.17**	-0.28**	1.00													
(12) Observ_1	1.66	0.95	297	-0.10*	0.10*	0.17**	-0.10*	0.04	-0.08	-0.07	0.23**	0.21**	-0.20**	0.17**	1.00												
(13) Trialability_1	3.02	1.29	297	-0.05	-0.07	0.15**	-0.02	0.10	-0.12*	0.03	0.16**	0.11*	-0.13	0.08	0.14**	1.00											
(14) Trialability_2	2.86	1.24	297	-0.07	0.22**	0.03	-0.08	-0.07	0.04	-0.11*	0.07	0.04	-0.02	0.29**	0.27**	-0.18**	1.00										
(15) Trialability_3	3.35	1.16	297	-0.04	0.06	-0.10*	-0.04	-0.10*	0.14*	-0.11*	0.10*	0.14**	-0.06	0.23**	0.19**	-0.17**	0.58**	1.00									
(16) Compatibility_1	2.63	1.03	297	-0.17**	-0.08	0.11*	-0.09	0.00	-0.03	0.00	0.57**	0.54**	-0.28**	0.17**	0.38**	0.19**	0.13	0.16**	1.00								
(17) Compatibility_2	4.00	1.31	297	-0.19**	0.09	0.08	-0.05	0.04	-0.02	-0.09	0.05	0.00	0.06	0.22**	0.01	-0.01	0.19**	0.16**	0.11*	1.00							
(18) Compatibility_3	4.42	0.79	297	-0.12*	-0.29**	-0.07	-0.02	0.13*	-0.06	0.02	0.28**	0.35**	-0.17**	0.18**	0.02	-0.03	-0.01	0.11*	0.24**	0.02	1.00						
(19) Compatibility_4	4.25	0.85	297	-0.29**	-0.24**	-0.10*	0.01	0.09	-0.05	0.04	0.28**	0.45**	-0.18**	0.11*	-0.03	0.02	-0.07	0.10*	0.22**	-0.05	0.44**	1.00					
(20) Compatibility_5	3.85	1.08	297	-0.17**	-0.30**	-0.09	-0.04	0.12*	-0.01	0.08	0.34**	0.51**	-0.28**	0.16**	0.09	0.04	-0.04	0.03	0.35**	-0.08	0.46**	0.65**	1.00				
(21) Complexity_1	3.37	0.88	297	-0.04	0.05	-0.20**	0.00	0.03	0.00	-0.01	0.04	0.10*	-0.10*	0.32**	0.14**	-0.18**	0.36**	0.42**	0.06	0.20**	0.03	0.05	0.06	1.00			
(22) Complexity_2	2.84	0.93	297	0.13*	-0.10*	0.06	0.00	-0.02	-0.04	0.06	-0.02	-0.04	0.24**	-0.29**	0.05	0.19**	-0.22**	-0.27*	0.05	-0.12*	0.07	-0.10*	-0.07	-0.55**	1.00		
(23) Prevention_1	3.89	1.17	297	-0.29**	-0.36**	-0.13*	-0.04	0.18**	-0.15**	0.16**	0.48**	0.66**	-0.39**	0.17**	0.13**	0.04	-0.01	0.11*	0.43**	-0.03	0.48**	0.49**	0.59**	0.07	-0.01	1.00	
(24) Prevention_2	3.73	1.08	297	-0.23**	-0.30**	-0.03	-0.02	0.17**	-0.06	0.09	0.33**	0.47**	-0.25**	0.17**	0.01	0.04	-0.05	0.06	0.35**	-0.01	0.46**	0.66**	0.76**	0.04	-0.07	0.59**	1.00

