2025

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Barriers to Nature-Inclusive Design in early-stage real estate development: analysing relationships and designing a tool to inform strategic decision-making

Information author:

Initials and surname: A.R.D. van Loevezijn

Student number: 1507400

Masters Program:

University: University of Technology Eindhoven

Program: Construction Management and Engineering

Course: 7CC40

ECTS: 40

Supervising committee:

Chairperson: Tunçer, Bige

First supervisor: Ersad Sarabi, Shahryar

Second supervisor: Tunçer, Bige

Third supervisor: Dane, Gamze

Internship supervisors: Femke Oskamp & Robin Kops (extern from Company Brink Management/Advies)

Eindhoven, 7th of November 2025

Preface

This master thesis was written as the final part of my masters program Construction Management and Engineering at Eindhoven University of Technology (TU/e). The research was conducted in collaboration with Brink Management/Advies. It focused on understanding the barriers to Nature-Inclusive Design (NID) and their mutual relationships, and translates these findings into a practical decision-support tool.

I would like to express my sincere gratitude to my supervisors from TU/e Mr. Sarabi, Mrs. Tunçer and Mrs. Dane for their valuable insights and support throughout the research. I also want to thank my company supervisors Femke Oskamp, Robin Kops and other colleagues from Brink for their valuable guidance, trust and enthusiasm. For me, the professional expertise of a company being involved in process added great practical value to the research and made my experience even more informative.

I have experienced working on this project particularly as rewarding since I have combined analytical research with the creation of something tangible and applicable in practice, which made the process more enjoyable for me.

Finally, I am proud of the result and I hope the reader will enjoy reading this thesis and that it provides useful insights.

Ard van Loevezijn

November, 2025

Abstract (Dutch)

Nature-Inclusive Design (NID) krijgt steeds meer aandacht omdat het een belangrijke strategie is om de biodiversiteit in de gebouwde omgeving te verbeteren. De implementatie van NID in vastgoedontwikkeling blijft echter beperkt vanwege een aantal barrières die nog niet volledig worden begrepen. Dit onderzoek heeft als doel een beter inzicht te verkrijgen in deze barrières en te onderzoeken hoe deze barrières kunnen worden vertaald naar relevante informatie voor besluitvormingsprocessen in de vroege fase van vastgoedontwikkeling. Het onderzoek heeft een literatuuronderzoek gecombineerd met interviews met deskundigen om een lijst van 18 relevante barrières voor de implementatie van NID op gebouwniveau op te stellen. Vervolgens werden Interpretive Structural Modelling (ISM) en MICMAC-analyse toegepast om deze barrières te structureren in een hiërarchisch model om hun onderlinge relaties te benadrukken en hun 'driving' en 'dependence power' te identificeren. Barrières zoals beperkte politieke prioriteit voor biodiversiteit, het ontbreken van gestandaardiseerde en effectieve biodiversiteitsmaatstaven en het ontbreken van duidelijke NID-doelstellingen vóór de ontwikkeling bleken belangrijke driving barrières te zijn, wat betekent dat het aanpakken van deze barrières met minimale inspanning meerdere andere barrières voor de implementatie van NID zou kunnen verminderen.
Daarnaast werd een prototypische plug-in voor QGIS ontwikkeld met de naam "NID viewer" om besluitvorming te ondersteunen. Deze plug-in stelt de meest geschikte NID-maatregelen voor een geselecteerd gebouw voor op basis van gebouw specifieke gegevens en locatiegegevens van de omgeving van het gebouw, samen met hun meest relevante barrières. De plug-in werd tijdens een evaluatiesessie beoordeeld door drie deskundigen, die de tool bruikbaar en relevant achtten in de vroege fase van vastgoedontwikkeling. De deelnemers waardeerden de transparantie van de gegevens, maar wezen op het abstracte karakter van sommige barrières en de beperkte reikwijdte tot afzonderlijke gebouwen als belangrijke beperkingen.

Abstract (English)

Nature-Inclusive Design (NID) is gaining more attention as it is an important strategy to enhance biodiversity in the built environment. However, the implementation of NID in real estate development remains limited because of a range of barriers which are not yet fully understood. This research aims to provide a deeper understanding of these barriers and explores how to translate these barriers into relevant information for decision-making processes in early-stage real estate development. The study hereby combined a literature review with expert interviews to identify a list of 18 relevant barriers to NID implementation on building scale. Then, it applied Interpretive Structural Modelling (ISM) and MICMAC analysis to structure these barriers into a hierarchical model to highlight their interdependencies and identify their driving and dependence power. Barriers such as *limited political prioritization on biodiversity*, *lack of standardized and effective biodiversity metrics* and *lack of clear NID targets before development* were found to be key driving barriers, meaning targeting these barriers could reduce multiple other barriers to NID implementation with minimal effort.

In addition, a prototypical plug-in for QGIS named “NID viewer” was developed to support decision-making. It suggests the most suitable NID measures for a selected building based on building specific data and location data of the surroundings of the building, together with its most relevant barriers. The plug-in was evaluated by three experts in the field during an evaluation session, which resulted in the tool being perceived as usable and relevant in early-stage real estate development. Participants did appreciate the transparency of the data, but indicated the abstract nature of some barriers and the scope on single buildings as important limitations.

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1. Introduction

Urbanization is one of the most important causes of environmental change in the 21st century. Where cities are growing and real estate development is expanding, the pressure on ecosystems increases. This leads to fragmentation of habitats and loss of biodiversity in these areas. At the moment, sustainability is becoming more integrated into urban planning, where the needs of non-human species are often still overlooked. This thesis focuses on the concept of Nature-Inclusive Design (NID), which is an approach to integrate biodiversity more in the built environment. The research investigates the barriers which limit the implementation of NID in real estate development on building scale, and explores how information systems can help to address challenges related to NID implementation.

1.1 Problem Definition

The increasing rate of urbanization and the expansion of real estate development have been found to cause a degradation of the environment, resulting in a loss of biodiversity (Grimm et al., 2008; McDonald et al., 2020). The expansion of urban areas is a result of the rapid increase in the growth of the world population. This leads to an increase in pollution and habitat losses, resulting in biodiversity losses (Rogan & Lacher, 2018). The World Economic Forum (2025) ranks biodiversity loss as the second most important long-term global risk, which indicates the importance of the preservation of biodiversity in urban areas to improve sustainability, climate resilience and both mental and physical health for residents (Mcdonald & Beatley, 2021).

Even though the awareness on the importance of biodiversity (including both plants and animals) is increasing, current sustainability rating systems like BREEAM and LEED overlook biodiversity and are more human-centered (Kiss et al., 2025; Oberti & Plantamura, 2017). Nature is often incorporated in urban design via Nature-Based Solutions (NBS), but this is usually done to meet human needs or to solve human-centric problems where the needs of the non-human users are left out, instead of prioritizing the needs of these non-human species (Maller, 2021).

Nature-Inclusive Design (NID), or Biodiversity-Inclusive Design (BID) is an approach which does include local non-human species. It mainly focusses on the preservation of the local biodiversity during the design process (C. Hernandez-Santin et al., 2022). Instead of the NBS strategies which prioritize finding sustainable solutions inspired by nature (European Commission Directorate-General for Research and Innovation, 2015), NID prioritizes the preservation of local species by protecting their natural habitats or by recreating their habitats in urban areas to enable coexistence between humans and nun-human species (C. Hernandez-Santin et al., 2023). However, the concept of NID is often still too much on general biodiversity instead of specific, local non-human actors which are directly involved (Gualtieri et al., 2023).

Even though the ecological and social benefits of NID as mentioned in Section 2.1 and 2.3, the adoption within real estate development remains limited. This is due to various barriers, such as the lack of a clear and unified definition of NID, gaps in policy and regulation, stakeholder uncertainty about implementation in company practices, the confusion of NID with broader biodiversity or Nature-Based Solutions, limited knowledge among stakeholders, the insufficient integration of local non-human actors in design processes, low willingness to pay and lack of budget (Gualtieri et al., 2023; van Haaster-De Winter et al., 2022). In addition, biodiversity is difficult to quantify and monitor and the implementation of NID is often perceived as risky, especially in the private sector where decision-making is shaped by feasibility studies and return-on-investment calculations (Booth et al., 2024; Dijkshoorn-Dekker et al., 2020).

This thesis investigates the barriers that limit the adoption of NID within real estate development on the building scale. By identifying and structurally analysing these barriers using Interpretive Structural Modelling (ISM) and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analysis, the study aims to offer insights into how NID can be more effectively integrated in real estate development. Additionally, this research explores how a GIS-based information system can be used to support decision-making processes related to NID. These systems enable building-specific data-driven suggestions for NID measures, enhancing biodiversity. These suggestions for NID measures are linked to their most relevant barriers. The study thus not only maps the complexity of the barriers, but also provides a practical tool to support developers in early-stage decision making regarding the integration of NID.

1.2 Research Questions

In order to address this, the research question of this study is formulated as follows:

"*What are the barriers to Nature-Inclusive Design in early-stage real estate development on building scale and how to develop an information system to effectively inform the strategic decision-making processes?".*

To answer the main research question, four sub-questions are developed to guide the research:

1. "What are the key barriers to implementing Nature-Inclusive Design in construction projects?"
2. "How are barriers to Nature-Inclusive Design perceived by professionals in the real estate development sector?"
3. "What are the relationships between the barriers, and which barriers are of higher importance?"
4. "How to translate the systemic understanding of the barriers into policy regulations and strategic decision-making processes, using information systems?"

The research was conducted in collaboration with the consultancy company 'Brink Management/Advies', active in the Dutch real estate and construction sector with expertise in project and process management. The expert interviews in this study were mainly be conducted with professionals from partner organizations which have worked together with Brink Management/Advies.

1.3 Research Design

This research consists of two parts, where both parts contribute to supporting the integration of NID real estate development on building scale. The first part consists of a structural analysis of the barriers to NID adoption, where an ISM and MICMAC analysis is used. This approach uses both qualitative and quantitative approaches, where it maps relationships between the barriers which were identified in literature review and expert interviews. In the expert interviews, the experts validated the barriers and identified their interrelationships. The ISM method was used to create a hierarchical model of the barriers, where the MICMAC analysis was applied to assess the driving and dependence power of each barrier where they are classified according to their influence on the system.

The second part of this study involves the development of a tool supporting decision-making. The tool was created in the form of a QGIS plug-in, named 'NID viewer'. The plug-in aims to assist developers and designers in identifying biodiversity enhancing NID measures specific to their project, linked to their most relevant barriers. The relevance of the barriers per NID measures, are based on the results of the second expert interviews. The plug-in uses public available GIS datasets to retrieve the needed building and location specific data in order to suggest suitable NID measures together with its barriers. In doing so, it bridges the gap between abstract strategies and concrete design decisions.

A connection can be made between the results of the ISM and MICMAC analysis and the NID viewer plug-in. where the most important barriers linked to the suggested NID measures in the NID viewer plug-in may be related to other barriers displayed in the ISM and MICMAC analysis. In this way, the analyses effectively complement the results of the NID viewer plug-in. Together, the ISM and MICMAC analysis and the NID viewer plug-in both provide a conceptual framework and a practical tool to better understand and overcome challenges related to NID implementation in real estate development on building scale.

1.4 The Practical / Social and/or Theoretical / Scientific Importance of the Thesis

The global issue of loss of biodiversity which is caused by urbanization and real estate development is causing major environmental challenges. By focusing on Nature-Inclusive Design (NID), this research explores how real estate development can be improved to preserve biodiversity in urban areas. The theoretical and scientific importance of this research lies in the lack of structured prioritization and relational analysis of the enablers/barriers in existing literature. This research does provide insights in the relationships between the enablers/barriers and their relative importance, by using a systematic modelling approach. In addition, the NID viewer was created as a tool in the form of a QGIS plug-in. The plug-in supports the users in decision-making for suitable NID measures on a selected building and to explore the their barriers, bridging the gap between theory and application.

The social importance of this research lies in addressing the global issue of biodiversity loss caused by urbanization and real estate development. The practical importance lies in the currently limited application and understanding of NID in practice and in the lack of instruments to support decision-making processes regarding NID implementation. By combining structural analysis with the interactive QGIS plug-in, this research provides a practical framework to support decision-making processes on the implementation of NID measures. The insights in relationships within the barriers and their relative importance offers a guide for private actors and public authorities to more effectively stimulate the use of NID in real estate development. The NID viewer plug-in makes these insights more accessible and applicable within projects and decision-making processes.

1.5 Reading Guide

This thesis consists of five main chapters.
Chapter 1 introduces the context and the scope of the study, the motivation for conducting the research and the research questions and objectives. It ends with this reading guide.
Chapter 2 presents the theoretical background with an in-depth literature review. It explores the concept of NID, its relevance in real estate and sets a first list of barriers to NID implementation. It further introduces the ten NID measures used for the NID viewer plug-in, and it ends with the identification of research gaps.
Chapter 3 outlines the methodology and presents the results. First, the approach for the expert interviews and the application of the ISM and MICMAC analysis are explained. These approaches were used to structure the barriers identified in the expert interviews. Second, the development of the NID viewer plug-in is explained, followed by the expert evaluation of the plug-in.
Chapter 4 discusses the results of both the ISM and MICMAC analysis and the expert evaluation of the plug-in in relation to the literature, where it indicates the strengths, limitations and practical implications.
Chapter 5 concludes the thesis by summarizing the main findings, addressing their scientific and societal relevance and providing recommendations for follow-up research.

2. Literature review

In order to better understand the current state of NID in real estate development and the barriers of its implementation, this chapter presents a comprehensive literature review. The literature review provides the theoretical foundation for this study where it defines the concept of NID, presents the ecological urgency for the preservation of biodiversity in urban areas and explores the application within the real estate sector. It also presents barriers to NID implementation found in scientific literature, discusses ten different NID measures and it concludes by identifying the key research and practical gaps this thesis aims to address.

2.1 Introduction and Context

Urbanization and real estate development have been found to majorly drive a change in the environment, which mostly causes a degradation of the environment. This change in the environment leads to a loss of biodiversity in the area (Grimm et al., 2008; McDonald et al., 2020). In this research, the concept biodiversity includes both plants and animals. A rapid increase in the world population causes the expansion of urban areas. This leads to an increase in pollution and habitat losses, resulting in biodiversity losses (Rogan & Lacher, 2018). A 2010 assessment using the 'relative Mean Species Abundance of originally occurring species' (MSA) indicator found that population sizes of native species in Dutch ecosystems had been reduced by approximately 85% compared to their estimated sizes in a natural, undisturbed situation (CLO, 2016). This decline is significantly larger than the estimated reductions in native species in Europe (approximately 60%) and worldwide (approximately 30%) (CLO, 2016).

Biodiversity losses are considered as second most important long-term (10 years period) global risk as it weakens ecosystems by causing irreversible damage and it has social and economic consequences (World Economic Forum, 2025). This indicates the importance of the preservation of biodiversity in urban areas where cities which include nature are more sustainable, resilient to extreme weather events and improve both the mental and physical health of residents (Mcdonald & Beatley, 2021). In addition to these sustainability and well-being benefits, the inclusion of nature and biodiversity in urban areas can also contribute to cooling cities (saving energy), filtering water, enhancing air quality and capturing carbon (Humphrey et al., 2025).

The increase of the world population is expected to continue in the upcoming years, representing a real challenge for real estate development where innovative approaches are needed to integrate nature with urban landscapes to minimize and restore biodiversity losses in these areas (Simkin et al., 2022). Most of contemporary design planning theory has a more human-centered approach (Houston et al., 2018). Even when nature is used in design planning (e.g. in the form of Nature-Based solutions), nature is used by the designer for human needs or to solve human-centric problems without considering the needs of the non-human users (Maller, 2021). Maller (2021) suggests a more-than-human thinking approach and in order to move Nature-Based solutions beyond anthropocentrism.

In contrary to carbon reduction, for which internationally recognized targets and measurement methods exist, such concrete and widely applicable standards for improving biodiversity are lacking

(Layman et al., 2024). Even though there are clear biodiversity goals set for 2050[1], together with 2030 targets to achieve these in the Kunming–Montréal Global Biodiversity Framework's (KMGBF), actionable biodiversity objectives are still lacking in real estate development (Convention on Biological Diversity, 2022; Kiss et al., 2025). Practices and policies need to be drastically changed to achieve the 2050 biodiversity goals from the KMGBF (White et al., 2024).

2.2 The Definition of NID

Standard sustainability rating systems such as BREEAM and LEED only incorporate environmental considerations, where their focus is primarily on sustainability through categories like energy, water efficiency, indoor environmental quality and site sustainability while it often does not include specific requirements on biodiversity (Kiss et al., 2025; Oberti & Plantamura, 2017). This often results in biodiversity being treated as an externality or biodiversity being used for aesthetics, without ecological function. Nature-Inclusive Design (NID) is an innovative more-than-human approach which integrates nature with real estate, where it does not only rely on human-centered design, but on a biodiversity-centered design (C. Hernandez-Santin et al., 2022). This means that in NID, the preservation of local biodiversity as the non-human users of the location is specifically prioritized in the design. This is contradictory to classic design methods which usually leave biodiversity-enhancing potential out of the design if it does not service the human need (Ahern et al., 2014).

In this article, the term NID has been chosen even though other terms might have (somewhat) the same meaning (like biodiversity inclusive design, nature positive design, regenerative design, etc.). At the same time, research from Gualtieri et al. (2023), states that based on a literature review on classical participatory design and NID, that the concept of NID is still evolving and needs to be better integrated in new and existing designs. The focus is still too much on general biodiversity, not centralizing the directly involved non-human actors (animals, plants) in the direct environment.

To ensure clarity, it is important to clearly state the definition of NID beforehand. In this article, the definition of NID is based on the article from C. Hernandez-Santin et al. (2023), which states that "NID is a collaborative process that intentionally positions local biodiversity as the non-human users of place to inform design thinking and decision-making." In this approach, the preservation of local species is prioritized by protecting their natural habitats or by recreating their habitats in urban areas for the species to coexist with humans. This is also where it differs from Nature-Based Solutions in design. Nature-Based Solutions prioritize maintaining the value of nature and are designed to be resilient, energy-efficient and locally adapted. The concept stands out by focusing on finding sustainable solutions inspired by nature itself (European Commission Directorate-General for Research and Innovation, 2015). While Nature-Based Solutions often focus on broad ecosystem services and climate resilience, NID specifically prioritizes integrating biodiversity within the built environment to support the survival of local species.

[1] The four global biodiversity goals for 2050, as adopted in the Kunming-Montréal Global Biodiversity Framework: (1) Ecosystems and Species Conservation; (2) Sustainable Use and Nature's Contributions to people; (3) Fair and Equitable Benefit Sharing; and (4) Means of Implementation.

2.3 Sectoral Perspectives on NID in Real Estate

2.3.1 NID in the Real Estate Sector in General

NID is an approach that integrates ecological principles and biodiversity goals into the design, construction and utilization phase of real estate projects. Within the real estate sector, particularly in urban areas and at the building scale, NID is increasingly seen as necessary compared to traditional design practices which often neglect biodiversity and ecological systems.

Biodiversity planning does succeed best when integrated with other goals, so one of the primary objectives of NID in real estate development is the integration of biodiversity goals (Ahern et al., 2014). In other words, NID should be an integral part of development processes to restore or enhance biodiversity in urban areas and to create biodiversity resilient areas. This includes supporting local ecosystems, restoring habitats for flora and fauna and improving the connectivity between different urban green spaces (Birkeland, 2022; C. Hernandez-Santin et al., 2023). Next to the enhancement of ecosystems and biodiversity, NID also contributes to the climate adaptation goals, reduction of urban heat island effects and water retention (Monti, 2020). Another important aim of NID next to ecological and biodiversity gain, are the co-benefits of NID for humans. NID seeks to create areas where species coexist with humans, where NID is also likely to enhance aesthetic and recreational value for humans. Next to species biodiversity in an area, enhanced aesthetics and connection with greenery promotes human health and mental well-being (Gualtieri et al., 2023; C. Hernandez-Santin et al., 2023; Pearlmutter et al., 2020). This makes NID a very important strategy for cities and developers aiming to implement more resilient and sustainable urban areas for both humans and non-humans. These general principles of NID apply to both public and private sectors, but their implementation pathways, motivations and perceived barriers may differ depending on the type of stakeholder involved.

2.3.2 NID in the Private Real Estate Sector

In terms of application, NID in the private real estate sector can take various forms of NID measures. The most common types are measures on building scale like green roofs, green façades and nesting spaces for birds and bats (Gemeente Amsterdam, 2018). These measures are mostly tailored to the building's specifications, location and surrounding landscape. Even though these measures on building scale seem relatively small in scale, their cumulative impact across multiple developments can have major impacts on biodiversity gains, especially when implemented systematically across a neighbourhood or urban area. Projects incorporating NID are usually seen as future-proof, adding long-term value to the building next to aligning with environmental regulations and sustainability certificates (Senanayake et al., 2024).

However, even though NID comes with its benefits for biodiversity and has positive side-effects for humans, the adoption to NID in the private sector is still limited in many parts of the world including the Netherlands. Design decisions within the private real estate sector are mainly shaped by feasibility studies, risk assessments and return-on-investment calculations, where NID implementation is still perceived as risky because of its perceived high costs and uncertainty about long-term returns (Booth et al., 2024; Dijkshoorn-Dekker et al., 2020; Mattijssen et al., 2023; van Haaster-De Winter et al., 2022; White et al., 2024). Where monitoring and measuring biodiversity has often been found complex since biodiversity indicators and metrics are often underpowered, biodiversity is vulnerable to omission in the design stage (Bowen-Jones, 2024; Humphrey et al., 2025; Purvis, 2025; Senanayake et al., 2024). For private actors, unclear rules and the lack of financial and

knowledge incentives are also significant barriers (Luxton et al., 2024; Mattijssen et al., 2023). As a result, NID is often left out in the early design stages.