*p<0.05
**p<0.01

TABLE II
REGRESSION ANALYSIS RESULTS

Variable	*Model 1* *B (Std. Err)*	*Model 2* *B (Std. Err)*	*Model 3* *B (Std. Err)*
(Constant)	4.090 (0.631)***	5.506 (0.899)***	7.170 (1.108)***
Demographics_gender	-0.403 (0.179)**		-0.738 (0.177)***
Demogrphcs_age	0.048 (0.066)		0.071 (0.063)
Demographics_income What is your household's total gross income (income before tax) per year	-0.060 (0.048)		-0.056 (0.044)
Household_type: What is the type of housing?	-0.127 (0.125)		-0.043 (0.113)
Household_size: What is the floor area of your house/flat?	-0.001 (0.002)		-0.001 (0.002)
Household_mngmt: What is the form of ownership of your house/flat?	-0.008 (0.178)		-0.182 (0.161)
Reladv_1: Switching to a solar electricity contract will make a good impression on other people.		0.146 (0.104)	0.203 (0.103)**
Reladv_2: Switching to a solar electricity contract will make me feel good		-0.422 (0.115)***	-0.476 (0.115)***
Reladv_3: I think a solar contract is expensive		-0.060 (0.102)	0.009 (0.105)
Reladv_4: It is economically feasible for me to switch to a solar contract		-0.220 (0.078)***	-0.163 (0.081)**
Observ_1: I know more than one person who has switched their electricity contract to a solar electricity contract		-0.150 (0.097)	-0.150 (0.098)
Trialability_1: Before changing my electricity contract, I would like to talk to someone who has already switched to a solar electricity contract		-0.005 (0.067)	-0.031 (0.066)
Trialability_2: I have enough information about the solar electricity contract to make a decision to switch		-0.064 (0.084)	-0.038 (0.084)
Trialability_3: I know where I can get reliable information about my solar contract.		0.136 (0.090)	0.133 (0.090)
Compatibility_1: Many people who are important to me think it would be good if I switched my electricity contract to a solar electricity contract.		0.048 (0.105)	0.053 (0.104)
Compatibility_2: It is entirely up to me to change my electricity contract		-0.206 (0.065)***	-0.224 (0.064)***
Compatibility_3: It is important to me to protect nature.		0.112 (0.124)	0.032 (0.122)
Compatibility_4: It is important to use renewable energy to reduce emissions		-0.431 (0.136)***	-0.409 (0.133)***
Compatibility_5: I feel an obligation to reduce the negative consequences of my energy consumption		0.257 (0.126)**	0.245 (0.125)*
Complexity_1: I find it easy to switch to a solar contract		0.241 (0.119)**	0.253 (0.119)**
Complexity_2: I think it takes a long time to tender a solar contract		0.220 (0.113)*	0.199 (0.112)*
Prevention_1: I consider it important that switching to a photovoltaic contract allows me to save natural resources and reduce greenhouse gas emissions		-0.171 (0.106)	-0.208 (0.106)*
Prevention_2: People like me should do all they can to reduce emissions and prevent climate change		-0.060 (0.126)	-0.097 (0.124)
Dependent variable: In which period would you be willing to take up a Solar PV contract?			
N	297	297	297
Adj. R^2	0.003	0.205	0.246
F	1.155	5.502	5.209

*p < .1
**p < .05
***p < .01

These findings are in line with previous studies identifying factors that promote the adoption of preventive innovations. When studying products for prevention, Sung & Slocum [7], D'Souza et al. [8] and Kuperstein-Blasco et al. [6] identified relative advantage and compatibility as significant predictors in the intent to adopt even though preventive innovations are considered slow to diffuse due to their low relative advantage [9]. Similar to Xiao and Hong [22] analysis on gender differences in environmental behaviors, we identified women as more likely to engage in this form of environmental behavior. However, the positive coefficient from the variable describing the obligation to reduce the negative effects of one's environmental behavior was unexpected as the altruistic nature of the adoption of this preventive innovation shows in other variables.