2.3.3 NID in the Public Real Estate Sector

In the public real estate sector, NID implementation is guided by spatial planning on larger scale and environmental policy goals. Municipalities and other public authorities often play an important role in setting the preconditions for the adoption of NID, for example by embedding biodiversity goals into zoning plans, sustainability regulations or local incentives.

In contrary to private actors, public authorities are not always limited by feasibility studies, risk assessments and return-on-investment considerations (Mattijssen et al., 2023; Senanayake et al., 2024). They are able to include biodiversity goals in long-term plans to make urban areas more resilient in terms of biodiversity. However, the implementation of NID in the public real estate sector still encounters barriers like fragmented responsibilities in policy departments, lack of political prioritization for biodiversity and lack of standardized and effective biodiversity metrics (Layman et al., 2024; Mahmoud et al., 2025; Russo, 2025). Furthermore, public actors can play an important role in creating demonstration projects using NID, adjusting permitting frameworks or by supporting biodiversity awareness among citizens and developers. This shows that public authorities play a key role in stimulating and expanding the implementation of NID by other stakeholders.

2.4 Common Barriers of NID in the Real Estate Sector

2.4.1 Categorized NID Barriers According to Literature

An extensive literature research has been performed to set a first list of most common barriers of NID in the real estate sector. There has been made no distinction between public and private sector barriers here. The complete list of barriers with its references is shown in Table 1, where they were also allocated to 7 categories.

Table 1: Complete list of barriers with its references

Category	Barrier	References	Citation Count
Community and Stakeholder Engagement	Low community engagement and acceptance	(Davies & Tippler, 2024; Humphrey et al., 2025; Mahmoud et al., 2025; Pretty et al., 2025)	4
	Other preferences than ecological gain	(Davies & Tippler, 2024; Thornhill et al., 2025)	2
	Lack of interdisciplinary cooperation	(Russo, 2025)	1
	Fixed mindsets	(Humphrey et al., 2025)	1
Knowledge, Capacity and Design Tools	Lack of a clear and unified definition of NID	(Birkeland, 2022; Booth et al., 2024; Luxton et al., 2024; White et al., 2024; zu Ermgassen et al., 2022)	5

	Limited knowledge and data	(Dijkshoorn-Dekker et al., 2020; C. Hernandez-Santin et al., 2022; Kandel & Frantzeskaki, 2024; Layman et al., 2024; Luxton et al., 2024; Mattijssen et al., 2023; Pierce et al., 2024; Purvis, 2025; Senanayake et al., 2024; Thomson et al., 2022; Thornhill et al., 2025; van Haaster-De Winter et al., 2022; White et al., 2024; zu Ermgassen et al., 2022)	14
	New concept NID not yet recognized as a distinct discipline	(Gualtieri et al., 2023)	1
	Limited understanding of NID benefits	(Monti, 2020)	1
	Lack of biodiversity objectives in rating schemes	(Kiss et al., 2025)	1
	Greenwashing of results because of conceptual misuse and misinterpretation	(Booth et al., 2024; Layman et al., 2024; Luxton et al., 2024; Pretty et al., 2025)	4
Strategic Planning and Corporate Integration	Gap between planning and implementation of NID	(Bowen-Jones, 2024; Pierce et al., 2024; Thornhill et al., 2025; van Haaster-De Winter et al., 2022)	4
	Business model and market misalignment	(van Haaster-De Winter et al., 2022; White et al., 2024)	2
	Lack of corporate collaboration	(Booth et al., 2024)	1
	Lack of corporate transparancy on biodiversity loss	(Senanayake et al., 2024)	1
	Competing priorities	(C. Hernandez-Santin et al., 2022)	1
	Biodiversity offsetting off-site	(L. Hernandez-Santin et al., 2025; Humphrey et al., 2025; Kiss et al., 2025)	3
	Lack of clear NID targets before development	(L. Hernandez-Santin et al., 2025)	1
	NID perceived as risky since it is new and untested	(Booth et al., 2024; Dijkshoorn-Dekker et al., 2020; Mattijssen et al., 2023; van Haaster-De Winter et al., 2022; White et al., 2024)	5
	Long-term implementation challenges	(Kandel & Frantzeskaki, 2024; Luxton et al., 2024)	2
Policy and Regulatory Instruments	Limited political prioritization on biodiversity	(Layman et al., 2024; Pierce et al., 2024; Russo, 2025; Senanayake et al., 2024; Thomson et al., 2022)	5
	Fragmented responsibilities over policy departments	(Mahmoud et al., 2025; Mattijssen et al., 2023)	2
	Weak governance	(Humphrey et al., 2025; Luxton et al., 2024; Russo, 2025; Senanayake et al., 2024; Thornhill et al., 2025)	5
	Weak post-construction monitoring and enforcement	(Kiss et al., 2025; Thornhill et al., 2025)	2
	Regulatory gaps and inertia	(Birkeland, 2022; Mattijssen et al., 2023)	2
	Enforcement loopholes and exemptions	(Kiss et al., 2025; zu Ermgassen et al., 2022)	2
Financial and Market Instruments	Cost-related constraints	(Luxton et al., 2024; Russo, 2025; White et al., 2024)	3
	Lack of funds or rewards for biodiversity models	(Mahmoud et al., 2025; Mattijssen et al., 2023; Purvis, 2025)	3
	Low customer willingness to pay for NID	(van Haaster-De Winter et al., 2022)	1

	Perceived profitability and revenue challenges of NID	(Dijkshoorn-Dekker et al., 2020; Mattijssen et al., 2023; Stoeckl et al., 2025; van Haaster-De Winter et al., 2022)	4
	Risk of market shift	(Booth et al., 2024)	1
	Profit oriented private development often lack biodiversity aspects	(Monti, 2020)	1
Metrics, Monitoring and technological limitations	Lack of standardized and effective biodiversity metrics	(Bowen-Jones, 2024; Humphrey et al., 2025; Layman et al., 2024; Pierce et al., 2024; zu Ermgassen et al., 2022)	5
	Different biodiversity priorities in frameworks	(Pierce et al., 2024; Senanayake et al., 2024)	2
	Biodiversity is hard to measure and monitor	(Kandel & Frantzeskaki, 2024; Purvis, 2025; Senanayake et al., 2024; White et al., 2024; zu Ermgassen et al., 2022)	5
	Technological limitations to measure biodiversity	(Booth et al., 2024; C. Hernandez-Santin et al., 2022)	2
	Technical limitations for NID on building level (especially on green roofs)	(Bouw Adaptief, n.d.)	1
Design Standards and Approaches	Anthropocentric and human-centered standards	(Gualtieri et al., 2023; C. Hernandez-Santin et al., 2022; Monti, 2020; Paoliello et al., 2024; Thomson et al., 2022)	5
	Design conflicts between species needs (human and non-humans)	(Gualtieri et al., 2023; Monti, 2020)	2

2.4.2 Community and Stakeholder Engagement

This category includes both the engagement of stakeholders in decision-making processes and the underlying preferences and behavioural tendencies influencing these decisions. The most frequently reported barrier in this category is *Low community engagement and acceptance*. This barrier includes among other things a public resistance to urban biodiversity trade-offs due to inconveniences like allergens, species which come along with pests and nuisance of insects (Humphrey et al., 2025). In addition to this, compared to the urgency of ecological transformation, the communal support for NID is usually relatively low (Pretty et al., 2025). Furthermore, the level of citizen participation in NID processes is also low in most areas (Mahmoud et al., 2025).

Another barrier belonging to this category is other preferences than ecological gain in real estate development, causing ecological gain to not be prioritized. This barrier contains aesthetic preferences which is often prioritized over ecological gain (Thornhill et al., 2025), where there are also often cultural biases towards more charismatic species or mammals over ecologically beneficial species (Davies & Tippler, 2024; Thornhill et al., 2025).

What also is frequently lacking, is an interdisciplinary cooperation between ecologists, urban planners, architects, engineers and technologists (Russo, 2025). The engagement of the multiple stakeholders is essential here to align ideas and collaborate effectively to integrate biodiversity into real estate development. NID has a much higher change of being effective with these stakeholders collaborating because of the knowledge they can share about real estate development and biodiversity in certain areas. Another barrier in this category which often occurs according to the literature is the fixed mindsets and resistance to change among industry actors which remain deeply embedded (Humphrey et al., 2025). These attitudes and behaviours of the involved stakeholders could hinder the uptake of new concepts like NID.

2.4.3 Knowledge, Capacity and Design Tools

The most occurring barrier regarding knowledge, capacity and design tools was the lack NID knowledge and data among both public authorities and private sector actors, which has been found in 14 articles. This barrier is mainly explained by a limited access to ecological/scientific knowledge regarding NID (Dijkshoorn-Dekker et al., 2020; C. Hernandez-Santin et al., 2022; Kandel & Frantzeskaki, 2024; Layman et al., 2024; Luxton et al., 2024; Mattijssen et al., 2023; Pierce et al., 2024; Purvis, 2025; Senanayake et al., 2024; Thomson et al., 2022; Thornhill et al., 2025; van Haaster-De Winter et al., 2022; White et al., 2024; zu Ermgassen et al., 2022), but also by a lack transparency of the available NID data and a lack of employee skills or capacity because of a shortage of NID knowledge (Senanayake et al., 2024; zu Ermgassen et al., 2022). A lack of NID knowledge often leads to the omission of NID in real estate development, as it is perceived to increase project risks or include high costs for outsourcing.

Another barrier regarding this category which occurred frequently in the literature is the lack of a clear and unified operational definition of NID, which leads to uncertainty about the concept of NID (Birkeland, 2022; Booth et al., 2024; Luxton et al., 2024; White et al., 2024; zu Ermgassen et al., 2022). This uncertainty is likely to cause misuse of NID in real estate development and thus wrong implementation which is called greenwashing. This greenwashing of the NID results because of conceptual misuse and misinterpretations of the definition is also found to be a barrier according to the literature, where this kind of greenwashing may be intentional or unintentional (Booth et al., 2024; Layman et al., 2024; Luxton et al., 2024; Pretty et al., 2025). The greenwashing barrier is strongly related to the barrier *lack of a clear and unified definition of NID*, where the result of greenwashing because of a lack of a clear and unified definition of NID is usually only unintentional greenwashing.

Other barriers occurring in the literature related to this category include that the concept of NID is not yet widely recognized as a distinct discipline since NID is relatively new and is still evolving (Gualtieri et al., 2023), the limited understanding of the true benefits of NID among designers (Monti, 2020) and the lack of biodiversity objectives in rating schemes, where 85% of the Green Building Rating Schemes (e.g. BREEAM or LEED) lack biodiversity goals since their primary focus tends to lie on broader sustainability themes like energy efficiency and indoor climate (Kiss et al., 2025).

2.4.4 Strategic Planning and Corporate Integration

This category includes the barriers regarding to strategic planning and corporate integration, where systemic changes are heavily dependent on corporate policies and internal governance. When these are poorly designed or implemented insufficiently, several barriers may arise. The most occurring barrier in the literature from this category is that NID is often perceived as risky since the concept is relatively new and untested, coming with uncertainties around the outcomes in terms of actual biodiversity gains and potential profits or losses (Booth et al., 2024; Dijkshoorn-Dekker et al., 2020; Mattijssen et al., 2023; van Haaster-De Winter et al., 2022; White et al., 2024).

Next to NID being perceived as risky, it has also been found that there often is a gap between NID planning and the actual implementation of a NID because it is often not known how to bridge the intentions of the usage of NID with the actual implementation (Pierce et al., 2024; Thornhill et al., 2025; van Haaster-De Winter et al., 2022). This often goes hand in hand with a lack of a clearly communicated ambitious strategic plan for biodiversity goals, causing the gap between planning and implementation of NID (Bowen-Jones, 2024). Another barrier which seems quite similar to the barrier

regarding the gap between NID planning and implementation, is the barrier lack of clear NID targets before development. But where the barrier *gap between NID planning and implementation of NID* is mainly focussing on implementing the NID itself, the barrier *lack of clear NID targets before development* is mainly focussing on the lack of initial biodiversity assessments or targets before real estate development.

Lack of corporate transparency on biodiversity loss has also been found to be a barrier according to the literature, where there is no obligation for organizations to disclose information about the negative impact of its real estate development on biodiversity in the direct environment. If there was an obligation to disclose this information about harming the direct environment, organizations are more likely to limit this harm to the environment (L. Hernandez-Santin et al., 2025).

A barrier in this category which may not seem to be a barrier at first, is biodiversity offsetting off-site. This means that when an area is developed without the usage of NID, this lack of NID is compensated with biodiversity offsetting on other locations than the site. This is perceived as a barrier, since the local biodiversity on and around the site is still harmed (L. Hernandez-Santin et al., 2025; Humphrey et al., 2025; Kiss et al., 2025).

The other three barriers found in the literature which belong to this category are a lack of corporate collaboration, where there is a lack of incentives for systemic collaboration between companies for biodiversity outcomes (Booth et al., 2024), that because of competing priorities in real estate development like financial profit and aesthetic performance, biodiversity gain is not chosen as a priority (C. Hernandez-Santin et al., 2022) and the long-term implementation challenges which come together with NID, like the long timescales for ecosystem recovery causing a misalignment between business timelines and ecological restauration durations, and the long-term maintenance which is needed for nature-inclusive buildings (Kandel & Frantzeskaki, 2024; Luxton et al., 2024).

2.4.5 Policy and Regulatory Instruments

Policy and regulatory instruments can serve as powerful enablers for change when correctly designed and implemented. Yet, when this is not the case they can also create significant barriers. One of these barriers is that the political prioritization on biodiversity is limited (Pierce et al., 2024). This is explained in the literature by a lack of statutory planning policy for biodiversity gains (Senanayake et al., 2024; Thomson et al., 2022), where it leaves the integration of biodiversity largely voluntary. Moreover, general biodiversity targets equivalent to carbon targets are not on the political agenda (Layman et al., 2024), and smart city models often neglect biodiversity (Russo, 2025) illustrating that biodiversity gain is not a political priority.

It has also been found that governance regarding biodiversity goals is weak, with a lack of direction, clarity and enforcement and misalignments between policy and corporate actions (Humphrey et al., 2025; Luxton et al., 2024; Russo, 2025; Senanayake et al., 2024; Thornhill et al., 2025). Due to the weak governance, this misalignment between policy and corporate actions persists without any consequences for these organizations. Weak governance is also found just in post-construction monitoring and enforcement which often is weak or absent, forming a barrier itself (Kiss et al., 2025; Thornhill et al., 2025).

Governance responsibilities have also been found to be fragmented over different departments, with unclear responsibilities for green space management (Mahmoud et al., 2025; Mattijssen et al., 2023).

This fragmentation results in departments and institutions operating in their silos with distinct visions, goals, legal frameworks and ways of thinking (Sarabi et al., 2020).

In addition, regulatory gaps and inertia also act as a barrier, referring to the shortage of adequate rules and regulations for NID (Mattijssen et al., 2023) and the delay in NID uptake once implemented (Birkeland, 2022). Another related barrier to this category is enforcement loopholes and exemptions, where there is a resistance to legislation from high-impact sectors (zu Ermgassen et al., 2022) and often highly developed sites get exemptions from biodiversity requirements (Kiss et al., 2025).

2.4.6 Financial and Market Instruments

Financial and market instruments can play a crucial role in facilitating NID implementation in real estate development, since NID measures usually come with its additional costs. Cost-related constraints regarding NID measures already forms a barrier itself, including high transaction and administrative costs (Luxton et al., 2024), the general perception of NID costs being high (White et al., 2024) and budget constraints often faced by local governments, limiting green space expansion (Russo, 2025). The high transaction costs of NID measures are often caused by the need for intensive coordination between multiple stakeholders, complex permitting procedures and extended consultation processes raising the overall cost and effort required to implement NID (Luxton et al., 2024). Next to these cost-related constraints, NID often is also linked to profitability and revenue challenges in real estate development because there is a lack of business models to translate NID into financial profit (Mattijssen et al., 2023; van Haaster-De Winter et al., 2022), a lack of prospective revenue models for nature-inclusive construction (Dijkshoorn-Dekker et al., 2020) and markets tend to prioritize profit over ecological benefit, unless tightly regulated (Stoeckl et al., 2025).

A great measure to overcome the cost-related constraints of NID measures would be funds or rewards for biodiversity models. If NID costs are perceived as high, a lack of funds or rewards for biodiversity models could be perceived as a barrier, where there is simply a lack of funding streams for biodiversity models where NID elements are not rewarded in environmental labels, or the funding streams are unclear (Mahmoud et al., 2025; Mattijssen et al., 2023; Purvis, 2025).

A low customer willingness to pay for NID could also be a barrier (van Haaster-De Winter et al., 2022), next to profit oriented private development which often lacks biodiversity aspects because it restricts spatial flexibility (Monti, 2020) and a risk of market shift, where positive actions by one company regarding NID might shift harm elsewhere (Booth et al., 2024).

2.4.7 Metrics, Monitoring and Technological Limitations

Measuring and monitoring biodiversity is really important for the evaluation of the successes of NID. If NID does not result in a local biodiversity gain, it is not correctly implemented. But biodiversity itself is hard to measure and monitor since it is multi-dimensional and scale-dependent (Purvis, 2025; Senanayake et al., 2024), existing biodiversity reports are often weak (Kandel & Frantzeskaki, 2024; Senanayake et al., 2024; zu Ermgassen et al., 2022) and monitoring biodiversity outcomes correctly can be costly (White et al., 2024).

A lack of standardized and effective metrics for biodiversity also impedes measuring the successes of NID in real estate development. At the moment, existing biodiversity indicators and metrics are often underpowered and complex (Bowen-Jones, 2024; Humphrey et al., 2025; Pierce et al., 2024), and

there are no standardized widely accepted metrics, but a fragmentation of biodiversity metrics (Layman et al., 2024; Pierce et al., 2024; zu Ermgassen et al., 2022).

There are several frameworks related to biodiversity, but they often have different biodiversity priorities (Senanayake et al., 2024). Variability in how cities prioritize biodiversity indicators could be one cause of this (Pierce et al., 2024). This lack of consistency makes it difficult to compare or align biodiversity efforts across regions.

Technological limitations could also hinder NID implementation. Current technologies for measuring biodiversity are still limited (Booth et al., 2024; C. Hernandez-Santin et al., 2022). There could also be technical limitations for NID at the building level, where green roofs for instance cannot be applied to roofs with an angle higher than 35 degrees or where the load-bearing capacity of the roof is limiting the possibilities of NID implementation (Bouw Adaptief, n.d.).

2.4.8 Design Standards and Approaches

Finally, current design standards and approaches shape how biodiversity is included or excluded in certain areas. Current design standards remain anthropocentric and human centered (Gualtieri et al., 2023; C. Hernandez-Santin et al., 2022; Monti, 2020; Paoliello et al., 2024; Thomson et al., 2022). An example is participatory design tools, which are primarily built for humans, limiting direct engagement with non-human actors (Gualtieri et al., 2023).

When designing for both human and non-human actors, design conflicts between their needs of could occur because of the different needs between human and non-human actors (Gualtieri et al., 2023). A great example is the preference of humans for light implementation in urban areas, while this light pollution affects nocturnal species like bats (Monti, 2020).

2.5 NID Measures

2.5.1 Selection and Categorization of NID Measures

Pearlmutter et al. (2020) explains the possibility of green implementation on three different levels: green building materials, green building systems and green building sites. In this research, we only focussed on NID implementation on the green building system level as explained by Pearlmutter et al. (2020), which means only NID implementations on the building envelope are considered. Building materials and the building site are left out of the scope. According to this scale, ten NID measures applicable on the building envelope are selected. These were selected from “Natuurinclusief bouwen en ontwerpen in twintig ideeën: Handboek voor stedenbouwers, ontwerpers, architecten, landschapsarchitecten en ontwikkelaars”, which is a manual from the municipality of Amsterdam containing 20 different NID measures ideas to apply on buildings and public space (Gemeente Amsterdam, 2018). The ten chosen options are applicable both in new construction and renovation contexts.

The ten selected NID measures on building level can be categorized into façade-based NID measures, roof-based NID measures and ground-based NID measures. The façade-based NID measures include built-in nesting stones for birds, bat enclosures and insect hotels. These NID measures aim to directly support local species. A green façade can also be added to this category, which added greenery indirectly supports local species. Roof-based NID measures include three types of green roofs, brown

roofs, and water roofs. The green roof types are extensive green roofs (thin layer of green), intensive green roofs (wide variety in greenery) and nature roofs (mix of extensive and intensive). These different roof types provide combined benefits of biodiversity support, water retention and thermal regulation. Ground-based NID measures include only façade gardens on building scale, which are small strips on the ground with plants adjacent to the building façade. Figure 1 displays these NID measures in the built-environment (Gemeente Amsterdam, 2018). Only the NID measures on building scale are displayed in the legend.

Figure 1: NID measures in built-environment

2.5.2 Façade-Based NID Measures

Nesting stones are special built-in nests in the façade of a building, used to attract and protect urban bird species to support biodiversity. They can be visible or hidden in the façade. There are different nesting stones for different kinds of birds, where it is important to use the right nesting stones for the local species occurring in the environment. The local species depend the size and height of the needed nesting stones, the distance to other nesting stones, the location on the façade and if a clear

flight path is needed to the entrance (so no trees or other obstacles in the way). The environment around the nest may also be important, where some birds to need tall green plants in the environment which can make it more difficult to effectively use nesting stones.

Bat enclosures are special built-in enclosures in the façade of a building which provide shelter for bats. The enclosures can be made visible or almost invisible, where they are built in the cavity wall. Built-in bat enclosures are often preferred, since they offer better conditions for bats. In some cases, open joints between bricks and gaps in buildings are also used by bats, so these can also be left open on purpose. It is important to take into account the bat species occurring in the environment, since they favor different kinds of height for the enclosures. Furthermore is it important that the enclosures are not placed on the southwest side of the building, and not above windows.

Insect hotels are built in insect stones or holes in the façade to support bee and butterfly populations. These are vital insects for ecosystems and human food supply, as they are responsible for around 60% of the pollination of our fruit and vegetables. These insect hotels and stones can be used both in existing buildings and in newly developed buildings. It is important for them to be placed on the sunny southwest side of the building, and to protect them from wind and rain. It is also important to have native nectar and pollen-rich plants in the direct environment of the insect hotels and stones.

Next to improving local biodiversity, green facades also isolate buildings and help reduce heat island effects in urban areas. In summer, it helps to cool buildings by providing shade and by evaporation, where in winter it reduces heat loss. Green facades provide food, shelter and nesting spaces for birds, bats, insects and plants. Because the greenery grows vertically, it adds many square meters of green without occupying much ground space. Green facades can be combined with bird nesting boxes made of stone or wood. It is important to choose the plant species depending on the sun or shade orientation of the façade.

2.5.3 Roof-Based NID Measures

Green roofs add value to the environment by providing space for biodiversity, recreation and water management. It offers habitat space for insects, birds, bats and native plants, while it also stores rainwater, reduces heat and lowers the rooftop temperature which improves efficiency of solar panels. A green roof can be installed on both new and existing buildings, where there are three types of green roofs: extensive green roofs, intensive green roofs and nature roofs. These different kinds of green roofs are used as separate NID measures. Extensive green roofs are roofs with a thin layer of soil, planted with moss, sedum and sometimes herbs or grasses. These kind of roofs are lightweight and require little maintenance. Intensive green roofs consist of a deep substrate layer, which supports all kinds of plants like grasses, herbs and even small trees. They do offer the highest ecological and recreational value, but they also require strong roofs and regular maintenance. Nature roofs are a combination of extensive and intensive green roofs, where the soil layers vary in thickness. These varying thickness supports diverse plant and animal species. Each type of green roof contributes differently to biodiversity.

Next to the three types of green roofs, brown roofs or water roofs are also roof-based NID measures. Brown roofs are covered with sand, gravel and recycled rubble. These roofs are designed to support biodiversity and store rainwater. It replicates dry, open habitats and is especially suitable for birds that nest on sandy terrains. There are no strict rules for brown roofs. The more sand, gravel and rubble, the better.

Water roofs are flat rooftops designed to store rainwater temporarily. This helps cooling the building, it supports local biodiversity and it acts as a water buffer. The stored water attracts insects which attract bats, and it can serve as drinking water for birds. A water roof with water plants or a helophyte filter can also support fish to keep the water clean by eating algae and insects. It can also be combined with intensive green roofs, to combine both ecological benefits.

2.5.4 Ground-Based NID Measure

Façade gardens are small strips on the ground with plants adjacent to the building façade. These façade gardens support local biodiversity and connect green spaces in the city. It provides food, shelter and nesting opportunities for birds, bats, insects and for hedgehogs. It can be discussed whether they belong to the building envelope, but they are included here since they are the only measure which supports ground life like hedgehogs and since they are so close to the building façade. The small garden strips also help with rainwater infiltration in the soil. Façade gardens can be combined with nesting stones and insect hotels and stones for species which require greenery in the surroundings.

2.6 Research Gap

So far, studies on the adoption of NID in real estate development have been done through literature reviews, case studies and stakeholder engagement through interviews. These qualitative thematic approaches are primarily exploratory and interpretive, relying on qualitative methods and sometimes supplemented by quantitative methods like surveys and regression analysis. These studies have primarily focussed on exploring and interpreting individual factors in specific contexts, where they do not provide a systematic understanding of how these factors influence one another. This results in a research gap where a structured prioritization and a relational analysis of the barriers is lacking. In this study, this research gap is addressed by instead of a thematic approach, applying a systematic modelling approach to map the relationships between the barriers. This approach offers strategic insights which can better support the decision-making processes in the implementation of NID. Also, previous research into the adoption of NID in real estate development on building scale is limited, where it is mainly focussed on public sector area development.

In this study, extensive literature research in combination with interviews with experts are performed first to identify the barriers to NID in real estate development. Then, Interpretive Structural Modelling (ISM) is used to identify the relationships within the barriers. This was done in combination with Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) to analyse the driving and dependence power of the barriers. With the driving and dependence power of the barriers it is possible to more deeply assess the impact of each barrier and classify all barriers separately into four categories (according to driving power and dependence power). The ISM and MICMAC analysis is a well-known and well-established systematic modelling approach to identify barriers in different studies (Attri et al., 2013). Using the ISM and MICMAC analysis to identify the relationships within barriers of NID in real estate development has not been done before. The ISM and MICMAC analysis on the barriers of NID can provide a better understanding of the relationships within the barriers. The ISM model and dependence power diagram (constructed by MICMAC) in this study can help to understand these complex relationships. This can guide companies and public authorities in finding solutions to effectively stimulate NID in real estate development by overcoming the most important barriers.

Next to the analytical research gap as described here, there also is a clear practical gap where a decision-making tool is missing which gives developers an integrated overview of the barriers they are likely to face for specific NID measures at the building scale early in the real estate development process. Existing instruments are lacking the bridge between suggesting NID measures and showing the possible barriers related to these NID measures as there is a lack of clear NID measure-specific barriers in early stages, a lack of actionable guidance and clarity on NID and a lack of widely accepted standards for biodiversity integration (Booth et al., 2024; Dijkshoorn-Dekker et al., 2020; Layman et al., 2024). The tools often do not show the measure-specific potential barriers, are not project-specific, are not on building scale or do not automatically give an overview of what is suggested and what not together with its barriers. As a result, decision-makers cannot match NID measures to a project context in a transparent way together with their most probable barriers.

In order to address this practical research gap, a NID plug-in in QGIS has been developed which suggests building specific NID measures from a report of Gemeente Amsterdam (2018) on a selected building on a map. The NID measures are suggested on the basis building specific data of the selected building and data of its surroundings. The barriers related to the NID measures are based on results of the expert interviews. Experts are asked in the first interview to rate the relevance of the different barriers on the 10 NID measures from Gemeente Amsterdam (2018) (nesting stones for birds, bat enclosures, extensive green roof, green façade, etc.) on a scale from 1-5 (where 1 is not relevant at all, and 5 is very relevant). This ensures the plug-in to be evidence-based as it combines literature and expert judgement to create barrier relevance profiles for each NID measure. In the end, the ISM and MICMAC models created can then be used on the barriers shown with the suggested NID measures to find out to which other barriers these barriers in the NID plug-in are related, their level of importance and to classify the barriers based on their driving and dependence power.

3. Research Methodology and Results

This chapter describes how the research has been designed, how the data was collected and analyzed and how the methods were chosen to contribute to answering the research questions. The research process is explained in detail here in order to achieve transparency and so that the study can be understood, replicated and evaluated. The study combines qualitative and quantitative research methods in the ISM and MICMAC analysis, together with the development of a prototypical QGIS plug-in in order to address the research question: "*What are the barriers to Nature-Inclusive Design in early-stage real estate development on building scale and how to develop an information system to effectively inform the strategic decision-making processes?*". To answer the main research question, sub-questions are developed to guide the research. (1) "What are the key barriers to implementing Nature-Inclusive Design in construction projects?" This is done by extensive literature research in order to create a list of barriers. Then, interviews with experts in the field are conducted to validate the list of barriers and to refine the list where needed. (2) "How are barriers to Nature-Inclusive Design perceived by professionals in the Dutch real estate development sector?" Experts review the refined list, and rate the importance of each barrier by a Likert scale. (3) "What are the relationships between the barriers, and which barriers are of higher importance?" Partitioning of levels is then used to establish the importance level of each barrier, and sub-divide the barriers among importance levels regarding the implementation of NID in real estate development. (4) "How to translate the systemic understanding of the barriers into policy regulations and strategic decision-making processes, using information systems?" The study here investigates how the results can be used in the field to support the implementation of NID in real estate development. Also, a plug-in in QGIS was created as a tool to suggest suitable NID measures early in the real estate development process, together with their most important barriers.

3.1 ISM and MICMAC Analysis

The steps taken for the ISM and MICMAC analysis are shown in Figure 2, and are based on an ISM and MICMAC analysis performed by Sarabi et al. (2020). In the first step, the qualitative research consists of the collection of primary and secondary data in order to set the list of barriers for the quantitative research in the next steps. The secondary data collection consisted of an extensive thematic literature research to set a first list of barriers. 27 articles were selected in this way via the search engines Google Scholar and Scopus using this search query: ("nature-inclusive design" OR "biodiversity-inclusive design" OR "design for nature" OR "nature-positive") "biodiversity". Another 3 articles (of which 2 are grey literature) were added with exploratory research. In the primary data collection, experts in the NID field are interviewed to validate and refine the list of barriers found in the literature.

The goal of the quantitative research is to map the relationships between the barriers (step 2) and rank the barriers itself by using a systematic modelling approach (step 5). The data for the quantitative research in step 2 was gathered by a second interview, where the participants define the relationships between the barriers. The ISM and MICMAC analysis in step 7 and 8 is then used to create a visual model to show the relationships between the barriers and the ranking of the barriers.

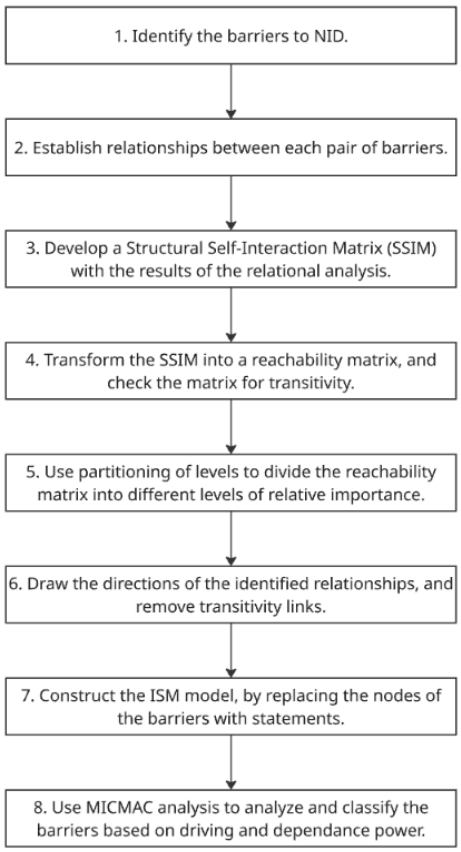

Figure 2: Research Design ISM and MICMAC analysis

3.1.1 Identify the Barriers to NID

As explained in Section 3.1, the secondary data for this research is collected first by an extensive literature research. With this extensive literature research, a first list of 38 barriers to use NID in real estate development has been set, which is shown in Table 2. Primary data has been collected by taking this list of 38 barriers into the first interview round with 9 experts. The experts were contacted by mail, and were mainly partner organizations which have worked together with the company Brink Management/Advies, which is the company with which this research was carried out.

The complete interview of round one can be found in Appendix A. In order to collect some background information, the experts were asked first what their function is, how long they have experience in the field of NID and give a short explanation of a relevant NID project they are working on or have worked on. Each of the experts has at least 4 years of experience in the field of NID and they all work for different companies with functions varying from architects, project developers, project managers, plan developers and project advisors. The participants were selected based on their involvement in real estate development projects and their experience with NID principles. Part of the interviews were conducted in person, and part of the interviews were conducted online via Microsoft Teams.

The first interview round is sub-divided into two parts, where part II is data collection for the QGIS plug-in which is discussed in section 3.2.1. In part I, the list of 38 barriers from the literature is shown to the experts. Each of the barriers is treated one by one, where first the category of the barrier is mentioned together with an explanation to make sure the barrier is well understood. Then, the participant is asked if this barrier is relevant in real estate development and on building scale. This is

in order to filter out irrelevant barriers to this research, and since ISM can only contain 15-25 variables in order to for the model to not be overcomplicated (Attri et al., 2013). The barrier is then either coloured green or red. Green when the barrier is identified as relevant, red when the barrier is identified as irrelevant. When a barrier is identified as relevant by more than half of the experts, so five times, the barrier is considered as relevant and taken to the second interview round. The 19 barriers which were indicated as relevant by five or more experts are shown in Table 2 together with the frequency they were identified as relevant. The complete barrier table with frequencies from the first interview round is shown in Appendix B.

Table 2: The 19 remaining barriers after the first round of interviews, frequency border at 5

Nr:	Barrier	Frequency
1	Competing priorities	9
2	Cost-related constraints	9
3	Greenwashing of results because of conceptual misuse and misinterpretation	9
4	Lack of funds or rewards for biodiversity models	9
5	Design conflicts between species needs (human and non-humans)	8
6	Lack of biodiversity objectives in rating schemes	7
7	Anthropocentric and human-centered design standards	7
8	Fragmented responsibilities over policy departments	7
9	Lack of corporate transparency on biodiversity loss	6
10	Other preferences than ecological gain	6
11	NID perceived as risky since it is new and untested	6
12	Lack of clear NID targets before development	6
13	Limited understanding of NID benefits	5
14	Weak governance	5
15	Gap between planning and implementation of NID	5
16	Limited political prioritization on biodiversity	5
17	Lack of standardized and effective biodiversity metrics	5
18	New concept NID not yet recognized as a distinct discipline	5
19	Different biodiversity priorities in frameworks	5

3.1.2 Establish Relationships Between Each Pair of Barriers

The second round of interviews builds upon the barriers presented in Table 2. Since the barriers ‘Competing priorities’ and ‘Other preferences then ecological gain’ are so much alike, these barriers are merged from now on, so the second interview continues with 18 barriers. A segment of the second interview is shown in Appendix C. In this round, each barrier is once individually positioned on the left side of the sheet. The experts are then asked whether they see a relationship between the left-side barrier and each of the barriers listed on the right side. This process is repeated until every barrier has been on the left side once, where the relationship is only assessed in one direction: from left to right. To ensure clarity, each barrier is briefly reintroduced and explained again before the experts evaluate the relationships. For this round, six people were interviewed, five of whom had also participated in the first interview round. The remaining participants from the first interview round were either unavailable for the second interview round or did not respond. The extra person added is a sustainability consultant, which is just added to the second round to collect just a little more data.

3.1.3 Development Structural Self-Interaction Matrix (SSIM) and Transformation into Reachability Matrix

After the second round of interviews, each of the interviews were transformed in a Structural Self-Interaction Matrix (SSIM). This has been done by using the symbols V, A, X and O of which their meaning is described in Table 3. Each of the SSIMs of the second interview round is shown in Appendix D. All 6 SSIMs were then merged into one single SSIM. This was done using majority vote as the primary method. However, in cases of ties or results marked as 'X', the researchers own interpretation was applied. This was done because ties cannot be transformed into a reachability matrix, and too many 'X's in the SSIM would result in only one level of relative importance in the ISM, which is undesirable. The final merged SSIM is shown in Table 4. The number of pairs of barriers is calculated with the formula: $\big((n) * (n-1)\big)/2$, with n referring to 18, which is the number of barriers. This resulted in 153 pairwise comparisons being addressed.

Table 3: Symbols used in SSIM and their meaning

Symbol	Meaning
V	Variable i affects variable j
A	Variable j affects variable i
X	Variable i and variable j affect each other
O	Variable i and variable j are unrelated/ no relation between variables i and j

Table 4: Merged SSIM

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1		A	V	A	A	A	X	X	A	A	A	A	O	V	A	A	X	X
A2			O	X	O	O	V	A	V	X	V	X	A	O	A	O	A	O
A3				O	O	A	A	A	A	A	A	X	O	O	A	A	A	A
A4					V	A	X	A	A	V	V	A	A	O	A	V	X	V
A5						O	X	O	O	A	A	A	A	O	A	O	A	A
A6							X	A	V	V	V	X	A	O	A	X	A	A
A7								A	V	A	X	X	A	O	V	V	X	O
A8									O	V	V	V	A	O	V	V	V	V
A9										O	O	V	A	O	A	O	A	O
A10											V	X	A	A	A	A	X	A
A11												A	A	X	A	A	A	A
A12													A	O	X	A	X	V
A13														O	X	V	X	V
A14															O	O	O	O
A15																V	X	V
A16																	A	V
A17																		V
A18																		

For the ISM and MICMAC analysis, the SSIM then must be transformed into an initial reachability matrix. The transformation of the SSIM into the initial reachability matrix has been done according to the rules in Appendix E, where the symbols are transformed in binary numbers 0 and 1. The initial reachability matrix is shown in Appendix F. For further analysis, RStudio has been used in combination with the ISM package. The initial reachability matrix in an Excel file has been given as

input in R, which checks the initial reachability matrix for transitivity. Transitivity is a basic assumption which states that if i is related to k and k is related to j, then i is necessarily related to j. After checking for transitivity, the final reachability matrix has been given as an output which is shown in Table 5. The grey cells are the ones added by transitivity, where the ones in the white cells are the direct relationships from the SSIM.

Table 5: Final reachability matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
A2	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
A3	1	1	1	1	1	1	0	0	0	1	0	1	0	0	1	1	0	0
A4	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
A5	1	0	1	1	1	1	1	1	0	1	1	0	0	1	0	0	1	1
A6	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1
A7	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1
A8	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1
A9	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1
A10	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1
A11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A13	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1
A14	1	1	1	1	1	1	1	0	1	1	0	0	0	1	0	0	0	0
A15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A16	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1
A17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A18	1	0	1	1	1	1	1	1	0	0	0	1	0	1	0	0	1	1

3.1.4 Partitioning of Levels

The partitioning of levels step was also conducted in RStudio, and is explained in this section. Partitioning of levels is carried out in order to establish the relative importance in levels of each barrier to using NID design in real estate development, specifically on the building scale. The barriers are assigned to levels using Roman numerals, where barriers at level I have the least relative importance, and the higher levels are the most structurally significant, which means they influence many other barriers.
For each barrier (or variable), three sets are calculated:

The Reachability Set (R): All barriers that the given barrier can influence (reach row-wise)
The Antecedent Set (A): All barriers that can influence the given barrier (reach column-wise)
The Intersection Set (R ∩ A): The set of barriers which are common to both the Reachability and Antecedent Sets.

After establishing these sets, the barriers for which the Reachability set is equal to the Intersection set (R = R ∩ A) are assigned to the current level or relative importance. These first assigned barriers are considered to have no further influence on any other unassigned barriers and are thus assigned to a relatively lower level of relative importance (I or close to I). When the barriers are assigned to a level, they are removed from the matrix and the process is repeated for the remaining barriers. This iterative process continues until all barriers are assigned to a level.

The partitioning of levels output from RStudio where the three sets are calculated are shown in Appendix G. The levels of the barriers as result of the partitioning of levels are shown in Table 6.

Table 6: Levels of the barriers, and the quadrants based on driving and dependence power in MICMAC analysis

Level	Barriers	Tag	Quadrant
I	Competing priorities/Other preferences than ecological gain	A1	III
	Greenwashing of results because of conceptual misuse and misinterpretation	A3	II
	Lack of funds or rewards for biodiversity models	A4	III
	Design conflicts between species needs (human and non-humans)	A5	II
	Lack of biodiversity objectives in rating schemes	A6	II
II	Anthropocentric and human-centered design standards	A7	III
	Lack of corporate transparency on biodiversity loss	A9	I
	Different biodiversity priorities in frameworks	A18	II
III	Cost-related constraints	A2	III
	NID perceived as risky since it is new and untested	A10	II
	Lack of clear NID targets before development	A11	IV
	Limited understanding of NID benefits	A12	III
IV	Fragmented responsibilities over policy departments	A8	IV
	Weak governance	A13	I
	Gap between planning and implementation of NID	A14	II
	Lack of standardized and effective biodiversity metrics	A16	IV
V	Limited political prioritization on biodiversity	A15	IV
	New concept NID not yet recognized as distinct discipline	A17	III

3.1.5 Final ISM Model Construction

After determining the levels of relative importance for the barriers, the ISM model was constructed. In step 6 from Figure 2, the directional relationships were drawn based on using the final reachability matrix from Table 5, and transitive links were removed in order to maintain visual clarity of the ISM model. In this way, only direct causal relationships between barriers remain in the model. The ISM model with all relational arrows generated by RStudio is shown in Appendix H.

In step 7 from Figure 2, the numbered tag notes (A1-A18) were replaced with their full barrier statements, so that the representation of the final ISM model is easily readable. The final ISM model is displayed in Figure 3. At the top of the model, the five barriers *Competing priorities/Other preferences than ecological gain* (A1), *Greenwashing of results because of conceptual misuse and misinterpretation* (A3), *Lack of funds or rewards for biodiversity models* (A4), *Design conflicts between species needs* (human and non-humans) (A5) and *Lack of biodiversity objectives in rating schemes* (A6) are shown in level I, which are identified as the barriers with the least relative importance. The barriers *Limited political prioritization on biodiversity* (A15) and *New concept NID not yet recognized as distinct discipline* (A17) at the bottom belong to level V, and these barriers are identified as the barriers with the highest relative importance and thus highest structural significance. The remaining barriers are located in level II, III or IV between level I and V.

The arrows in Figure 3 show the direct relationships between the barriers. It can be concluded that all barriers in each level are directly related, and each barrier of a lower level is directly affected by a barrier of a higher level, and indirectly affected by many other barriers of higher levels.