Previous studies have identified factors that influence the adoption of preventive innovations with and without direct material referent; our findings contribute to this body of knowledge. Particularly, our study expands preventive innovation studies through empirical evidence of a service with preventive characteristics and identifies factors that influence time to adoption. Furthermore, this study contributes to a seldom explored field of renewable energy as preventive innovation against climate change: renewable electricity contracts.

This study has its limitations. Driving factors of renewable energy adoption are context-specific and rely on country-specific conditions for which the findings of this study cannot be generalized as they belong to the scope of solar panel rental in Finland. However, this research process can be replicated in another context. Furthermore, our analysis excluded respondents who had already adopted a renewable energy contract, for which we could not get insights on what actual adopters value when renting a solar panel. Despite these limitations, this study provides an overview on the drivers for the adoption of a preventive innovation as a service. Our insights on the perceived value of renewable energy contracts can be useful for suppliers of these services.

This study opens interesting future research avenues. For example, the preventive nature of an innovation as part of how adopters and providers view it and how these may contrast. Our study shows that a preventive innovation as a service has altruistic component on adopters' side, but does this show in the producers' side of value creation as part of the value propositions? Also, preventive innovation as a construct calls for further investigations into how it is described, its elements, attributes, and features. This would be crucial for its precise, scientific use in future studies. Furthermore, future studies could focus on insights from individuals who have already rented a solar panel to identify what they perceive as valuable.

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ARTICLE
V

Recognizing the preventive quality in the adoption of innovations: the case of third-party ownership photovoltaic systems

Kuperstein-Blasco, D., & Mäkinen, S.

(Unpublished manuscript, submitted to a journal)

ARTICLE
VI

Incumbent actions in adopting preventive innovations: Cases in the Finnish construction sector

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Incumbent Actions in Adopting Preventive Innovations: Cases in the Finnish Construction Sector

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Abstract - **Wood construction differs from traditional concrete materials in technical and organizational requirements for which it can be studied as an innovation. Thanks to health and climate change mitigation and prevention capabilities, wood construction can be categorized as a preventive innovation. The purpose of this study is to explore incumbent actions in the adoption of wood materials. The context of this paper is an interview study that analyzes public procurement of school buildings that illustrate the role of incumbent actions in the adoption of wood materials. We study the actions of incumbent organizations and identify how these actions relate to the preventive innovation's elements of probability, severity, and time-lapse to see benefits. Findings indicate that the probability and severity of an unwanted event make incumbents more likely to select wood materials and future-oriented benefits are not a deterrent for adoption but instead, are often utilized to argue potentially larger investments. This study provides an overview of prevention-related benefits derived from building materials and highlights what construction sector incumbents ponder when adopting innovations.**

Keywords – **preventive innovation, wood construction, incumbent**

I. INTRODUCTION

Achieving carbon neutrality goals requires changes in products, processes, and organizations, particularly within specific sectors. The construction sector is one of the most carbon-intensive sectors, responsible for over 20% of global carbon dioxide emissions [1]. Better practices would significantly influence final energy expenditure, greenhouse gas emissions, and water consumption [2].

Among the proposed solutions to reduce emissions in the construction sector, there is the use of sustainable building materials, such as wood. Wood is considered an environmentally friendly material [3], a low-carbon alternative, and a sustainable housing solution [4]. Wood outperforms concrete counterparts in greenhouse gas (GHG) emissions, carbon storage [5], and carbon emissions. The use of wood helps mitigate indoor moisture, which prevents bacterial growth [6], and improves indoor air quality and thermal comfort [7]. However, the widespread use of wood as a building material is challenged as associated fire regulations are relatively strict, materials can be up to 25% more expensive [8], and consumer perception places wood as inferior in technical characteristics [3].

19th-century building technologies led to the widespread use of steel and reinforced concrete and the decline of traditional wooden structures [9]. Organizational processes and technical capabilities to work with wood are nowadays perceived as new [10]. However, the use of wood as an innovation has been scarcely studied.