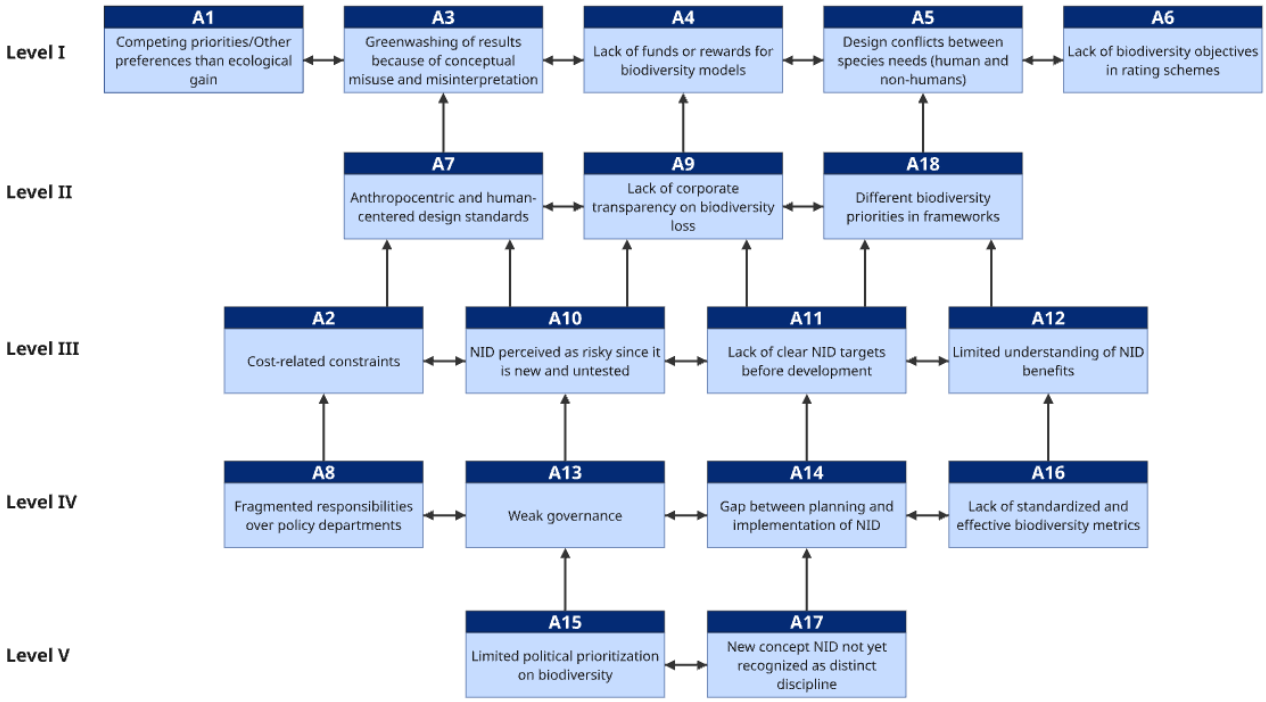

Figure 3: Final ISM model for NID barriers, sub-divided in 5 levels of relative importance

3.1.6 MICMAC Analysis

Finally, the MICMAC analysis (Cross-Impact Matrix Multiplication Applied to Classification, in French 'Matrice d'Impacts Croises Multiplication Appliqúe an Classment') is performed (Attri et al., 2013). Where the ISM model presents relationships and the hierarchy of the barriers based on their structural significance, the MICMAC analysis complements the ISM model by analyzing the driving and dependence power of each barrier. The driving power refers to the total number of other barriers (including the barrier itself) that this barrier influences. It is calculated by summing the values in the row corresponding to that barrier in the final reachability matrix. The dependence power refers to the total number of barriers on which the given barrier depends, and is calculated by summing the values in the corresponding column of the final reachability matrix. The driving and dependence power of the final reachability matrix are shown in Appendix I. The ISM and MICMAC analysis together provide a clearer understanding of how the barriers to NID implementation interact.

According to the driving and dependence power of the final reachability matrix, the MICMAC analysis in Figure 4 was constructed. The eighteen barriers are sub-divided in four categories, explained in Table 7.

Table 7: Barrier categories MICMAC analysis

Category	Explanation
Autonomous barriers (Quadrant I)	With low driving and dependence power, these barriers are relatively disconnected from the system. They do not strongly influence by other barriers, but are also not significantly influenced by others. As such, they may be context-specific, of low priority or not structurally significant in the broader barrier landscape.
Dependent barriers (Quadrant II)	Dependent barriers do not influence many other barriers, but are on the other hand strongly influenced by other barriers. Addressing them directly may have limited effect, unless their underlying causes are also targeted.
Linkage barriers (Quadrant III)	These barriers are both heavily influenced by other barriers and strongly influence other barriers. They are highly dynamic and unstable. Changes in these barriers can cause the whole system to change, but they are also sensitive to changes elsewhere. Because of this, they require careful management and attention.
Driving barriers (Quadrant IV)	Driving barriers have a strong influence on many other barriers while being relatively unaffected by others. It is important to address these barriers, because solving them can help reducing multiple dependent or linkage barriers. They often appear at the lower levels of the MICMAC analysis.

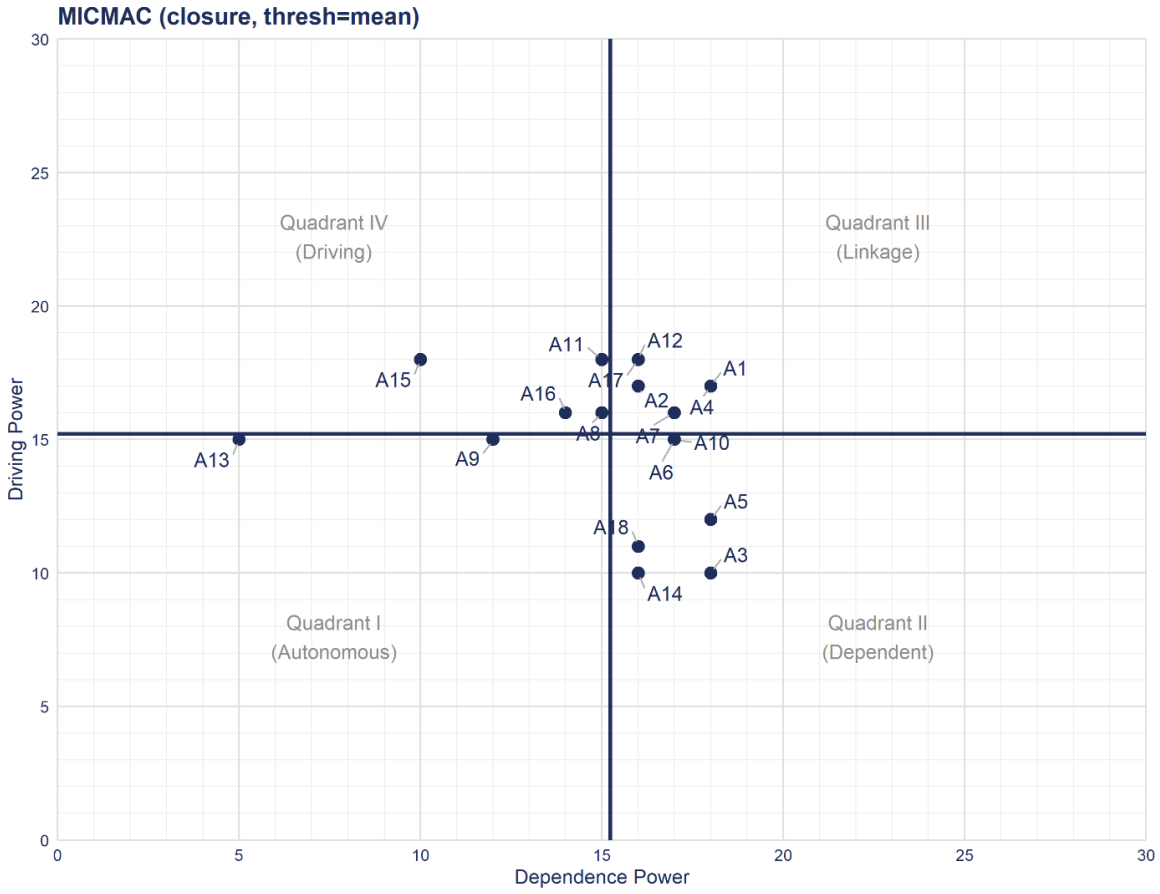

Figure 4: MICMAC analysis

Part of the ISM and MICMAC analysis is the comparison of the position of the barriers in the MICMAC analysis in Figure 4 with the levels the barriers are in in the ISM model in Figure 3. The barriers A15 and A17 which are located at the bottom in the ISM model in Figure 3 belong to the highest level These barriers are according to the ISM model identified as the barriers with the highest relative importance and thus highest structural significance. In the MICMAC analysis in Figure 4, we see A15 located in Quadrant IV, and A17 in Quadrant III, showing that A15 is likely to directly affect A17 and affect the barriers in level IV directly and indirectly via A17. The barrier A17 is likely to be affected by A15 but not much since it has not a really high dependence power (it is located close to the Y-axis). With its driving power, A15 also directly affects the other barriers in level IV. Both of these barriers match their position in the MICMAC analysis with the assigned level in the ISM model. The consistency in both methods confirms their critical role in the system, suggesting that targeting these barriers could lead to significant positive changes.

The barriers A1, A3, A4, A5 and A6 are on top in the ISM model in the lowest level, indicating they have the lowest structural significance and thus do not influence other barriers, but are influenced directly and indirectly by many other barriers. In the MICMAC analysis, A1 and A4 are located in Quadrant III, and A3, A5 and A6 are located in Quadrant II. This means that A3, A5 and A6 are influenced by other barriers, but do not influence many other barriers which matches their position in level I in the ISM model. The barriers A1 and A4 suggesting they are moderately influenced by other barriers according to the MICMAC analysis, but are also indicated to strongly influence other barriers. This does not match their assigned level in the ISM model, as level I barriers are not expected to be able to change the whole system by changing them. This difference shows how some barriers may be more influential in one model than in the other. This indicates the need for integrated interpretation of both the ISM and MICMAC model to ensure a more complete decision-making.

The barriers A2, A10, A11 and A12 assigned to level III in the ISM model which is the mid-level. These barriers can be located anywhere in the MICMAC analysis. A11 is located in Quadrant IV, A2 and A12 are located in Quadrant III A10 is located in Quadrant II. This indicates barrier A11 to not be affected by others while it heavily influences the other barriers, barrier A2 and A12 are both influenced heavily by other barriers and do influence other barriers, where barrier A10 is heavily influenced by others but does almost have no effect on other barriers. This distribution of the mid-level barriers across multiple quadrants shows the complexity of their role, where they often serve as mediators within the system. Because of this role as a mediator, they could offer strategic entry points for intervention when direct access to the driving barriers is limited.

Still, barriers from Quadrant II are connected with directional links to other adjacent barriers in the ISM model, where the same holds for barriers connecting with other Quadrant II or even Quadrant I barriers. This may seem contradictory at first, but this can be explained by the nature of both methods. Where the ISM model focuses on hierarchical structure and shows even limited direct influence through directional links, the MICMAC analysis quantitatively assesses the total number of direct and indirect influences (driving power) and dependencies (dependence power) for each barrier. Therefore, even barriers with a low overall driving power (as seen in the MICMAC analysis, such as A3 and A5) can still appear as influencers in the ISM model if they have any influence on other barriers. The ISM model does not show the strength or number of relationships, only that the relationship is present. This observation shows the importance of interpreting the results of the ISM model and MICMAC analysis together, instead of just on levels in the ISM model or quadrant positions.

The ISM and MICMAC analysis lays the foundation for strategic interpretation of the barriers to NID implementation. By categorizing the barriers based on driving and dependence power, the analysis

reveals where targeted interventions may have the greatest impact on the system. As explained in the discussion (chapter 4), this distinction helps both policymakers and private actors to understand which barriers to address first, and how these relate to broader decision-making challenges in NID implementation.

3.2 Prototypical QGIS Plug-in

In order to suggest suitable NID measures for real estate development early on in the process together with its related barriers, a prototypical tool was developed as a plug-in in the software QGIS. QGIS is a free and open-source Geographical Information System for viewing, editing and analysing geospatial data, which supports a wide range of vector, raster and database formats. QGIS version 3.40.5 (Bratislava) was used during the development of the plug-in (QGIS Development Team, 2025). The plug-in works on the basis of BAG, public green space, tree, insolation time and irradiation-irradiance data as shown in Figure 5. These datafiles are added as layers in QGIS. According to this building specific and location data, the plug-in suggests suitable NID measures on building scale for real estate development, together with its relevant barriers. The data about the relevance of the barrier per NID measure was achieved in the first interview with the experts as well, where the experts were asked to rank the relevance per chosen barrier on 10 different NID measures from 1-5, where 1 means 'not relevant at all', and 5 means 'very relevant'. The results of the ISM and MICMAC model could be useful as well here, where it could explain possible relationships of the barriers of the suggested NID measures with other barriers which are not mentioned.

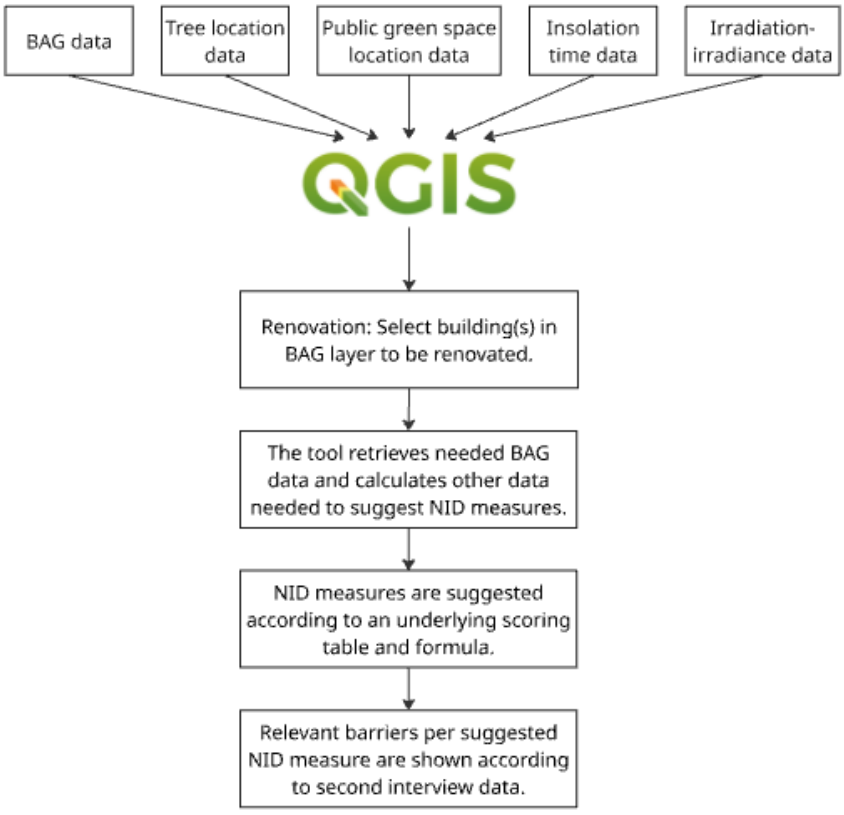

Figure 5: Workflow of GGIS NID viewer plug-in

3.2.1 Identify Relevance of Barriers per NID Measure

In order to identify the relevance of the selected barriers per NID measure, the first interview was sub-divided into two parts as indicated in Section 3.1.1. Part II of this interview is also shown in Appendix A. In this part, the barriers indicated as relevant in part I of this interview, are placed in the first column of a table. The headers of the other columns are the 10 NID measures as from Section 2.5. The experts were then asked to rank the relevance of each barrier for each of the NID measures on a scale from 1-5. 1 means 'not relevant at all', where 5 means 'very relevant'.

All 9 participants from the first interview round also participated in this part II. Per barrier, the answers of the participants were put in a table. Then, the mean of the answers of all of the participants per barrier has been taken to calculate the relevance of this barrier per NID option. The results of part II are given by the means of all participant answers per barrier in Appendix J, and these are the results used in the plug-in for the selection of the top 3 barriers per NID option, where the three barriers with the highest score for this NID measure are chosen. These results thus lay the foundation for the three most relevant barriers per NID measure in the plug-in, making it possible to deal earlier and more effectively with these barriers when implementing certain NID measures. The discussion (chapter 4) examines more in detail how this link can support policy and design decisions.

The results for the separate barriers 'Competing priorities' and 'Other preferences than ecological gain' were merged here by again taking the means of the numbers for both barriers, since these barriers are merged based on their similarity. The results for part II of interview one for these barriers separate are shown in Appendix K. These results were carefully compared, and because these results were not strongly divergent, the results of this interview could be safely merged.

3.2.2 Introduction to Data Layers in QGIS

The goal of the plug-in is to suggest building specific NID measures together with its potential barriers early on in the process of real estate development. The plug-in distinguishes between renovation and new construction, where the prototype focusses on developing the renovation part. The renovation part has been chosen over new construction here because there is much more existing real estate than new construction. Renovation volume is growing faster due to outdated housing stock and strict sustainability goals.

For the plug-in to be functional, the plug-in has to be building specific in order to see which NID measures can be physically applied on the building, and location specific in order to see which NID measures fit in the environment best. For renovation, this was done by selecting a building polygon in QGIS on the BAG map. Hereby, building specific data can be retrieved from the BAG dataset and the location of the building can be determined. When the location of the building is determined, location specific data according to public green spaces, trees, insolation time and irradiation-irradiance be retrieved as well. The idea for the new construction part is the same, where the location of the new construction must be selected on a map. When these coordinates are known, the location specific data can be retrieved. Only the building specific data must be manually filled in, since no BAG data is available for buildings which are not yet built.

The *BAG dataset* used for this plug-in is the 3DBAG dataset (specifically BAG3D:lod22), which is a dataset developed by the 3D geoinformation research group of TU Delft and software developers from 3DGI (Peters et al., 2022). The 3DBAG dataset contains 3D building models of the Netherlands. The building data in 3DBAG consists of a combination of the Building and Adress register of the

Netherlands ('Basisregistraties Adressen en Gebouwen' (BAG)) and the national height model of the Netherlands ('Actueel Hoogtebestand Nederland' (AHN)). The Register of Buildings and Addresses (BAG) is the national open available register of buildings and addresses in the Netherlands. For each address it records attributes such as current function, year of construction and registration status and is regularly updated. It includes several geometry types, where BAG3D only uses the building polygons, where each polygon represents the outlines of a building. The National Height Model of the Netherlands (AHN) is the national open elevation dataset of the Netherlands, used to construct the 3D models of the buildings. LoD2.2 indicates how specific the data is, where LoD2.2 was the most specific of the three available datasets (LoD1.2, LoD1.3, LoD2.2). The 3DBAG data used is in WFS format. The study area of the prototypical is Eindhoven, which is a city in the South of the Netherlands.

The *tree location* and *public green space location data* used were obtained from the open database of the municipality of Eindhoven, from the two datasets 'bomen' (trees) (Gemeente Eindhoven, 2018) and 'openbaar groen' (public green space) (Gemeente Eindhoven, 2017). The trees dataset contains point data of all trees managed by the municipality of Eindhoven. The attributes contain labels such as municipally managed trees, valuable trees and monumental trees. Except for the point locations, the attributes were not used for this study and no additional modification has been done to the dataset. The public green space dataset contains polygon data with an overview of the public green spaces in Eindhoven, excluding solitary trees. It contains location, type of vegetation and management information. In this study only the geometry was used without further modification of the dataset. Analyses were performed on the snapshot downloaded on 2025-07-16, noting that these datasets are updated regularly.

The National Height Model of the Netherlands (AHN) which is also used in the 3DBAG dataset, is used here to create the *insolation time* and *irradiation-irradiance data layers*, with the insolation time in hours/m^2/day, and the irradiation-irradiance in Wh/m^2/day. Because of the AHN data being so large, the data is split up in map sheets. This means that all data in the Netherlands has been divided in rectangles, each covering an area of 6.25km by 5km. These map sheets are easier to download and handle than the whole dataset. For the prototypical plug-in, the map sheets covering Eindhoven were selected and downloaded. The map sheets are open source, and accessible at the website of Actueel Hoogtebestand Nederland (AHN) (2014). A total of eight map sheets were downloaded, where there was chosen for AHN4, the surface model with a 0.5m resolution. An overview of the eight map sheets is shown in Appendix L. In order to generate the insolation time and irradiation-irradiance data layers from the AHN data, QGIS tools were used. First, the r.slope.aspect tool from the GRASS toolbox in QGIS was used to calculate the slope and aspect of each map sheet. The default settings have been used here with the slope in degrees. The slope and aspect layer of each map sheet have then been used together with the AHN map sheet itself as input in the r.sun.insoltime tool, also from the GRASS toolbox. In the r.run.insoltime, also the default settings were used, where the number of the day of the year was set to 1, meaning the insolation time and irradiation-irradiance are calculated on a day at the first of January. These are all generated for each map sheet separately because of the size of the data. In the end, all map sheets of insolation time and irradiation-irradiance data were merged, and clipped over the municipality of Eindhoven to create fully functional data layers as input for the QGIS tool.

3.2.3 QGIS NID Viewer Plug-in Layout and Workflow

The way the renovation option of the plug-in works, is that at first the BAG3D:lod22 Eindhoven layer must be selected in the layer panel, on the left side of the QGIS-interface. The building to be renovated must then be selected from the 3DBAG layer on the map. It is also possible to select a cluster of buildings, by holding CTRL while clicking multiple buildings. The plug-in named 'NID viewer' can then be opened in the plug-in tab in QGIS. This then shows the GUI as in Figure 7, which contains the data from the run of a single selected building. The GUI is built with Qt designer, the visual UI builder which comes with QGIS. The empty GUI of the NID viewer plug-in is shown in Appendix M. On the top of the GUI, the 'type of development' can be selected. As explained already, for this prototypical plug-in, only the renovation function was developed. Then, there is a row where the 'focus on resilience' can be selected and 'how much the specific MF (multi-functionality) factor weights in the score'. These functions are explained in Section 3.2.4.

Under 'building information', general information of the selected building(s) is reported like the number of buildings which are selected. Next to this, the FID and identification of the selected building are displayed, or if a selection of buildings is made, the fid and identification of the first selected building is displayed. The maximum building height is also displayed here, which is retrieved from the 3DBAG dataset.

In the 'roof and façade information' panel, the plug-in retrieves the following data from the 3DBAG dataset: total flat roof area, total slanted roof area, (highest) roof angle, if there is glass roof present, the total exterior façade area from the 3DBAG dataset. Furthermore, the mean insolation time and mean global irradiation was retrieved from the calculated insolation time and irradiation-irradiance dataset, where the mean of the value is taken within the selected building polygon(s). For the free length at the north/east, south/east, south/west and north/west façade, an outward normal of each façade segment was used to assigns the orientation of each façade. Then, the plug-in checks if the façade is adjacent to another building polygon. If not, it measures the free length across the width of the façade, which is reported at the bottom of the 'roof and façade information' panel.

The 'distance to greenery' panel, reports the distance from each façade to the closest public green space or tree, and the minimal distance of the whole building to the nearest public green space or tree. The distance from each façade to the closest public green space or tree which is shown only shows the direct distance. This means that the public green space must be in the direct line of sight of the orientation the façade points to. If the line to the closest public green space or tree is blocked by a building, this distance is not displayed in the panel. This was done for birds, bats and insects, which favor greenery in their direct sight while leaving their potential housing in the façade. For the minimal distance from the whole building to the nearest public green space or tree the Euclidean distance was taken. This explains why the distance from the whole building to the nearest public green space or tree may be shorter than the shortest distance of all façade orientations to greenery.

When the 'Run' button is clicked, the plug-in starts to retrieve the data in the panels, and does suggestions for NID measures on the selected building based on the retrieved building and location data. Figure 6 displays a simplified box workflow of how to work with the plug-in. NID measures can have the same score, and thus share the same position in the rating. Selecting a NID measure in the rating shows the top three potential barriers related to this NID measure, according to the results of interview one part II (Section 3.2.1). If multiple NID measures share the same position in the rating as in Figure 7, a single NID measure at this position can be selected at the right side of the plug-in interface, showing its potential top three barriers. Hovering with the mouse over the NID measures, shows the checks which are performed to calculate the scoring for the NID measure. If a check is met,

the results are colored in green, and when a check is not met the results are colored in red. An example of the NID measure checks from position one in Figure 7 is shown in Appendix N. This visual representation of the checks directly translates technical information into understandable design choices. This transparency contributes to a more reliable tool and more informed choices for biodiversity. This is also confirmed by the evaluations of the NID viewer plug-in, discussed in chapter 4.

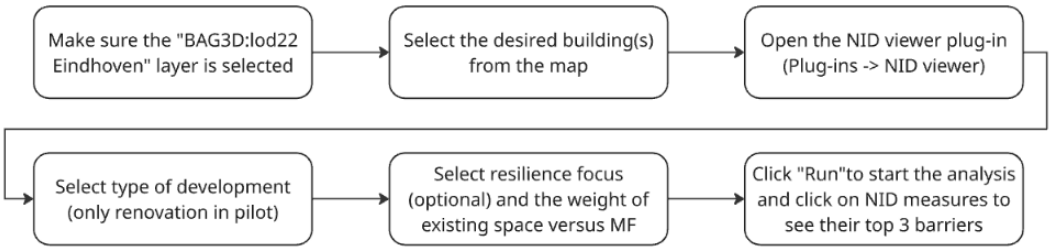

Figure 6: Box workflow working with the NID viewer plug-in

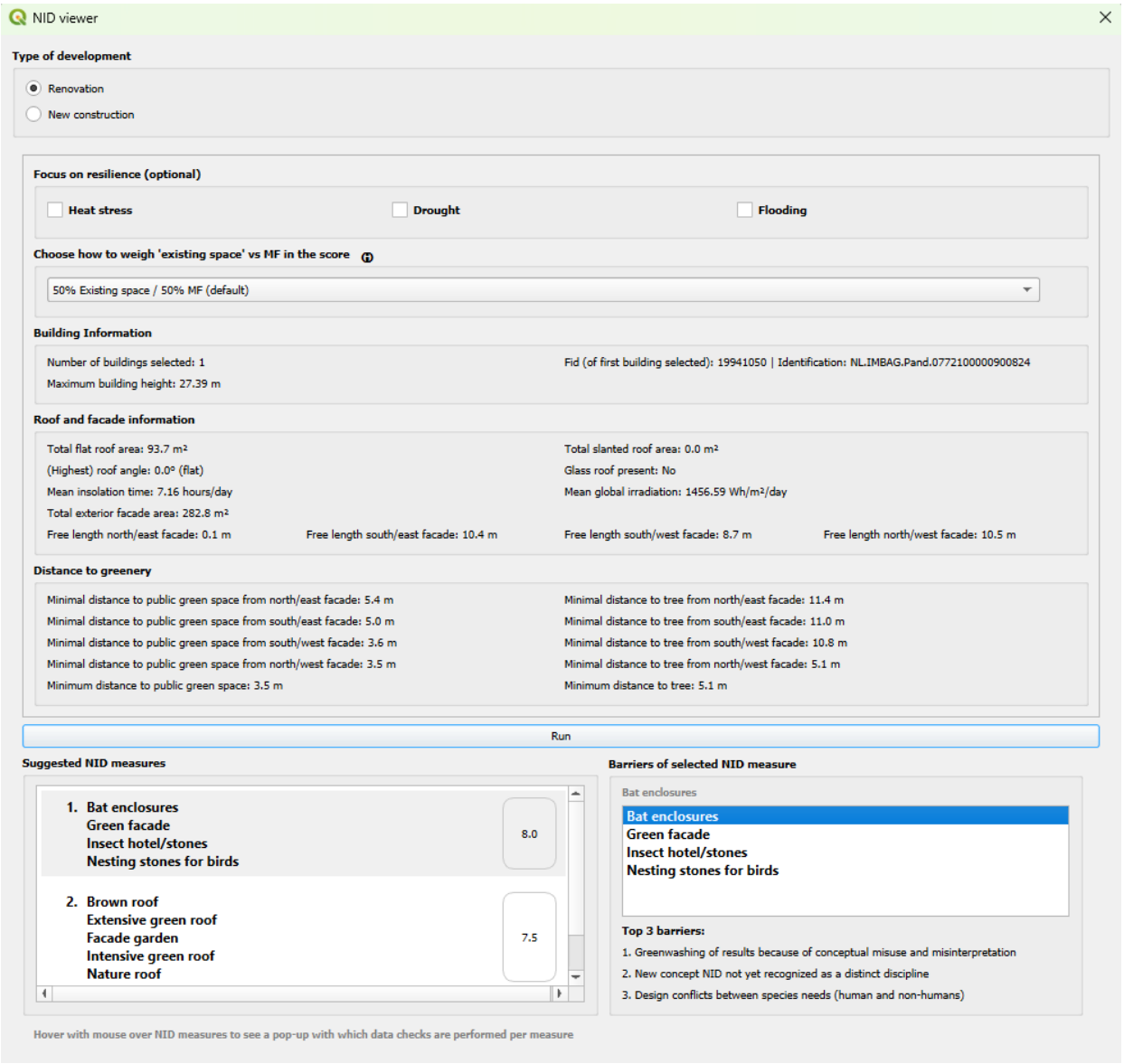

Figure 7: NID viewer GUI containing data from the run for one building

3.2.4 QGIS NID Viewer Plug-in Data Processing

As explained above, the NID viewer plug-in generates NID recommendations by scoring each NID measure using the retrieved building and location specific data. The scoring approach of the NID measures is based on the Deltares Climate Resilient City Tool (CRCTool) (Brolsma, 2022). The Deltares CRCTool calculates a score for the effectiveness of certain measures at the city level, based on their local conditions. It then ranks the measures according to the score. Where the Deltares CRCTool is focused on city level, the NID viewer plug-in operates at the building level. The elements of the Deltares CRCTool used by the NID viewer plug-in are the scores table schema, the soft gate mechanism and the multi-functionality factor combined with the site score in the formula. The scores table defines the checks which are evaluated against the retrieved building and location specific data, resulting in fails or passes to feed the formula and rank the NID measures based on their final scores.

The scores tables used by the NID viewer plug-in are documented in Appendices O1-O4. The scoring table is split into four tables, with one table containing the base checks matrix (Appendix O1), one the bonus for proximity to greenery (Appendix O2), one the values for the multi-functionality factor(Appendix O3) and one the matrices for the effect bonuses heat stress, drought and flooding (Appendix O4). The column headings for the multi-functionality and the effect bonus follow the Deltares CRCTool scores table, since these can also be applied on building scale. For the three measures extensive green roof, green facades and water roof which are present in both the CRCTool and the NID viewer plug-in, the same values were applied for the similar columns in the scores table of the NID viewer plug-in. The scores for the remaining NID measures in the NID viewer plug-in were estimated using the CRCTool values as a reference.

The base checks performed on the building and location data indicate which criteria are relevant for each measure. It contains the binary numbers 0 and 1, where 0 means the NID measure is not applicable and 1 means the NID measure is applicable. For example, for an extensive green roof the base checks matrix sets a 0 for ‘high slope roof (>35°)’, a 1 for ‘low slope roof (≤35°)’, a 1 for ‘flat roof’ and a 0 for ‘exterior façade area ≥50m^{2}’. This shows that an extensive green roof is possible on a flat roof and on a low slope roof, but not on a high slope roof. The outside façade area is irrelevant for the implementation of an extensive green roof. Which check is performed per NID measure is predefined. Table 8 summarizes which checks are performed per measure.

The checks are divided in base checks and soft gate. Base checks are a list of Booleans (true/false), assessing whether each NID measure is suitable for the selected building(s) and site. The soft gate checks whether the NID measure is feasible for the selected building(s), without major modifications. If a feasibility condition is not met for a NID measure because of the building specifications in the soft gate check (for example, an extensive green roof which cannot be applied on a roof with a high slope), the soft gate is set to 0.40. Otherwise, the soft gate is set to 1.00. This designed is used to down-weight NID measures instead of completely excluding them when certain checks are not met (implementation may still be technically possible after substantial changes to the roof, like reconstructing a steep roof to a low-slope or flat roof, which is not favorable but also not impossible).

Table 8: Base and soft gate checks of the NID measures

NID measure(s)	Base checks	Soft gate
Nesting stones for birds	Building height ≥ 3m Free façade at orientation NE/NW	Building height ≥ 3m
Bat enclosures	Building height ≥ 4m Free façade at orientation SW/NE	Building height ≥ 4m
Insect hotel/stone	Free façade at orientation SW/SE	-
Extensive green roof	Roof area ≥ 30m² Roof not glass Roof slope is low (≤ 35°) or flat	Same as base
Brown roof	Roof area ≥ 30m² Roof not glass Roof slope is low (≤ 35°) or flat	Same as base
Intensive green roof	Roof area ≥ 30m² Roof not glass Roof is flat	Same as base
Nature roof	Roof area ≥ 30m² Roof not glass Roof is flat	Same as base
Water roof	Roof area ≥ 30m² Roof not glass Roof is flat	Same as base
Green facade	Any free façade ≥ 3m Exterior façade area ≥ 50m²	Same as base
Façade garden	Any free façade ≥ 3m	Same as base

Following guidelines from the Municipality of Amsterdam (Gemeente Amsterdam, 2018), nesting stones for birds are best placed at the north-east or north-west side of the building to limit solar heating, at least 3 meters above ground level and away from windows. Bat enclosures are preferably mounted on the south-west façade and on the north-east façade for winter enclosures. They are preferably placed at a minimum height of 4 meters above ground level, a maximum height of 50 meters and also away from windows. Insect hotels or stones should be placed on facades at the sunny side of the building, typically the south-east or south-west facades. For birds, bats and insects, nearby vegetation like public green spaces or trees close to their enclosures is advantageous, preferably within 5 meters (Gemeente Amsterdam, 2018). For specific species, deviations from these general guidelines may be necessary.

All roof-based NID measures require a minimum usable roof area of $30m^2$. This minimum has been set, to avoid the NID viewer plug-in to suggest NID measures on roofs which are too small for roof-based NID measures to have a positive effect on the building or environment. It is also required for roofs to not be made out of glass, also not partly. Extensive green roofs and brown roofs can be placed up to a roof angle of 35°, whereas intensive green roofs, nature roofs and water roofs need a flat roof (Bouw Adaptief, n.d.). For façade measures, at least 3 meters of free façade is required, otherwise there is no space for these NID measures. Green façades additionally need a minimum exterior façade area of $50m^2$, also to prevent the NID viewer plug-in to suggest green facades at small façade areas where they would not have any positive effect on the building and it surroundings.

In the NID viewer plug-in, the scores of the suggested NID measures are calculated with the following formula:

$$Score(m) = w_{SpaceType} \times \min\left(10, 10 \times \frac{10 \times \frac{BCTrue_m}{BCTotal_m} \times SoftGate_m \times SolarCheck_m \times Orient_m + Bonus_m}{D_m}\right) + \left(1 - w_{SpaceType}\right) \times MF_m + EffectBonus_m \quad (1)$$

Formula (1) is divided in two components, the existing space component within the brackets, and the component outside the brackets. The existing space type part calculates a 0-10 suitability score indicating whether the current on-building space types (e.g. flat/low slope roof, free façade) are present and appropriate to host the NID measure without creating new space. MF_m is a predefined score for multi-functionality from 0-10, reflecting the potential for other functions on after implementing NID measure m on the location. For instance, a façade with nesting stones for birds retains more options for additional NID measures than a roof converted to a water roof, indicating the MF value for nesting stones for birds would be higher than the MF factor for water roofs. The $EffectBonus_m$ is the additional bonus assigned to the NID measure score when the user selects one of the resilience focusses heat stress, drought or flooding. If no resilience focus is selected, this score is always 0. If a focus is selected, the formula for the selected resilience focus is used, which are formula (2), (3) and (4).

In this formula, m stands for one of the ten NID measures. The parameter $w_{ExistingSpace}$ is the weight of site and MF factor set by the user at the top of the NID viewer tool to balance the site-based score and the multi-functionality (MF) score. By default, $w_{ExistingSpace}$ is set to 0.5. Within the site-based component, $BCTrue_m$ is the number of base checks which are true for measure m. Taking the example of extensive green roof again, if the slope of the roof is higher than 35°, this base check is not met, because according to the scores table the measure extensive green roof needs a low slope or a flat roof. $BCTotal_m$ stands for the total number of base checks for measure m. By calculating $BCTrue_m$/ $BCTotal_m$ for NID measure m, a number between 0 and 1 is given which then stands for the fraction of true base checks satisfied for NID measure m. $SoftGate_m$ is already explained above, where it checks whether NID measure m is feasible for the selected building(s), without major modifications. the value of $SoftGate_m$ is either set to 0.40 or 1.00, depending on the feasibility of NID measure m on the selected building(s). $SolarCheck_m$ is a check only applied to green NID measures. If both the mean insolation time ≥ 4h/d and the mean global irradiation ≥ 1000 Wh/m²/d, the value of $SolarCheck_m$ is set to 1.00. If exactly one is met, the value of $SolarCheck_m$ is set to 0.90, and if none is met the value of $SolarCheck_m$ is set to 0.80. The $SolarCheck_m$ is applied to lower the scores for green NID measures when insolation time or irradiation is insufficient for greenery. For non-green NID measures, $SolarCheck_m$ is always 1.00. $Orient_m$ is a check only applied on the green façade measure. For other NID measures, the value is always 1.00. If there is free facade space at the SW orientation, the value is set to 1.00. For the SE orientation, the value is 0.90, for the NW orientation 0.80 and for the NE orientation it is 0.70. These values are based on the position of the sun for greenery to reflect the usefulness of the green façade for cooling. $Bonus_m$ is a proximity bonus for nesting stones for birds, bad enclosures and insect hotels/stones when there is greenery/trees present within 5m of the façade. D_m is a normalizing denominator to keep the site based score on a 0-10 scale. For the NID measure nesting stone for birds, bat enclosure and insect hotel/stone D_m is set to 11 because of the extra $Bonus_m$. For the other NID measures, D_m is set to 10.

The formula for the heat stress bonus is as follows:

$$EffectBonus_{heat}(m) = \min\left(1,\ w_c \frac{cooling_m}{4} + w_{hp} \times HeatPrevention_m + w_{hc} \times HeatCoping_m\right) \quad (2)$$

In formula (2), three columns from the scores table are used, which are cooling, heat prevention and heat coping. $Cooling_m$ is a score from 0-4, rating the effectiveness of NID measure m for cooling the building. In the formula, $Cooling_m$ is normalized to 0-1 by division by 4. $HeatPrevention_m$ is a binary score of 0 or 1, where 0 means NID measure m is not able to reduce heat stress in the building, and 1 that it is able to reduce heat stress. $HeatCoping_m$ is a factor also containing the binary numbers 0 and 1, where 0 means that NID measure m does not help the building to cope with heat, while 1 means that NID measure m does help the building to cope with heat. In the formula, three different weights for each column are given, which are w_c (for cooling), w_{hp} (for heat prevention) and w_{hc} (for heat coping), with their weight values set to 0.5, 0.3 and 0.2, based on how important the factors are for heat stress. If $Cooling_m$, $HeatPrevention_m$ and $HeatCoping_m$ are 0 for measure m, the bonus for heat stress is 0, even if the heat stress is selected as resilience focus. This shows that measure m is not resilient for heat stress. The maximum of the $EffectBonus_m$ is set to 1.

The formula for the drought bonus is as follows:

$$EffectBonus_{drought}(m) = \min(1, w_{dp} \times DroughtPrevention_m + w_{dc} \times DroughtCoping_m) \quad (3)$$

In formula (3) for drought, the two binary indicators $DroughtPrevention_m$ and $DroughtCoping_m$ are used. $DroughtPrevention_m$ tells if NID measure m is able to prevent drought in the surroundings of the building, and $DroughtCoping_m$ tells if NID measure m improves how the building copes with drought. The weight for $DroughtPrevention_m$, w_{dp} is set to 0.6, and the weight for $DroughtCoping_m$ w_{dc} is set to 0.4, based on how important the factors are for drought. This indicates a higher priority for drought prevention than for drought coping.

The formula for the flooding bonus is as follows:

$$EffectBonus_{flood}(m) = \min(1, w_{fp} \times FloodPrevention_m + w_{fc} \times FloodCoping_m) \quad (4)$$

In formula (4), the two binary indicators $FloodPrevention_m$ and $FloodCoping_m$ are used. $FloodPrevention_m$ tells if NID measure m is able to prevent flooding in the surroundings of the building, and $FloodCoping_m$ tells if NID measure m improves how the building copes with floodings. The weight for $FloodPrevention_m$, w_{fp} is set to 0.6, and the weight for $FloodCoping_m$ w_{fc} is set to 0.4, based on how important these factors are for floodings. Also here, a higher priority for flood prevention than for flood coping is indicated.

3.2.5 NID Viewer Plug-in Evaluation

To assess whether the NID viewer plug-in supports strategic decision-making processes, a short evaluation session of the NID viewer plug-in was conducted. The evaluation session took approximately 30 minutes and involved three participants. All participants were employees of Brink Management/Advies with expertise in NID in three different fields: One project manager, one sustainability advisor and one information systems developer. Appendix P displays the full procedure and the questions used during the evaluation session, which consists of three parts. The answers of the participants per task are provided in Appendix Q, where the GUI of the plug-in containing the first run of each participant is provided in Appendix R. In the first part (T1 and T2), two tasks were carried out. First, a building (or a selection of buildings) was selected and the plug-in was used without applying a resilience focus. Participant were asked here to describe which measure they would

choose. Then, they repeated the task while toggling between different resilience focusses (heat stress/drought/ flooding), and compared the results. For both situations, the participants noted what would help them in decision-making processes, what confused them, what has changed and whether these changes were logical.

In the second part (T3), the participants were asked six open questions to evaluate the tool in terms of usability, relevance to the research question and potential application in real projects. The evaluation session ended with the third part (T4), using the System Usability Scale (SUS) developed by Brooke (1996). The SUS is a validated, quick and reliable questionnaire designed to assess the overall usability of a system (Brooke, 1996). It consists of ten standardized statements which the users rate on a 5-point Likert scale after using a system, where it captures their subjective experiences regarding ease of use, complexity and confidence while interacting with an information system. The SUS was used in order to check the usability of the plug-in next to the understanding, logic and practical relevance of the plug-in obtained from the open questions.

The three participants selected a building in Eindhoven they were familiar with, either because of projects they had done or because it was their previous (student) residence. After completing the first task (T1), all participants chose the NID measure which was suggested on top by the NID viewer plug-in as the NID measure they would implement. For one participant, the first position was shared by four NID measures, including green façade. This participant excluded green façade, as the participant was familiar with the building and knew the exterior facades mainly consisted of windows, making the NID measure green façade less feasible.

In the second task (T2), the participants discussed their understanding and the perceived usefulness of the performed checks for each NID measure, as well as differences in the scores when a resilience focus was selected. For the checks, the participants highlighted the usefulness of the red and green colors of the checks, which directly made clear which checks were met, which were not and why. One participant initially thought there was an error in the plug-in, as it indicated that there were three free facades instead of two while a terraced house was selected. However, after verifying the selection of the building, it became clear that the additional façade was the result from an extension to the house, meaning the information in the plug-in was indeed correct. For the climate resilience option, all participants selected the 'flooding' option. For two participants, this resulted that the NID measure façade garden became the first suggestion, where for the third participant this resulted in the NID measures intensive green roof and nature roof being ranked as the first suggestion. The participants agreed with these adjusted rankings, since the measures going up in score were all measures retaining water.

In the next part (T3), the participants answered six open questions regarding the practical and content-related relevance of the NID viewer plug-in. All participants indicated that the tool was both usable and understandable, with a sidenote from two participants that the addition of an introductory information screen explaining the NID measures and the barriers would have improved their experience. The participants found the NID suggestions really useful, as they clearly displayed the results in a transparent way with the help of visual checks. The inclusion of the barriers was considered less useful, where the participants indicated they were a decent addition but they are somewhat abstract in some cases and not specific to individual NID measures. For example, the barrier *limited political prioritization on biodiversity* applies to all NID measures and therefore offers limited insights at the level of individual NID measures. A remark of two participants was the high scoring for green façade, while the facades contained lots of glass. This seemed unusual for them.