In this paper, we classify wood as a building material as a preventive innovation. Rogers [11, p. 234] identified preventive innovations as those that individuals adopt to reduce the probability of an unwanted event in the future. Wood materials not only differ from concrete materials in technical and organizational requirements but also provide health-related and climate-change mitigation benefits that are preventive in nature [12].

Adopting preventive innovations in the construction sector could positively contribute toward sustainability goals. However, the adoption of innovations in the construction sector is challenging as this sector is well-known for being risk-averse [13], and path-dependent for which technological changes can take decades to be realized [14], [15]. Furthermore, incumbent organizations in the construction sector can struggle in the face of innovations. In an innovation context, incumbency refers to whether an organization participated in a previous product generation.

The purpose of this study is to explore incumbent actions in the adoption of wood materials. This study serves two objectives. First, it introduces the use of wood as a building material as a preventive innovation. Second, this study seeks to identify incumbent-related factors that influence the adoption of preventive innovations in the construction sector.

The context of this paper is an interview study where we analyzed public procurement of school buildings. In this study, we gathered narratives that illustrate the role of incumbent actions in selecting wood as a building material. Through our case, we identify the actions of incumbent organizations and identify how these relate to the preventive innovation's elements.

II. THEORETICAL BACKGROUND

A. Preventive innovations

Prevention is the action of stopping something from happening. The topic is widely covered in insurance literature [16] where utility functions are dependent on the probability of unwanted events with certain loss sizes. Loss prevention addresses the probability and severity of the loss. "Probability" refers to the extent to which an unwanted event is likely to occur, and "severity" refers to how harmful the event and its consequences might be.

There are different ways in which individuals can prevent an unwanted event, one of them is the adoption of preventive innovations. Preventive innovations are those that individuals adopt to reduce the probability of an unwanted event in the future [11, p. 234] or to mitigate the severity of the consequences of the unwanted event. Given that preventive innovations are closely linked to the unwanted event, it seems important to consider the probability and severity of the unwanted event in the discussion of preventive innovations.

On the other side, the relative advantage of preventive innovations depends on the time lapse between adoption and beneficial consequences where desired consequences are distant in time, in comparison to non-preventive innovations [11, p. 234].

An application of preventive innovations that has not been explored is the use of wood as a building material for both health-related and climate-change mitigation and prevention [12]. In buildings, the use of wood helps mitigate indoor moisture, which prevents bacterial growth [6], and improves indoor air quality and thermal comfort [7]. Wood materials are superior at inhibiting moisture degradation through improved air circulation [17] and the risk of mold growth is low [7]. Mold exposure, dampness, and bacteria are associated with respiratory diseases [18].

On the other side, wood materials are generally considered an environmentally friendly material [3], a low-carbon alternative, and a sustainable urban housing solution [4]. When comparing wooden-framed structures with concrete-framed structures, wood outperforms the concrete counterpart in greenhouse gas (GHG) emissions, carbon storage [5], and carbon emissions. Furthermore, after its natural cycle, wood products can be utilized as biofuels if burned [5]. However incumbent organizations can struggle in the face of innovations for which the adoption of preventive innovations can be challenged.

B. Incumbents

When an innovation is introduced to an industry, new entrants contend against well-established incumbents for market leadership. In an innovation context, incumbency refers to whether an organization participated in a previous product generation. It is well argued that incumbent organizations struggle in the face of innovations; incumbents are so devoted to their success with a particular product generation or so hindered by bureaucratic processes that they fail to adopt the innovation [19].

According to Chanty & Tellis, [19], there are three reasons why incumbents are reluctant to introduce radical innovations. First, incumbents recognize small incentives to introduce a radical product innovation as they are already getting significant revenue from existing products and technologies. Second, organizational structures that screen out information that is not relevant to an organization's main tasks make incumbents less effective at engaging in radical innovation. Third, organizational procedures that incumbents carry out to efficiently manufacture and distribute large volumes of the current technology hinder the development of innovations.