When asked whether the outputs of the tool support existing decision-making processes in existing workflows, reflecting back to the research question, two participants answered this question with yes. They explained lots of municipalities are currently seeking for effective ways to achieve more biodiversity goals, where it is not always clear how to do this (on building scale). This plug-in provides a clear starting point, where it shows the possibilities on their real estate where it directly supports decision-making processes in early phases. It is quick to apply, and the results can be verified with the checks. The third participant indicated that the tool's usefulness depends on who uses the plug-in and at what stage of the development process. The participant indicated the usefulness of the tool for portfolio managers with large asset holdings, who could use the plug-in to identify which buildings offer the greatest potential for NID measures.

When asked what elements from the plug-in they would incorporate into their internal decision-making processes assuming they are in the concept phase of real estate development, the participants gave similar answers. They referred to the suggestions of the NID measures together with their checks as most useful, where the barriers were only considered as a point of attention as they were perceived as too abstract. When asked if the participants would use the plug-in in practice, two participants answered with yes. The third participant also responded positively, with the additional suggestion to further develop the tool to indicate the potential of the NID measures on multiple buildings in a given environment, to see which buildings have most potential for the NID measures here. Finally, the participants were asked to identify the most and least useful components of the NID viewer plug-in. As they already mentioned before, they indicated the suggestions of the NID measures together with its checks as most useful, as it immediately provides insight into the data. Indicated as least useful component are the barriers, since they are to abstract and lack measure specificity.

In the final part of the evaluation session of the plug-in (T4), the participants completed the SUS questionnaire after which the SUS scores per participant were calculated (Brooke, 1996). The participant specific SUS scores were 70, 72.5 and 82.5, with a mean score of 75. According to Bangor et al. (2008), SUS scores can be interpreted using an adjective rating scale, where scores above 85.6 are considered "excellent", scores between 72.8 and 85.6 as "good", scores between 52.0 and 72.7 as "OK", scores between 38.9 and 52.0 as "poor" and scores below 38.9 as "awful". Based on this rating scale, the participants rated the plug-in as "good". These results indicate that the NID viewer plug-in is already perceived as a usable and well-functioning tool, even though there is still room for improvement. For instance, the addition of an introductory information screen to further enhance user understanding which was indicated by two of the participants.

Even though this evaluation is limited in scale because of the number of participants, the positive responses indicate that there is potential to further develop the NID viewer plug-in into a useful support tool for decision-making. The following chapters reflect further on the value and application of the plug-in in broader policy and development context.

4. Discussion

This chapter reflects the main findings of the ISM and MICMAC analysis and of the evaluation of the NID viewer plug-in. It interprets the outcomes according to the literature, highlights the theoretical and practical implications and discusses the strategic relevance for both public and private stakeholders. The discussion starts with analysing the systemic roles of individual barriers and how they are related to each other based on their positions in the ISM and MICMAC models. Then, it explores if there are patterns for the positions in the ISM and MICMAC models within the barrier categories. Next to this, it evaluates the findings from the NID viewer plug-in and the contribution of the plug-in to supporting decision-making processes. This chapter concludes with a reflection on the practical applicability, limitations and opportunities for future development of both the ISM and MICMAC models and the NID viewer plug-in.

4.1 Interpretation of the ISM and MICMAC Findings

4.1.1 Comparing Literature and Expert Judgement

In order to better understand the relevance of the findings it is important not to view them in isolation, but in relation to their significance for decision-making, policy and design choices in practice. Something which stands out in the data, is the chosen barriers by the experts compared to the count of the barriers in the literature. For example, the barrier with the highest citation count in Table 1, 'Limited knowledge and data', is only labelled as relevant by one expert, despite its frequent mention in the literature (Mattijssen et al., 2023; van Haaster-De Winter et al., 2022; White et al., 2024). The same holds for the barriers 'Lack of a clear and unified definition of NID' and 'Biodiversity is hard to measure and monitor'(Kandel & Frantzeskaki, 2024; zu Ermgassen et al., 2022). According of their regular appearance in the literature, the barriers would have been expected to be also labelled as relevant by the experts. However, since experts in the field of NID already do have a certain level of knowledge about NID this could explain why the experts would not see barriers such as 'Limited knowledge and data' and 'Lack of a clear and unified definition of NID' since they do have the knowledge already and know the definition of NID. With this theory, it could be that some barriers were labelled as not relevant, when they actually were relevant.

The results of the ISM and MICMAC analysis together provided a structured understanding of the interrelationships and relative importance of the barriers to NID implementation in real estate development on the building scale (Attri et al., 2013). The ISM model displayed the interrelationships of the barriers over different barrier levels based on relative importance, where the MICMAC analysis classified the barriers into four quadrants based on their driving and dependence power. These findings provide insight into which barriers to address first in order to stimulate the adoption of NID in real estate development.

4.1.2 Driving Barriers (Quadrant IV)

The four barriers located in *Quadrant IV* of the MICMAC analysis in Figure 4 are: A8 (*fragmented responsibilities over policy departments),* A11 (*lack of clear NID targets before development*), A15 (*limited political prioritization on biodiversity*) and A16 (*lack of standardized and effective biodiversity metrics*). Three of these four barriers (A8, A15 and A16) are positioned to level IV and V in the ISM model in Figure 3, while one barrier (A11) is positioned in level III. This placement indicates that the

three barriers A8, A15 and A16 have relatively high structural significance and a strong driving power, meaning they influence many other barriers within the system.

Of these three barriers, A15 stands out with its significantly lower dependence power and being positioned in level V of the ISM model. This suggests that A15 is largely unaffected by other barriers but strongly influences many others, which makes it the most structurally significant barrier within the model. According to both the ISM and MICMAC analyses, increasing political prioritization of biodiversity could play a critical role in addressing many of the other barriers identified in this study, and thus stimulate the uptake of NID in real estate development (Pierce et al., 2024; Russo, 2025; Thomson et al., 2022).

The barriers A8 and A16 both have a moderately high driving power, but also a moderate dependence power. This suggests that while integrating responsibilities across policy departments and establishing standardized biodiversity metrics significantly influence the system, where these barriers are also influenced by other factors and may thus not be fully independent. These barriers significantly influencing the system by themselves too indicates their importance as indicated in the literature (Bowen-Jones, 2024; Layman et al., 2024; Mahmoud et al., 2025).

The barrier A11 has similar driving power as A15, but is located near the threshold of Quadrant III and IV. This means that setting clear NID targets before development influences many other barriers, but is also moderately shaped by them. Its position in level III of the ISM model strengthens this interpretation, where it holds a critical position that enables it to drive systemic change while at the same time it is sensitive to changes elsewhere in the system. The critical position of *lack of clear NID targets before development* within the system shows the importance of tackling this barrier (L. Hernandez-Santin et al., 2025).

4.1.3 Linkage Barriers (Quadrant III)

Quadrant III of the MICMAC analysis includes the six barriers: A1 (*competing priorities/other preferences than ecological gain*), A2 (*cost-related constraints*), A4 (*lack of funds or rewards for biodiversity models),* A7 (*anthropocentric and human-centered standards*), A12 (*limited understanding of NID benefits)* and A17 (*new concept NID not yet recognized as a distinct discipline*). Of these six barriers, the mindset-related barriers A12 and A17 are two of the four barriers (alongside A11 and A15) with the highest driving power. Because of their moderate dependence power, they are located in Quadrant III. Barrier A2 shares a similar dependence power and a slightly lower driving power, so it can be interpreted similar to A12 and A17. The three barriers A2, A12 and A17 thus influence a wide range of other barriers, but are themselves also influenced by others. This indicates feedback loops, where interventions targeting these barriers (on altering the understanding of NID benefits, recognizing NID as a distinct discipline or limiting the costs) may cause widespread changes in the system, while at the same time being shaped by shifts elsewhere in the system. These barriers are very sensitive to changes in the system and changes in these barriers can cause the whole system to change, indicating the importance of these barriers (Gualtieri et al., 2023; Monti, 2020; White et al., 2024).

A12 also holds a central position in the ISM model fitting their location in the MICMAC analysis, and it functions as a mindset-related barrier. Since it is more about attitudes and perceptions toward NID and not about rules or systems, this barrier is easier to address through for example awareness campaigns, training or demonstration projects. Its position in the mid-level allows it to act as a feedback mechanism in the whole system, where improving the understanding of NID benefits can

positively influence both lower-level and higher-level barriers. Barrier A17 is assigned to level V in the ISM model, which suggests a high structural significance. A17 does have a high driving power, but its high dependence power makes its allocation to level V less expected. However, the barrier is located closed to the threshold between Quadrant III and IV, suggesting it functions both as a driver and as a dependent barrier shaped by system-wide dynamics. Furthermore, barrier A17 shows important changes to the whole system as a result of mindset change in the same way as A12. Enhancing the recognition of NID as a distinct discipline can stimulate nature-inclusive thinking to be integrated more into design and planning practices. Together, the barriers A12 and A17 show that changing the mindsets of professionals in the field and organizations could offer a good starting point for broader systemic change. Further, barriers A2 is also assigned to level III in the ISM model, also fitting its locations in the MICMAC analysis. This central level in the ISM model typically includes both the influencing barriers and the barriers which are influenced by others.

The other three barriers in this quadrant, A1, A4 and A7 do have a relatively low driving power, but also a high dependence power. This means these barriers are strongly influenced by other barriers, where they only moderately influence the system itself. In the ISM model, A1 and A4 are assigned to level I, the lowest level from which the limited structural influence fits their high dependence power, but not their moderate driving power. A7 is assigned to level II, which is more expected according to its moderate driving and high dependence power. These results suggest that the barriers competing priorities/other preferences than ecological gain, lack of financial incentives for biodiversity models and human-centered design standards are mainly the result of deeper problems in the system. For example, a *lack of clear NID targets before development* (A11, level III barrier with high driving power) is a key barrier here (L. Hernandez-Santin et al., 2025), as it can lead to NID being left out as a priority or human-centered design standards being applied. Still, these barriers cannot be neglected as they still moderately influence other barriers.

4.1.4 Dependent Barriers (Quadrant II)

Similarly to Quadrant III, *Quadrant II* of the MICMAC analysis also contains six barriers. These barriers are: A3 (*greenwashing of results because of conceptual misuse and misinterpretation*), A5 (*design conflicts between species needs (human and non-humans)*), A6 (*lack of biodiversity objectives in rating schemes*), A10 (*NID perceived as risky since it is new and untested*), A14 (*gap between planning and implementation of NID*) and A18 (*different biodiversity priorities in frameworks*). Barrier A3 and A5 have the highest dependence power, while having very limited driving power. This indicates that these issues are mainly the results of other underlying problems in the system, rather than direct causes. This means that in order to achieve progress on greenwashing of results and design conflicts between species, this progress is more likely to be achieved by addressing barriers influencing these barriers rather than addressing these barriers themselves. This theory fits the allocation of both A3 and A5 to the lowest level of the ISM model (level I), suggesting low structural significance and confirming their position in the system as highly dependent.

The barriers A14 and A18 are located close to the threshold of Quadrant I and II, with moderate dependence and a low driving power. This suggests a limited influence on the broader system, while they may still be affected by some other barriers. A18 is assigned to level II in the ISM model, which fits its MICMAC position indicating that aligning the biodiversity priorities in different frameworks is an issue shaped by more foundational barriers. However, A14 is assigned to level IV in the ISM model, suggesting a relatively high structural significance. This appears contradictory to its MICMAC position, but it could be the case that it has low influence on a small number of highly central barriers such as

A15 or A17. This would mean that even though A14 does not affect many barriers directly, it affects the right ones in order to increase its structural role in the ISM model.

The final two barriers A6 and A10, are located near the threshold of Quadrant II and III, with slightly higher driving power than the rest of the quadrant. The barriers both show a high dependence and moderate driving power. This suggests they are not entirely passive in the system. This means that changes in other barriers strongly affect them, but they can also moderately influence others in return. The allocation of A6 to level I in the ISM model fits these observations. The lack of biodiversity objectives in rating schemes seems to be more a result of other more foundational issues. A10 is assigned to level III in the ISM model, being more connected with other mid-level barriers where it both influences and is being influenced by them. An example is that addressing the lack of standardized and effective biodiversity metrics results in more evidence on ecological and financial benefits of NID. This visibility reduces uncertainty about NID outcomes, lowering the perception of NID as risky. On the other hand, NID perceived as less risky could lower the human-centered design standards as it is able to compete with these standards because of its lower risk. This indicates the importance of the barrier NID being perceived as risky (Booth et al., 2024; White et al., 2024), even though it is located in Quadrant II.

4.1.5 Autonomous Barriers (Quadrant I)

Only two barriers are located in *Quadrant I*, which are both located near the threshold of Quadrant I and IV. The two barriers are: A9 (*lack of corporate transparency on biodiversity loss*) and A13 (*weak governance*). A9 has a low dependence power and a moderately low driving power, and is assigned to level II in the ISM model. This position fits the MICMAC quadrant it is located in where the lack of corporate transparency on biodiversity loss is not highly influential, and even though it still moderately influences other barriers it remains relatively independent within the system.

Barrier A13 stands out because of its exceptionally low dependence power, the lowest of all barriers in the system. A13 is assigned to level IV in the ISM model, typically indicating a higher structural significance and influence on the system. This seems inconsistent with its MICMAC position in Quadrant I, where a higher driving power would be expected for a barrier located in such a high ISM level. A possible explanation could be A13 slightly influences one or more key barriers in the ISM model, especially the ones positioned at higher levels on the bottom like. So weak governance might not affect a large number of barriers, but it could influence a few critical ones which shape the rest of the system. For example, the critical barrier *lack of clear NID targets before development* (A11) is likely to be influenced by a *weak governance*, where more effective governance could aim for clearer NID targets (L. Hernandez-Santin et al., 2025). Its low dependence power indicates that the influence on A13 itself is limited, which strengthens its position as somewhat independent barrier which is nevertheless structurally important.

These patterns in the position and influence of barriers suggest that different stakeholder groups such as public authorities and private actors interact with different parts of the barrier system. The strategic relevance of these differences will be explained in more detail in Section 4.3.

4.2 ISM and MICMAC Findings per Barrier Category

Another important observation is the distribution of the ISM levels and MICMAC quadrants of the barriers, over the different barrier categories (Table 1). Table 9 presents the 18 barriers used in the ISM and MICMAC analysis, categorized based on Table 1, together with their assigned levels of structural significance and quadrants positions based on driving and dependence power. What stands out, is the three barriers in the category "policy and regulatory instruments" all being positioned in the two highest ISM levels (IV and V). This high structural significance in this barrier category highlights the importance of policy and regulatory instruments (Birkeland, 2022; Mahmoud et al., 2025; Thornhill et al., 2025). Addressing these barriers may therefore have a significant effect in overcoming multiple lower-level and more dependant barriers and are thus really important for policymakers to consider.

The barrier categories "community and stakeholder engagement" and "design standards and approaches" mainly contain barriers assigned to the lower ISM levels (I and II), meaning these categories contain low structural significance and are thus not the main focus in stimulating the uptake of NID in real estate development. However, the presence of some mid-level barriers (because of their location in the MICMAC model) within these categories shows that they still play a supportive role and cannot be neglected. These mid-level barriers can act as entry points for change, especially within organizations. Except for the barrier categories "policy and regulatory instruments" , "community and stakeholder engagement" and "design standards and approaches", no other barrier categories only contain barriers with low, moderate or high structural significance. They all contain a mix, where no other barrier category stands out than these three. This highlights the importance of using a systematic modelling approach such as the ISM and MICMAC analysis to guide strategic decision-making, rather than only relying on categorical classification.

Table 9: Categorized barriers with their assigned ISM level and MICMAC quadrant

Category	Barrier	Tag	Level	Quadrant
Community and Stakeholder Engagement	Competing priorities/Other preferences than ecological gain	A1	I	III
Knowledge, Capacity and Design Tools	New concept NID not yet recognized as a distinct discipline	A17	V	III
	Limited understanding of NID benefits	A12	III	III
	Lack of biodiversity objectives in rating schemes	A6	I	II
	Greenwashing of results because of conceptual misuse and misinterpretation	A3	I	II
Strategic Planning and Corporate Integration	Gap between planning and implementation of NID	A14	IV	II
	Lack of corporate transparency on biodiversity loss	A9	II	I
	Lack of clear NID targets before development	A11	III	IV
	NID perceived as risky since it is new and untested	A10	III	II
Policy and Regulatory Instruments	Limited political prioritization on biodiversity	A15	V	IV
	Fragmented responsibilities over policy departments	A8	IV	IV
	Weak governance	A13	IV	I
Financial and Market Instruments	Cost-related constraints	A2	III	III
	Lack of funds or rewards for biodiversity models	A4	I	III

Metrics, Monitoring and technological limitations	Lack of standardized and effective biodiversity metrics	A16	IV	IV
	Different biodiversity priorities in frameworks	A18	II	II
Design Standards and Approaches	Anthropocentric and human-centered standards	A7	II	III
	Design conflicts between species needs (human and non-humans)	A5	I	II

4.3 Implications and Strategic Reflection

The application of the ISM and MICMAC analysis in this study does not only provide insight into which barriers for NID implementation are relevant and how they are connected, but it also presents a new methodological contribution to the field of NID. Other than previous studies which mainly used thematic and exploratory approaches, this study systematically prioritizes and identifies barriers together with its relationships to better support research, but also practice by facilitating decision-making processes for NID implementation. Because of this analysis, this study directly bridges the research gap identified in Section 2.6. The results highlight that addressing the barriers for NID implementation requires a systemic approach rather than isolated interventions, where in this study a system-level relational approach is used. For example, targeting high-level structural barriers such as *limited political prioritization on biodiversity* (A15) and *fragmented responsibilities over policy departments* (A8) potentially generates positive effects across the entire barrier system. On the other hand, focusing only on lower-level or highly dependent barriers such as *greenwashing of results because of conceptual misuse and misinterpretation* (A3) or *Design conflicts between species needs* (A5) is unlikely to significantly impact the entire barrier system. This suggests that in order to effectively address barriers, it is required to address the underlying structural drivers that shape the rest of the system.

The findings of this study also show that different types of stakeholders face and influence different parts of the barrier models. As discussed in Section 2.3, actors from the private sector are often limited by more short-term financial or knowledge reasons and more likely to encounter barriers such as *cost-related constraints* (A2), *NID perceived as risky since it is new and untested* (A10) and *limited understanding of NID benefits* (A12). These are often mid-level (or lower-level) barriers coming from deeper problems and being influenced by other barriers. On the other hand, public authorities are less affected by financial or knowledge deficits and have the ability to influence higher-level policy-related barriers. These barriers include *fragmented responsibilities over policy departments* (A8), *limited political prioritization on biodiversity* (A15) and *lack of standardized and effective biodiversity metrics* (A16). This difference between public and private sector barriers shows the importance of aligning strategies with either public or private responsibilities to effectively overcome barriers of NID implementation. The ISM and MICMAC analysis provides useful insights to align these different strategies, by showing which barriers are most relevant to each sector.

According to the results, an implication for private real estate actors is that the most influential barriers like governance and regulatory barriers lie outside of their immediate control. However, understanding the interdependencies of the barriers within the model enables private real estate developers to seek collaborative partnerships with governmental actors or to engage in conversation with governmental actors about policy changes supporting NID implementation (Mahmoud et al., 2025). Next to this, companies could still develop strategies to in order to address mid-level barriers within their reach such as *lack of clear NID targets before development* (A11), by simply giving more

attention to NID in concept phases or *limited understanding of NID benefits* (A12) which is mindset-related, by investing in NID knowledge or awareness. By addressing these mid-level barriers, progress on more dependent barriers such as *competing priorities/other preferences than ecological gain* (A1) *or anthropocentric and human-centered design standards* (A7) will also be made. Next to this, addressing the mid-level barriers possibly even feeds back into deeper systemic barriers because of their central positions and interconnections within the system.

With the policy and regulatory barriers as foundational barriers this study shows the importance of political support, indicating the important role of policymakers and urban planners (Mattijssen et al., 2023; Russo, 2025). For the policymakers and urban planners, the model serves as a strategic decision-making tool as it identifies where policy efforts are likely to have the most impact on stimulating the implementation of NID. For example, addressing the barrier *lack of standardized and effective biodiversity metrics* (A16) not only improves biodiversity monitoring, but it also reduces perceived risks on NID projects (A10) by creating more clarity on the expected outcomes of biodiversity gain. Similarly, increasing the political prioritization on biodiversity (A15) could stimulate the development of NID knowledge overcoming several barriers, where it for example could bridge the *gap between planning and implementation of NID* (A14) as the developed knowledge is the missing link.

Finally, this study shows the potential of structured system-thinking methodologies like the ISM and MICMAC analysis (Attri et al., 2013), as it complements the qualitative and interpretive approaches in existing studies. Where the expert judgements could reflect some subjective biases, the ISM and MICMAC analysis provide analytical clarity about the complex and interrelated barriers to the implementation of NID in real estate development. Hereby, it guides both public and private sector stakeholders toward more effective strategies to overcome the barriers and stimulate the uptake of NID in real estate development.

4.4 Limitations and Future Research ISM & MICMAC

While this study provides a more systematic and relational understanding of the barriers to implementing NID in real estate development, several limitations should be taken into account. These limitations provide context for the interpretation of the results and identify certain points for further research.

The first limitations relate to the data collection used in the ISM and MICMAC analyses, where expert opinions are used to define the barriers and the relationships between the barriers. Even though the experts were carefully selected based on their knowledge of NID and real estate development and their experience in the field, the number of participants was limited and their perspectives may not fully represent the diversity of views in the broader field. Next to this, expert judgement contains elements of subjectivity up to a certain level, which could have influenced the structuring and prioritization of barriers. Only interviewing experts in the field may also be a limitation, where experts in the field may not recognize certain barriers anymore like limited availability of knowledge and data. Since they are experts in the field, they already hold a certain level of knowledge and data because of which they do not recognize the limited availability.

Second, the experts which were interviewed in this research were employees of private organizations or housing associations. Input from public authorities like municipalities is missing here. Future studies could further build on this work by expanding the number and diversity of experts, or by conducting comparative analyses. Comparative analysis could be done between public authorities

and private actors, or across different stakeholder groups like policymakers, developers and ecologists to find out if there are differences in perception of barrier importance and relationships between barriers.

Finally, the limitations of the ISM and MICMAC analysis itself may also not be neglected here. As noted by Attri et al. (2013), the ISM and MICMAC methodology becomes increasingly complex as the number of variables increases. In order to manage this complexity, only a limited number of barriers can be included in the model, where in this study the boundaries are set between 15-25 barriers. While this boundary made the model easier to understand and manage, it also means that the relationships between the barriers were analysed at a broader level instead of in full detail. As a result, even though all key barriers were included in the analysis, some smaller or context-specific links between barriers may not have been fully captured because some barriers are left out.

Even though these limitations of the study, it provides a strong foundation for future research and practice. By systematically modelling the barriers and the relationships between the barriers, this work contributes to a deeper understanding of the barriers to NID implementation in private sector real estate development.

4.5 Interpretation of the NID Viewer Plug-in Findings

The evaluation session of the NID viewer plug-in resulted in promising results regarding the potential of the plug-in to support strategic decision-making processes in the early phases of real estate development. All participants selecting the NID measure suggested by the plug-in because it was on top of the ranking, shows how the output of the plug-in aligns with the reasoning of professionals in the field. This indicates that the foundation of the tool which is based on building specific data, location data and specific checks per NID measure leads to outputs which are both relevant and applicable to real world projects.

In the second task (T2), where the participants selected the resilience focus, the plug-in adapted the recommendations based on this selected resilience focus. These changes in the results were perceived as logical by the participants. This finding is important, as it shows that the resilience focus options feature is a reliable addition to the plug-in for climate adaptation. The relevance of climate resilience in both public and private real estate development is significantly growing, where this feature of the plug-in could thus add significant value in projects with next to NID goals, clear goals for climate adaptation are set. The participants highlighted the importance of the checks per NID measure, which is made visual by hovering over the suggested NID measures. The red and green indicators in the checks give direct insight into which checks are met and which checks not, simplifying the complex data into an immediately understandable overview. This is one of the key strengths of the NID-viewer plug-in, where it has the ability to translate technical building and location specific data into decision-relevant information, which is especially valuable in interdisciplinary settings where the users are no specialists in the field of NID.

However, some components of the tool received more critical feedback from the participants, where the relevance of the barriers is now perceived to be relatively limited. The participants did understand the purpose of these barriers where they should have highlighted organizational or policy challenges, but their perceived abstraction and lack of being specific per NID measure limited their perceived usefulness. This is in line with the research gap found in the literature, where the absence of NID measure-specific barriers in decision-making early in the real estate development process limits the adoption of NID (Booth et al., 2024; Dijkshoorn-Dekker et al., 2020; Layman et al., 2024).

The NID viewer plug-in is an important step into linking suggested NID measures early in real estate development to their possible barriers by indicating the importance of barrier awareness here, but in order to fully bridge the research gap greater specificity of the barriers per NID measure is needed.

4.6 Usability and Practical Application

The results of the System Usability Scale (SUS) with a mean score of 75, means that the NID viewer pug-in is positioned within the "good" category of usability (Bangor et al., 2008). This indicates that even the prototype of the plug-in is considered as user-friendly and functionally effective by professionals in the field with different expertise backgrounds. Given the short introduction the participants had, these findings show that there were no complications with using the NID viewer plug-in, and that learning to cope with the plug-in is not considered as complex and will thus not take a lot of time. The evaluation session also revealed areas for improving the plug-in, especially for new users or people not experienced in the field of NID. Two participants mentioned here that an introductory information screen which explains the NID measures and their associated barriers would improve their understandings, since it shows in one overview which NID measures and barriers are used in this plug-in. Users can retrieve the contextual information of the plug-in here without being overwhelmed. Even though the usability was already rated as "good", the information screen could thus improve getting along with the tool, reduce uncertainties and thus support more confident use.

Furthermore, one participant suggested to extend the tool, in order to be able to evaluate multiple buildings simultaneously to enable prioritization at a portfolio level. Even though this is not in the scope of this study where the focus is on building scale, this comment reflects the need in real-world planning contexts where decisions usually are not made on a single building in isolation. For larger stakeholders like housing corporations, municipalities or investors with lots of real estate assets, this functionality could significantly improve the value of the plug-in by enabling comparisons in NID potentials of buildings within larger sets of real estate assets.

4.7 Implications for Future use and Development NID viewer

The findings of the evaluation session showed that the NID viewer plug-in has clear potential in supporting decision-making processes in real estate development on building scale. Especially in the early conceptual phases of real estate development, where it could be helpful for stakeholders to identify suitable NID measures in a quick and transparent way early on in the project. For municipalities and developers which seek to achieve biodiversity goals with real estate development on the building scale, this plug-in offers a great starting point in translating complex data into decision-relevant information.

However, the effectiveness of the tool may vary per user and per stage in real estate development. As indicated by one participant, the plug-in may be especially useful for portfolio managers or strategic advisors possessing lots of real estate assets, who quickly want to see the potential of NID measures within their possession. But the plug-in is now only focused on the potential of NID measures on single building scale. Next to this, the scoring for green façade seemed a little high for some participants. This is the case, since data about the amount of glass in facades is missing in the building specific dataset of the NID viewer plug-in. In future research, this data could be added together with a check for the NID measure green façade, where its score is lowered if the façade contains a certain amount of glass. It would even be more useful to remove the static nature of the collected data layers

in future research and substitute those with dynamic data layers, which are updated when the original datasets are updated.

Combining the relatively positive usability scores from the SUS with the feedback on potential improvements of the plug-in, show the importance of iterative development using the feedback of potential users. Incorporating an information screen and/or the multi-building analysis function would thus greatly improve the functionality of the plug-in, and would serve more diverse user groups. Next to this, the perceived abstraction of the barriers is indicated as an implication, where in future research the barriers could be better linked to specific NID measures. In this study, this was done by generally rating the relevance of each barrier to all NID measures, where in future research it is critical to improve this step to enhance the contextual relevance of the barriers.

Finally, even though the evaluation resulted in positive and relevant insights into the usability and perceived value of the NID viewer plug-in, the low sample size must be taken into account when interpreting the findings. Because of time constraints, only three participants were involved in the evaluation session, which were all employed by the same private organization (Brink Management/Advies) and were also familiar with NID and the application of NID. This does make the evaluation suitable for exploring expert-based insights and usability among users already possessing NID knowledge, but it does necessarily suit the experience of users with like municipal employees, architects or asset managers from other organizations with limited NID knowledge. Future research could therefore aim to validate the findings of the evaluation through more diverse user testing, involving participants from various backgrounds and with different levels of NID knowledge.

5. Conclusion

This final chapter summarises the key findings of this thesis, where it reflects on the scientific and societal relevance of the results and evaluates the extent to which the research objectives were met. It goes back to the main research question and provides insights into how both the ISM and MICMAC analysis and the NID viewer plug-in contribute to a better understanding and implementation of NID in real estate development. Next to this, it also discusses the broader implications of the study and it presents the limitations and recommendations for future research.

5.1 Scientific Relevance and Reflection on Research Question

The objective of this study was to gain a deeper understanding of the barriers to NID in real estate development, and provide insight into how these barriers are related to each other and affect the implementation of NID measures on building level. With an extensive literature research, this study identified 38 barriers across 7 barrier categories. Then, with a combination of expert interviews and the ISM and MICMAC analysis, this list was refined to 18 barriers, structured into a hierarchical model and mapped according to their driving and dependence power. The models made it possible to distinguish between driving and dependent barriers, allowing stakeholders to better understand which barriers to prioritize when aiming to stimulate the implementation of NID.

In addition, a prototypical decision-support tool has been developed in the form of a plug-in for QGIS. This NID viewer plug-in has been evaluated to test whether suggesting NID measures together with its barriers early on in the process of real estate development can support strategic decision-making for real estate professionals. This evaluation session showed that the NID viewer plug-in is perceived as usable and relevant in early project phases, particularly in identifying feasible NID measures for the selected building while it provides transparency on the barriers associated with these NID measures. Overall, the research objectives have been achieved by both providing the relevant barriers in hierarchical structure and by providing a practical, user-tested tool to bridge the gap between data, design and biodiversity objectives.

The central research question of this study was: "*What are the barriers to Nature-Inclusive Design in early-stage real estate development on building scale and how to develop an information system to effectively inform the strategic decision-making processes*?". This research shows that decision-making can be supported in two complementary ways, first at strategic level and then at project level.

This research supports decision-making at strategic level by providing a structured understanding of the complex network of barriers related to NID by the ISM and MICMAC analysis. The models from the ISM and MICMAC analysis show that barriers such as *limited political prioritization on biodiversity*, *lack of standardized and effective biodiversity metrics* and *lack of clear NID targets before development* are key driving barriers influencing many other barriers. Targeting these barriers can cause to reduce multiple other barriers to NID implementation with minimal effort, reducing the overall resistance to NID implementation. These key barriers are less accessible for private actors, where only public authorities might be able to address these barriers. In addition to these systemic and policy-related barriers, this research also identified important mindset-related barriers like *limited understanding of NID benefits* and *new concept NID not yet recognized as a distinct discipline*. Mindset-related barriers are more accessible and thus easier to address for both public authorities and private actors. Their mid- and higher-level positions in the ISM model allow them to influence both lower- and higher-level barriers, meaning these barriers are effective starting points to change

the whole system through awareness, education or professional development. This study thus shows that the relevance and influence of certain barriers can differ depending on the type of stakeholder which is involved. Public authorities often use more long-term-plans and policies, in order to include biodiversity goals more easily over time. In comparison to public authorities, private actors are usually more restricted by financial feasibility, return-on-investment expectations and perceived risks. The ISM and MICMAC models help with highlighting the most relevant barriers per sector, making it easier to design interventions that are better aligned with either public or private responsibilities.

Finally, this research supports decision-making at project-specific level with a digital tool. The developed NID viewer plug-in combines building specific data and location specific data of the surroundings of the building with expert-informed barrier relevance scores to suggest suitable NID measures together with the barriers which may hinder its implementation. The models resulted from the ISM and MICMAC analysis are useful here, in showing which barriers to address best in order to overcome the barriers of the selected NID measure. The plug-in was found useful by professionals to quickly evaluate and compare different NID measures in early design phases.

5.2 Societal Relevance

This research contributes to the growing societal need for sustainable and nature-inclusive real estate development. NID has the potential to transform practices in real estate development by promoting the value of biodiversity next to economic growth. However, the implementation of NID is often hindered by several barriers which are difficult to address in practice. This study offers a practical step forward by indicating the most influential barriers and by offering a plug-in which supports decision-making in early real estate development to facilitate the implementation of biodiversity in the design of single buildings. The approach used in this research combines structured prioritization of barriers with transparency, local adaption and user-centered decision making, where it stimulates to achieve long-term ecological resilience which is especially important in the context the decline of global biodiversity.

5.3 Recommendations

This study highlights that even though awareness of biodiversity in real estate development is growing, translating biodiversity goals in functional designs remains challenging. While this research is very useful as it combines academic insights with practical application, it still comes with its limitations.

One key limitation concerns the ISM and MICMAC analysis. Even though it provided valuable insights into the hierarchy and relationships between the barriers, there are some limitations with this method. The first limitation is the reliance of the model on the expert input and the limited number of participants. Follow-up research could therefore build on this work by expanding the number and diversity of the experts, or by comparing results of different expert groups like policymakers, developers and ecologists to find out if there are differences in the perception of the importance of the barriers to NID implementation.

A related limitation lies in the relatively small sample size used in the evaluation of the NID viewer plug-in. Only three participants from the same private organization were involved here. Follow-up research should therefore test the NID viewer plug-in with professionals from both private and public authorities from different fields and with varying levels of NID knowledge, to better assess its

usability and relevance in broader settings. Another issue concerns the lack of data about the amount of glass in facades of buildings. In follow-up research, these data should be found and added together with a check for the NID measure green façade to make its score more accurate.

Next to this, the method used to link the most relevant barriers to the NID measures could be improved to make the barriers more specific per NID measure. This could be done by adding literature research on each NID measure separately and finding its specific barriers before conducting the expert interviews. Finally, the data gathered from the interviews has a static nature, where it does not allow for real-time updates when the data, policies or local circumstances change. Follow-up research could explore more NID measure specific barriers for the plug-in, and explore the integration of more dynamic or data-driven methods to make the plug-in more responsive to changes.

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Appendix

A. Interview first round

Interview (English)

In separate (secured) file: Name, email, function & company

- What is your role and area of expertise?

- How many years of experience do you have in the field of Nature-Inclusive Design?

- What is your definition of nature-inclusive design? Does it align with mine?

- Can you briefly explain the project in question, what stage it is in and how Nature Inclusive design has been applied here?

Part I

Below is a list of barriers to using Nature Inclusive Design in real estate development, based on literature review. The intention is to adjust the list as needed (remove barriers, add barriers if necessary until the desired number between 15 - 25 drivers is reached).

Barriers

Category	Barrier
Community and Stakeholder Engagement	Low community engagement and acceptance
	Other preferences than ecological gain
	Lack of interdisciplinary cooperation
	Fixed mindsets
Knowledge, Capacity, and Design Tools	Lack of a clear and unified definition of NID
	Limited knowledge and data
	New concept NID not yet recognized as a distinct discipline
	Limited understanding of NID benefits
	Lack of biodiversity objectives in rating schemes
	Greenwashing of results because of conceptual misuse and misinterpretation
Strategic Planning and Corporate Integration	Gap between planning and implementation
	Business model and market misalignment
	Lack of corporate collaboration
	Lack of corporate transparancy on biodiversity loss
	Competing priorities
	Biodiversity offsetting off-site
	Lack of clear NID targets before development
	NID perceived as risky since it is new and untested
	Long-term implementation challenges
Policy and Regulatory Instruments	Limited political prioritization on biodiversity
	Fragmented responsibilities over policy departments
	Weak governance
	Weak post-construction monitoring and enforcement
	Regulatory gaps and inertia

	Enforcement loopholes and exemptions
Financial and Market Instruments	Cost-related constraints
	Lack of funds or rewards for biodiversity models
	Low customer willingness to pay for NID
	Perceived profitability and revenue challenges of NID
	Risk of market shift
	Profit oriented private development often lack biodiversity aspects
Metrics, Monitoring and technological limitations	Lack of standardized and effective biodiversity metrics
	Different biodiversity priorities in frameworks
	Biodiversity is hard to measure and monitor
	Technological limitations to measure biodiversity
	Technical limitations for NID on building level (especially on green roofs)
Design Standards and Approaches	Anthropocentric and human-centered standards
	Design conflicts between species needs (human and non-humans)

Part II

Below, 10 NID options are shown. This is just to give an explanation of each NID option. Indicate how strong every barriers is per NID option (1 – 5, where 1 is not strong at all, 5 is very strong).
These results are filled in in the matrix down below.

Nr.	NID option	Demands/explanation
1	Nesting stones for birds on facade	Northeast side of facade (and not above windows)
2	Bat enclosures in facade	On the southwest side of the façade between four feet (lower limit) and fifty feet (upper limit) height (and not above windows).
3	Insect hotels in facade	The hotel should face the southwest facing. Bee hotels can also be placed on the roof.
4	Extensive green roof	Constructed of a thin soil layer of about four to seven inches and moss or sedum vegetation, possibly supplemented by herbs and grasses. By varying the soil thickness, microclimates can be created.
5	Intensive green roof	Has the highest diversity in all respects. With a thick substrate layer of between 80 and 120 centimeters, grasses, herbs, shrubs and even trees grow. An intensive roof is like a real garden, but on top of a building.
6	Nature roof	A variation on an intensive roof in which the substrate layer has varying thicknesses (between 20 and 40 centimeters), creating different gradients. This creates more opportunities for different types of fora and fauna.
7	Brown roof	In brown roofs, the roofing material consists mainly of sand and stone, such as recycled rubble. Brown roofs have an ecological and water buffering value. In particular, birds that originally nest on sandy terrain, use brown roofs as nesting sites.
8	Water roof	Flat roofs can be designed that they buffer some of the precipitation. After heavy rainfall, the water temporarily remains on the roof and has a cooling effect
9	Green facade	A wall can be completely covered with greenery, the greenery can surround certain floors or it can climb up while zigzagging. Built-in flower boxes for balconies entice residents to green their balconies.
10	Facade garden	The minimum depth of a properly functioning facade garden is 45 centimeters and the width is 120 centimeters. A wider garden naturally allows more species to grow and provides more cover for species such as the hedgehog.

	Nesting stones for birds on facade	Bat enclosures in facade	Insect hotels in facade	Extensive green roof	Intensive green roof	Nature roof	Brown roof	Water roof	Green facade	Facade garden
Barriers which are indicated as relevant are placed here										

B. Complete list of barriers after the first round of interviews together with their frequency.

Nr:	Barrier	Frequence
1	Competing priorities	9
2	Cost-related constraints	9
3	Greenwashing of results because of conceptual misuse and misinterpretation	9
4	Lack of funds or rewards for biodiversity models	9
5	Design conflicts between species needs (human and non-humans)	8
6	Lack of biodiversity objectives in rating schemes	7
7	Anthropocentric and human-centered design standards	7
8	Fragmented responsibilities over policy departments	7
9	Lack of corporate transparancy on biodiversity loss	6
10	Andere voorkeuren dan ecologische winst	6
11	NID perceived as risky since it is new and untested	6
12	Lack of clear NID targets before development	6
13	Limited understanding of NID benefits	5
14	Weak governance	5
15	Gap between planning and implementation of NID	5
16	Limited political prioritization on biodiversity	5
17	Lack of standardized and effective biodiversity metrics	5
18	New concept NID not yet recognized as a distinct discipline	5
19	Different biodiversity priorities in frameworks	5
20	Weak post-construction monitoring and enforcement	4
21	Lack of interdisciplinary cooperation	4
22	Low customer willingness to pay for NID	4
23	Perceived profitability and revenue challenges of NID	4
24	Biodiversity is hard to measure and monitor	4
25	Lack of a clear and unified definition of NID	3
26	Long-term implementation challenges	3
27	Biodiversity offsetting off-site	3
28	Enforcement loopholes and exemptions	3
29	Profit oriented private development often lack biodiversity aspects	2
30	Regulatory gaps and inertia	2
31	Technical limitations for NID on building level (especially on green roofs)	2
32	Business model and market misalignment	2
33	Low community engagement and acceptance	1
34	Limited knowledge and data	1
35	Lack of corporate collaboration (no collaborative goal)	1
36	Technological limitations to measure biodiversity	1
37	Fixed mindsets	1

C. Interview round 2

Interview Round 2 (English)

In this interview, the relationships between the barriers to using nature-inclusive design in real estate development (at the building scale) by private parties are visualized.

- This is done by drawing a line from a barrier on the left side of the paper to one or more barriers on the right side.
- The relationships are always shown from left to right!
- Each barrier is shown only once on the left side. A mutual relationship can therefore be represented by connecting the same barriers across two separate sheets.