On the other side, there are opportunities that incumbents have in comparison to new entrants. An incumbent has the best position to benefit from an innovation when success is determined by who has access to complementary assets [20]. Incumbents also have greater knowledge about customers. Furthermore, incumbents hold a strong reputation with their customer base. Finally, incumbent organizations hold market power which provides favored access to distribution channels necessary for the diffusion of the innovation [19]. In the construction sector, incumbent organizations are known for their risk aversion [13], and path dependency.

C. The construction sector

Reichstein et al. [15] and Mahapatra & Gustavsson [14] identified factors that shape the nature of innovation in the construction sector. Construction is a project-based activity where networks are impermanent and there is limited interaction among actors, which is vital for innovation. Construction is a site-specific endeavor that hinders routine development and creates uncertainty. A building's design and size are dependent on clients, for which it is difficult to innovate in the industrialization of building processes. Furthermore, there is little competition among big contractors, for which there is no motivation to innovate [14]. Finally, the final product has a long lifespan and a big scale, for which it is difficult to test innovations before implementation.

On the other side, the construction sector is subject to path dependency and tradition. Path dependency refers to how a decision that is made in the present is affected by past decisions [14]. Path dependency deters the willingness of construction professionals to work with materials that have lower standardization than other alternatives, especially ones with which they have little expertise [14]. On the other side, the selection of building materials varies due to traditions and culture, which can be the result of the availability of materials [21].

III. MATERIALS AND METHODS

A. Research process

This study was conducted with a qualitative approach where the strategy consisted of four main steps. First, we conducted 20 semi-structured interviews lasting between 60 to 150 minutes, which served as a primary source of data. Interviewees were identified from procurement documents and further on through snowball sampling; these included professionals overseeing project management, urban services, education, and city administration. Second, we retrieved information from official documents and news pieces where we gathered additional information on the procurement process. Third, we analyzed the interviews in Atlas.ti, a qualitative data analysis software. Interviews were coded according to the research approach discussed below. Fourth, we identified incumbent actions and how these influence the adoption of preventive innovations.

B. Context of procurement cases

We analyzed five public procurement cases from the Finnish construction sector: each case belonged to a school building that included wood as a building material. These schools were open to new construction with wood because they had indoor air quality issues with their old school buildings. All cases were selected from a region with leading status in wood construction. These represent various procurement processes, award criteria, and wood usage as depicted in Table 1.

All cases were based in Finland and operated under the same EU regulations [22]. When this study was conducted, EU regulations allowed for eight tendering procedures; the two procedures present in these cases were open procedure and competitive dialogue. Open procedure is utilized when there are a few candidates, limited competition, and technical expertise is required. Competitive dialogue is utilized when there is a complex project but contracting authorities cannot define how to meet their needs and assess what the market can offer.

According to European Commission regulations, authorities must select the best tender following specified award criteria; typically used criteria include the most economically advantageous tender (MEAT), lowest price approach, and best price-quality ratio approach. In MEAT, the contracting party awards a contract based on various criteria other than just price, these include quality, functional, environmental, and aesthetic characteristics, among others. The lowest price approach solely considers price as the deciding factor and in the best price-quality ratio approach, the contracting party selects the tender that offers the best value for money, which also includes criteria of qualitative, environmental, and social aspects [23].

C. Research approach

Through our interviews, we gathered narratives that illustrate the role of incumbent actions in the adoption of wood as a building material. In this study, we consider the municipalities that engage in the procurement of a building with wood to be incumbents. Interview data were coded to identify "why" and "what" incumbents in the Finnish construction sector are doing, and those factors relate to the probability and severity of the unwanted event and time-lapse to perceive the benefits of the innovation. Examples of coding groups include "what_probability" or "what_severity". These elements are explained in Table 2.

TABLE 1
OVERVIEW OF CASES

	Case 1	Case 2	Case 3	Case 4	Case 5
Procurement procedure	Open procedure	Open procedure	Competitive dialogue	Competitive dialogue	Competitive dialogue
Award criteria	Lowest price	MEAT	MEAT	Price-quality	Price-quality
Wood use in the building	Wood façade, (CLT)* interiors	Wood façade, concrete structure	Log façade, concrete structure	Concrete structure, wooden elements	Wooden logs

*CLT= Cross-Laminated Timber

TABLE 2
RESEARCH APPROACH

	What?	Why?
Probability -of the unwanted event	1. Does the probability of the unwanted event affect what incumbents do?	2. Does the probability of the unwanted event affect incumbent motives?
Severity - of the unwanted event	3. Does the severity of the unwanted event affect what incumbents do?	4. Does the severity of the unwanted event affect incumbent motives?
Time lapse - to perceive benefits	5. Does a long timelapse to perceive benefits affect what incumbents do?	6. Does a long timelapse to perceive benefits affect incumbent motives?

IV. RESULTS

We identified incumbent actions and their relation to the probability and severity of the unwanted event and the time-lapse to perceive benefits. Synthesized findings across cases are presented in Table 3.

TABLE 3
SYNTHESIZED FINDINGS

	What?	Why?
Probability - of the unwanted event	Considering a highly probable unwanted event, incumbent organizations are more likely to adopt a preventive innovation.	Probability influences motives and directs incumbents toward adoption even if they are unfamiliar with the innovation.
Severity - of the unwanted event	Severe issues made incumbents willing to adopt an innovation and develop a strong attitude against the previous alternative.	Severe issues led incumbents to seek projects that were reliable, could provide good reputation overruling other criteria such as price.
Time lapse - to perceive benefits	Incumbents seek future-oriented benefits, though this does not always point towards wood.	Incumbents are deciding in favor of the preventive innovation because they are expecting benefits on the long run.

A. Probability

"What?" and "Probability"

Our findings indicate that considering a highly probable unwanted event, incumbent organizations are more likely to adopt a preventive innovation, as occurred in case 3.

While all cases had problems with indoor air quality in one of their previous buildings, case 3 had major issues with indoor air quality in three old school buildings, where schools had to be shut down and students had to be transferred. For case 3, the probability of an unwanted event was perceived as high. Therefore, the main objective for case 3 became to have a "healthy" building, as expressed by the city's mayor *"It's really the major thing that we have [a] healthy building"* (09.02.2020).

This same logic applies to unwanted events related to environmental protection as it happened in case 1. Case 1 belongs to a city that has near-future carbon neutrality goals which affect the way constructions are planned, approved, and carried out due to the high impact of the construction sector. To lower the environmental impact of construction, the main objective of the school was to be made from wood.

"Why?" and "Probability"

Our findings indicate that the probability of an unwanted event influences incumbent motives and directs them toward adopting an innovation, even if they are not familiar with it. All cases had experienced at least one problem with indoor air quality in their old buildings, and, as highlighted by the urban services director of case 2, *"the whole country is fighting with this problem"* (23.09.2020). To address this problem, all cases considered building with wood even though they were not sure of its benefits, as highlighted in the quote *"some people think that in wooden schools, the indoor air would be better [...] I've read articles about it as well. But I don't know if it's actually something that is scientifically proved or anything"* (urban services director, 23.09.2020).

B. Severity

"What?" and "Severity"

In this aspect, we found that health-related issues were considered highly severe, and this made incumbents willing to adopt an innovation that had shown better results than the current alternative. Furthermore, incumbents developed a strong attitude against the previous alternative that had caused consequences.

This is clearly illustrated in case 2, where there were indoor air quality issues in three schools. Incumbents avoided the use of certain materials, such as plastic, as stated by the city's mayor *"we were doing everything to not choose plastic materials that cause some problems"* (02.09.2020) and mentioned that they seek to have a good image and the use of plastic could disturb it.

"Why?" and "Severity"

We found severity to help incumbents seek to implement reliable projects, could provide a good reputation, and could be done promptly. As portrayed in case 2, when the matter needed to be solved urgently, as discussed by the technical director *"[there were] serious health problems and threats that they [schools] had to be closed and procured with great urgency"* (29.11.2019). The project had such a priority that it overruled the price criterion, which was *"millions more than if it has some other material"* (technical director, 29.11.2019).

For case 3 health problems were not the only issue, but also the bad reputation that came alongside, as depicted by the urban services director when describing another school that had problems with indoor air *"they can't get rid of the reputation that they're having problems with the schools"* (23.09.2020). In this case, incumbents wanted a solution that gave a good reputation, and as recalled by the interviewee *"I think the image for wooden school helps for that"* (urban services director, 23.09.2020).

C. Time lapse to see benefits

"What?" and "Timelapse"

When we studied the influence of a long timelapse to see benefits we identified that incumbents seek future-oriented benefits, though this doesn't always point toward wood materials. For example, in case 2 other options besides wood, were analyzed as the durability of wood was questioned, as said by the mayor *"concrete construction still had supporters, because this (wood) and the durability of wood that it would last 50 years as an example was not necessarily believed"* (09.02.2020). However, wood was chosen as the priority was to have a healthy school.

"Why?" and "Timelapse"

When we looked at how a long timelapse to see benefits affects incumbent motives we identified that incumbents are making some decisions because they are expecting benefits in the long run. For example, incumbents from case 1 *"wanted to prepare for the future"* (project architect, 15.11.2019) by selecting a material that would cater to future environmental regulations in the construction sector. While environmental benefits take a long time to be realized, being prepared for upcoming environmental regulations appeared as a benefit realized in the present.

V. DISCUSSION AND CONCLUSIONS

In this paper, we studied decisions on the adoption of wood materials, categorized as preventive innovations. Our findings indicate that the probability and severity of an unwanted event that has already been experienced make incumbents more likely to adopt the preventive innovation. Regarding time-lapse, it appears that future-oriented benefits are not a deterrent for adoption and in fact, future benefits are often utilized to argue for potentially larger investments. We identified that preventive innovations can also bring immediate benefits, particularly in the form of a good reputation, being prepared for the future, and health benefits. Preventive innovations are often characterized as having a long timelapse from adoption to seeing benefits; however, future-oriented benefits could be a good fit for sectors with long-term projects, such as the construction sector.

This study contributes to diffusion studies, on the adoption of preventive innovations. This paper dealt with the probability and severity of the unwanted event in an exploratory fashion as these elements have not been covered in previous studies of preventive innovations. Findings highlight the role of probability, severity, and time lapse to perceive benefits. This study expands the domain of preventive innovations by applying the concept to the construction sector and broadens knowledge on "innovations", "wood construction" and "prevention" within construction sector literature.

On the other side, our findings contribute to the body of knowledge on prevention within the construction sector by presenting a different application to this concept: prevention-related benefits derived from building materials. While the environmental and health benefits of WMC have been identified previously [8], these have not been considered through the lens of prevention. Recognizing the preventive quality of wood construction could shed light on how to influence its rate of adoption.

This study has its limitations. The elements identified in this study cannot be generalized, as they belong to the scope of public procurement of school buildings in Finland. This study analyzed incumbents in the public sector, which has responsibilities in terms of community, democracy, economy, and wellbeing well-being [24]. Therefore, it is the responsibility of municipalities to provide conditions for the well-being of their residents, which might not be the case for other incumbents facing the decision to include wood in construction projects. Future studies could analyze willingness to adopt when incumbents have not experienced the unwanted event; this could also illustrate the role of past experiences on current decisions. Furthermore, future work seeks to identify the presence of probability and severity of an unwanted event quantitatively, as these were covered in an exploratory fashion in the present work.

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