Concurrerende prioriteiten/ Andere voorkeuren dan ecologische winst

Kosten gerelateerde beperkingen

Greenwashing door verkeerd gebruik van concept

Gebrek aan financiering/beloning voor biodiversiteitsmodellen

Ontwerpconflicten tussen behoeften van soorten (tussen menselijke en niet-menselijke stakeholders)

Geen biodiversiteitsdoelen in beoordelingssystemen

Antropocentrische en mensgerichte standaarden

Opgesplitste verantwoordelijkheden

Gebrek aan transparantie bij bedrijven

NID als risicovol gezien omdat het nieuw en weinig getest is

Geen duidelijke doelen vóór ontwikkeling

Beperkt begrip van voordelen van NID

Zwak bestuur

Kloof tussen planning en uitvoering

Lage politieke prioriteit voor biodiversiteit

Gebrek aan gestandaardiseerde en effectieve meetmethoden voor biodiversiteit

NID nog geen erkende discipline

Verschillende biodiversiteits-prioriteiten in frameworks

D. SSIMs of all 6 participants second interview

Participant 1

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1		X	X	A	X	X	X	X	X	X	X	X	X	X	X	V	X	V
A2			X	X	O	V	V	A	O	X	V	X	A	O	X	O	A	O
A3				A	A	X	A	A	A	V	X	X	X	A	X	A	A	O
A4					O	X	X	O	V	O	V	V	A	O	A	X	X	O
A5						O	X	O	O	X	O	O	O	O	O	O	O	O
A6							A	O	O	O	V	V	A	O	X	X	X	X
A7								O	V	A	V	O	V	O	V	V	V	O
A8									O	O	O	O	X	V	V	O	O	V
A9										O	O	O	A	O	A	O	A	O
A10											V	X	A	O	V	O	A	O
A11												O	A	O	A	X	X	V
A12													O	O	A	A	A	O
A13														O	V	X	X	V
A14															O	O	O	O
A15																X	X	V
A16																	X	X
A17																		V
A18																		

Participant 2

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1		X	A	X	A	A	X	X	A	A	X	X	V	A	X	X	X	X
A2			A	X	X	X	V	O	A	V	V	X	V	A	X	V	V	O
A3				O	O	V	V	A	O	V	V	V	X	O	V	V	V	O
A4					X	X	X	O	A	X	X	X	X	X	X	X	X	A
A5						X	X	A	A	X	X	V	X	O	V	X	V	A
A6							X	A	O	V	A	X	X	A	X	X	X	A
A7								A	O	X	V	V	O	O	V	V	V	O
A8									O	O	V	V	O	O	V	V	V	A
A9										V	V	O	V	O	V	V	V	O
A10											X	X	A	A	X	X	X	A
A11												V	O	A	V	V	V	O
A12													A	A	X	X	X	A
A13														O	X	V	V	A
A14															O	V	V	O
A15																X	V	O
A16																	X	A
A17																		A
A18																		

Participant 3

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1		X	A	X	X	X	X	X	X	X	X	X	X	X	X	A	X	X
A2			X	X	X	X	X	X	X	X	A	A	A	X	A	X	A	X
A3				V	X	V	A	A	X	V	A	X	A	O	A	A	A	A
A4					V	X	X	A	A	X	X	A	A	O	X	X	X	X
A5						X	X	X	X	A	A	X	X	X	X	A	A	X
A6							X	X	X	X	X	X	X	O	X	X	X	X
A7								X	V	X	X	X	X	X	X	X	X	X
A8									X	V	X	V	X	A	X	X	X	X
A9										X	X	X	X	A	A	X	O	V
A10											X	X	A	X	X	X	X	X
A11												X	X	X	X	X	X	X
A12													A	O	X	X	X	X
A13														X	X	X	X	X
A14															X	X	A	X
A15																X	X	X
A16																	X	X
A17																		X
A18																		

Participant 4

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1		A	V	A	A	X	X	X	A	A	A	A	O	O	A	A	X	A
A2			X	X	X	X	X	A	X	X	X	X	O	O	A	A	A	A
A3				X	X	A	X	A	A	A	A	A	O	O	A	A	A	A
A4					V	A	X	A	X	X	A	A	A	A	X	X	X	X
A5						A	X	O	X	O	A	X	A	A	A	X	A	A
A6							X	A	V	X	V	X	X	X	X	X	A	X
A7								X	X	A	X	X	A	X	X	X	X	X
A8									V	V	X	X	A	V	X	X	A	X
A9										X	X	X	A	X	A	X	A	X
A10											X	X	V	X	X	X	X	V
A11												X	X	V	X	X	X	X
A12													X	V	X	X	X	V
A13														A	X	X	X	X
A14															A	A	A	A
A15																X	X	X
A16																	X	X
A17																		X
A18																		

Participant 5

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1		X	V	X	V	X	X	X	X	V	X	X	X	V	X	V	X	X
A2			O	X	O	A	O	V	X	O	X	X	A	A	A	O	O	O
A3				O	O	X	O	V	A	X	V	A	O	X	A	X	A	A
A4					O	O	O	O	O	O	V	O	A	A	X	V	X	V
A5						O	X	X	O	A	X	X	V	O	V	O	X	O
A6							A	O	A	O	X	X	O	A	A	X	X	X
A7								X	O	X	X	X	O	O	X	V	X	O
A8									O	V	X	A	X	A	X	O	X	O
A9										O	O	V	O	A	O	V	X	V
A10											O	X	O	A	V	O	X	O
A11												X	A	X	X	V	X	X
A12													A	O	X	X	X	V
A13														A	X	V	X	V
A14															O	X	X	O
A15																X	X	A
A16																	X	X
A17																		X
A18																		

Participant 6

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1		X	O	A	X	A	X	X	A	A	O	A	O	V	A	O	A	O
A2			O	A	O	O	A	V	O	A	O	V	O	O	O	O	O	O
A3				O	O	O	O	O	O	O	A	O	O	O	O	O	O	O
A4					V	A	X	A	A	A	V	A	A	O	A	O	A	O
A5						O	X	O	O	O	X	O	O	O	V	O	A	O
A6							X	A	V	A	V	A	A	O	V	X	A	A
A7								A	O	X	V	X	X	O	V	V	X	O
A8									V	V	O	V	X	O	X	V	V	V
A9										A	O	V	A	O	A	O	X	O
A10											V	X	X	O	X	X	X	V
A11												A	O	O	A	A	A	O
A12													X	O	X	A	X	O
A13														O	X	V	X	O
A14															O	O	O	O
A15																O	X	O
A16																	A	X
A17																		O
A18																		

E. Rules transformation SSIM into reachability matrix

SSIM	Reachability matrix	
	Variable i affects variable j	Variable j affects variable i
V	1	0
A	0	1
X	1	1
O	0	0

F. Initial reachability matrix of merged SSIM

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1	1	0	1	0	0	0	1	1	0	0	0	0	0	1	0	0	1	1
A2	1	1	0	1	0	0	1	0	1	1	1	1	0	0	0	0	0	0
A3	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
A4	1	1	0	1	1	0	1	0	0	1	1	0	0	0	0	1	1	1
A5	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
A6	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
A7	1	0	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0
A8	1	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0
A9	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A10	1	1	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0
A11	1	0	1	0	1	0	1	0	0	1	1	0	0	0	1	1	1	0
A12	1	1	1	1	1	1	0	0	0	1	0	1	0	0	1	1	0	0
A13	0	1	0	1	1	1	0	0	1	1	0	0	1	0	0	0	0	0
A14	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0
A15	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1
A16	1	0	1	0	0	1	0	0	0	0	1	1	0	0	0	1	0	1
A17	1	1	1	1	1	1	0	0	0	0	1	0	0	0	1	1	1	1
A18	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1

G. Partitioning of levels output

Variable_Names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A1	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17 A18	1
A2	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17 A18	A1 A2 A3 A4 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17	A1 A2 A3 A4 A6 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17	0
A3	A1 A2 A3 A4 A5 A6 A10 A12 A15 A16	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A3 A4 A5 A6 A10 A12 A15 A16	1
A4	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17 A18	1
A5	A1 A3 A4 A5 A6 A7 A8 A10 A11 A14 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A3 A4 A5 A6 A7 A8 A10 A11 A14 A17 A18	1
A6	A1 A2 A3 A4 A5 A6 A7 A8 A10 A11 A12 A14 A16 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A10 A11 A12 A14 A16 A17 A18	1
A7	A1 A2 A3 A4 A5 A6 A7 A8 A10 A11 A12 A14 A15 A16 A17 A18	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A4 A5 A6 A7 A8 A10 A11 A12 A14 A15 A16 A17 A18	0
A8	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A16 A17 A18	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A15 A16 A17 A18	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A16 A17 A18	0
A9	A1 A2 A3 A4 A5 A7 A8 A9 A10 A11 A12 A14 A16 A17 A18	A1 A2 A4 A8 A9 A10 A11 A12 A13 A14 A15 A17	A1 A2 A4 A8 A9 A10 A11 A12 A14 A17	0
A10	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A17 A18	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A17	0
A11	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17	0
A12	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A3 A4 A6 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17 A18	A1 A2 A3 A4 A6 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17 A18	0
A13	A1 A2 A3 A4 A5 A6 A7 A9 A10 A11 A12 A13 A16 A17 A18	A11 A12 A13 A15 A17	A11 A12 A13 A17	0
A14	A1 A2 A3 A4 A5 A6 A7 A9 A10 A14	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17 A18	A1 A2 A4 A5 A6 A7 A9 A10 A14	0
A15	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A3 A4 A7 A11 A12 A15 A16 A17	A1 A2 A3 A4 A7 A11 A12 A15 A16 A17	0
A16	A1 A2 A3 A4 A5 A6 A7 A8 A10 A11 A12 A14 A15 A16 A17 A18	A1 A2 A3 A4 A6 A7 A8 A9 A11 A12 A13 A15 A16 A17	A1 A2 A3 A4 A6 A7 A8 A11 A12 A15 A16 A17	0
A17	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17 A18	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17 A18	0
A18	A1 A3 A4 A5 A6 A7 A8 A12 A14 A17 A18	A1 A2 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17 A18	A1 A4 A5 A6 A7 A8 A12 A17 A18	0

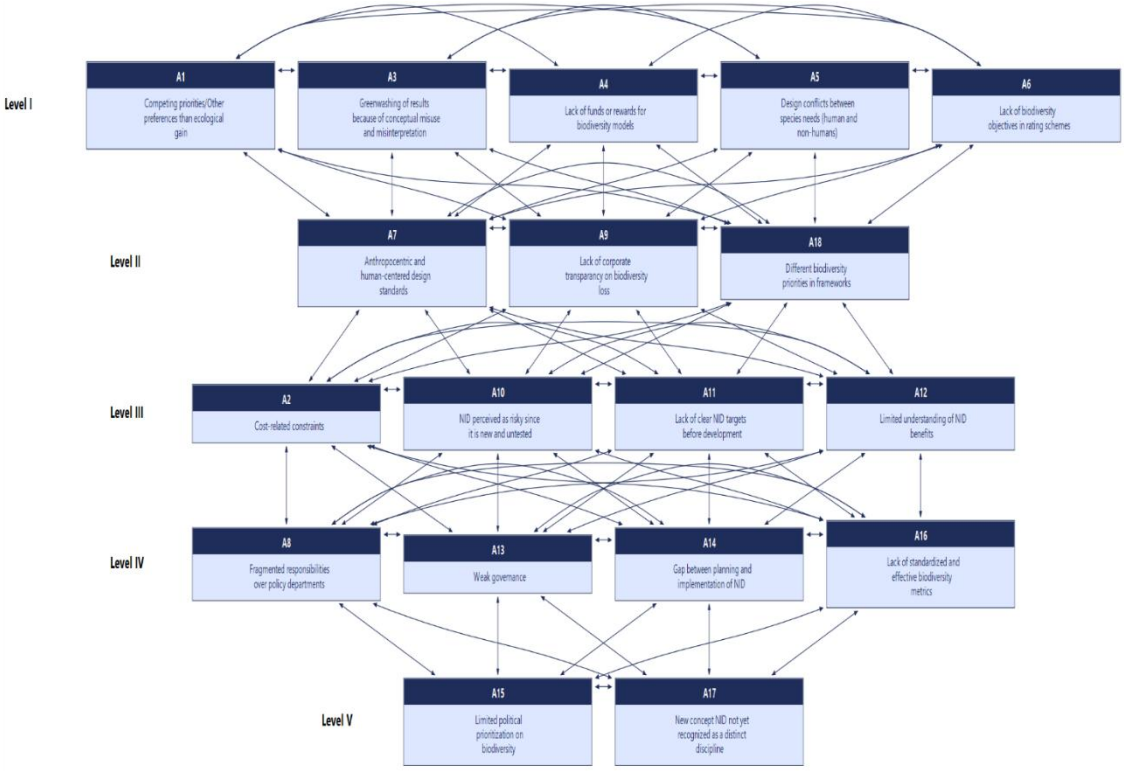
Variable_Names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A2	A2 A7 A8 A9 A10 A11 A12 A15 A16 A17	A2 A7 A8 A10 A11 A12 A13 A14 A15 A16 A17	A2 A7 A8 A10 A11 A12 A15 A16 A17	0
A7	A2 A7 A8 A10 A11 A15 A16 A17	A2 A7 A8 A10 A11 A12 A13 A14 A15 A16 A17	A2 A7 A8 A10 A11 A15 A16 A17	1
A8	A2 A7 A8 A9 A10 A11 A12	A2 A7 A8 A10 A11	A2 A7 A8 A10 A11	0
A9	A9	A2 A8 A9 A10 A11 A12 A13 A14 A15 A17	A9	1
A10	A2 A7 A8 A9 A10 A11 A12	A2 A7 A8 A10 A11 A12 A13 A14 A15 A16 A17	A2 A7 A8 A10 A11 A12	0
A11	A2 A7 A8 A9 A10 A11 A12 A13 A15 A16 A17 A18	A2 A7 A8 A10 A11 A12 A13 A15 A16 A17	A2 A7 A8 A10 A11 A12 A13 A15 A16 A17	0
A12	A2 A7 A9 A10 A11 A12 A13 A15 A16 A17 A18	A2 A8 A10 A11 A12 A13 A15 A16 A17	A2 A10 A11 A12 A13 A15 A16 A17	0
A13	A2 A7 A9 A10 A11 A12 A13	A11 A12 A13 A15 A17	A11 A12 A13	0
A14	A2 A7 A9 A10 A14	A14	A14	0
A15	A2 A7 A9 A10 A11 A12 A13 A15 A16 A17 A18	A2 A7 A11 A12 A15 A16 A17	A2 A7 A11 A12 A15 A16 A17	0
A16	A2 A7 A10 A11 A12 A15 A16 A17 A18	A2 A7 A11 A12 A15 A16 A17	A2 A7 A11 A12 A15 A16 A17	0
A17	A2 A7 A9 A10 A11 A12 A13 A15 A16 A17 A18	A2 A7 A11 A12 A15 A16 A17	A2 A7 A11 A12 A15 A16 A17	0
A18	A18	A11 A12 A15 A16 A17 A18	A18	1

Variable_Names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A2	A2 A10 A11 A12 A15 A16 A17	A2 A8 A10 A11 A12 A13 A14 A15 A16 A17	A2 A10 A11 A12 A15 A16 A17	1
A8	A2 A8 A10 A11 A12	A8	A8	0
A10	A2 A10 A11 A12	A2 A8 A10 A11 A12 A13 A14 A15 A16 A17	A2 A10 A11 A12	1
A11	A2 A10 A11 A12 A13 A15 A16 A17	A2 A8 A10 A11 A12 A13 A15 A16 A17	A2 A10 A11 A12 A13 A15 A16 A17	1
A12	A2 A10 A11 A12 A13 A15 A16 A17	A2 A8 A10 A11 A12 A13 A15 A16 A17	A2 A10 A11 A12 A13 A15 A16 A17	1
A13	A2 A10 A11 A12 A13	A11 A12 A13 A15 A17	A11 A12 A13	0
A14	A2 A10 A14	A14	A14	0
A15	A2 A10 A11 A12 A13 A15 A16 A17	A2 A11 A12 A15 A16 A17	A2 A11 A12 A15 A16 A17	0
A16	A2 A10 A11 A12 A15 A16 A17	A2 A11 A12 A15 A16 A17	A2 A11 A12 A15 A16 A17	0
A17	A2 A10 A11 A12 A13 A15 A16 A17	A2 A11 A12 A15 A16 A17	A2 A11 A12 A15 A16 A17	0

Variable_Names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A8	A8	A8	A8	1
A13	A13	A13 A15 A17	A13	1
A14	A14	A14	A14	1
A15	A13 A15 A16 A17	A15 A17	A15 A17	0
A16	A16	A15 A16 A17	A16	1
A17	A13 A15 A16 A17	A15 A17	A15 A17	0

Variable_Names	Reachability_Set	Antecedents_Set	Intersection_Set	Level
A15	A15 A17	A15 A17	A15 A17	1
A17	A15 A17	A15 A17	A15 A17	1

H. ISM model with all relational arrows generated by RStudio



I. Driving and dependence power of the final reachability matrix

Driving power:

Barrier	Value
A1	17
A2	17
A3	10
A4	17
A5	12
A6	15
A7	16
A8	16
A9	15
A10	15
A11	18
A12	18
A13	15
A14	10
A15	18
A16	16
A17	18
A18	11

Dependence power:

Barrier	Value
A1	18
A2	16
A3	18
A4	18
A5	18
A6	17
A7	17
A8	15
A9	12
A10	17
A11	15
A12	16
A13	5
A14	16
A15	10
A16	14
A17	16
A18	16

J. Results interview one part II

	Nesting stones for birds on facade	Bat enclosures in facade	Insect hotels/stones	Extensive green roof	Intensive green roof	Nature roof	Brown roof	Water roof	Green facade	Facade garden
Competing priorities/Other preferences than ecological gain	1,47	1,61	1,89	2,81	4,22	3,97	3,42	3,22	3,53	1,72
Cost-related constraints	1,11	1,22	1,22	3,00	4,78	4,11	3,56	4,56	4,00	1,67
Greenwashing of results because of conceptual misuse and misinterpretation	3,67	3,56	3,22	2,56	2,11	1,78	1,78	1,67	2,78	1,78
Lack of funds or rewards for biodiversity models	1,11	1,22	1,22	2,89	4,67	4,11	3,56	4,44	3,78	1,78
Design conflicts between species needs (human and non-humans)	2,25	2,75	2,50	1,63	2,25	2,00	2,00	2,00	2,63	2,13
Lack of corporate transparancy on biodiversity loss	1,83	1,83	1,83	2,33	2,50	2,33	2,17	2,17	2,33	2,00
Lack of biodiversity objectives in rating schemes	2,43	2,71	3,14	2,14	3,57	3,43	3,43	3,29	3,14	2,43

Anthropocentric and human-centered design standards	2,00	2,14	2,29	2,14	2,71	2,43	2,14	2,29	2,43	2,14
Fragmented responsibilities over policy departments	1,71	1,86	1,86	3,00	3,86	3,86	4,14	4,14	3,71	2,29
Limited understanding of NID benefits	1,80	1,80	2,00	2,40	3,60	3,40	3,60	3,40	3,80	2,80
NID perceived as risky since it is new and untested	1,50	1,50	1,50	2,33	4,00	3,17	3,50	4,00	3,67	1,67
Weak governance	2,20	2,20	2,20	2,80	4,60	4,60	4,60	4,60	4,00	2,40
Lack of clear NID targets before development	2,00	2,00	2,00	3,00	4,17	4,17	3,83	4,17	3,67	1,67
Gap between planning and implementation of NID	1,80	1,80	1,80	2,60	3,40	3,00	2,80	3,20	2,80	1,60
Limited political prioritization on biodiversity	2,20	2,20	2,20	3,00	4,00	4,00	4,00	4,00	3,40	2,60
Lack of standardized and effective biodiversity metrics	2,20	2,20	2,20	2,60	4,20	3,80	3,40	4,20	3,80	1,80

New concept NID not yet recognized as a distinct discipline	2,80	2,80	4,00	2,40	3,80	4,00	4,00	3,80	3,80	2,80
Different biodiversity priorities in frameworks	1,80	2,00	2,00	2,80	4,40	4,40	4,40	4,40	3,40	2,40

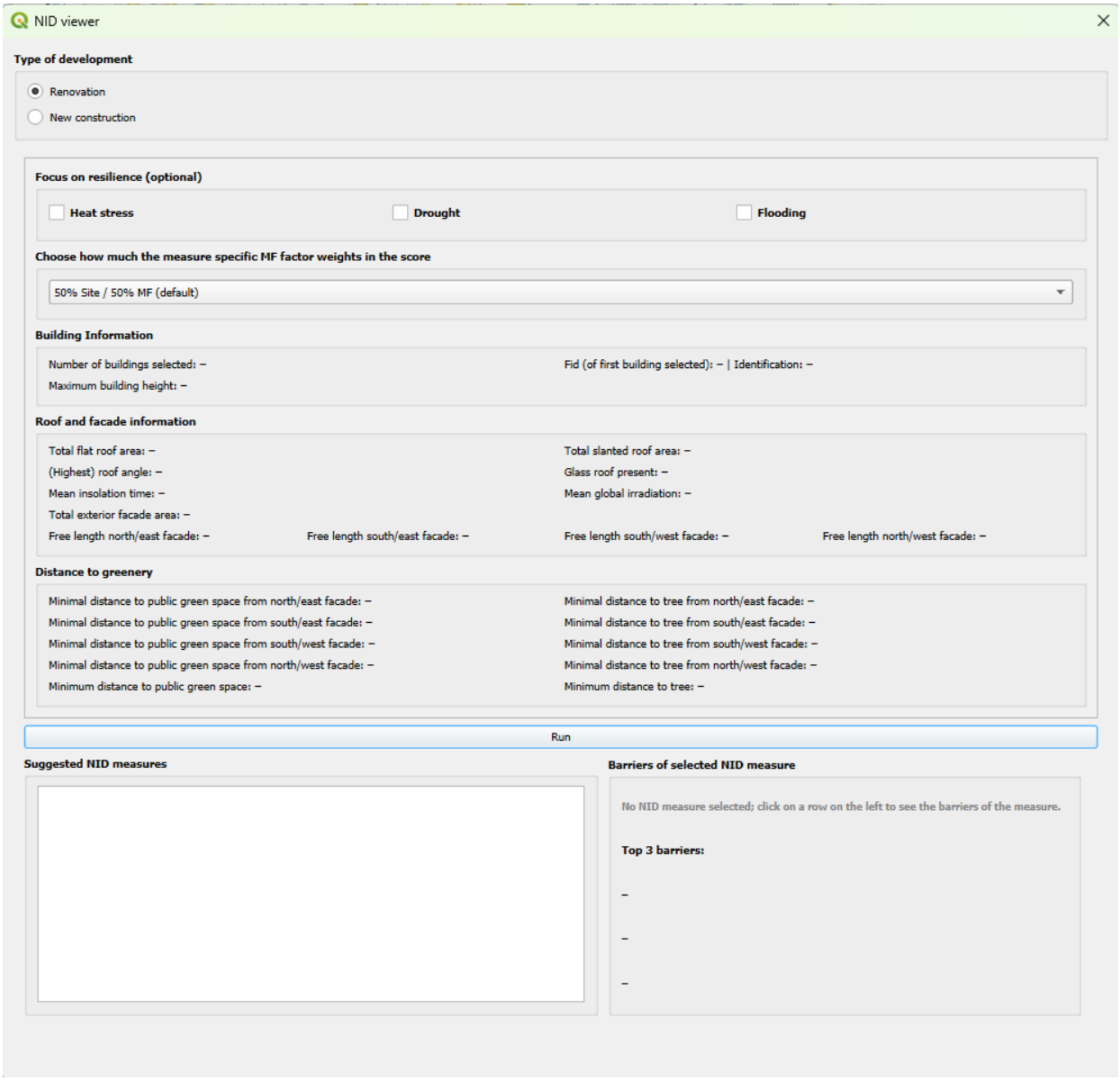
K. Results of interview one part II from the separate barriers 'Competing priorities' and 'Other preferences than ecological gain', and the mean forming the merged barrier

	Nesting stones for birds on facade	**Bat enclosures in facade**	**Insect hotels/stones**	**Extensive green roof**	**Intensive green roof**	**Nature roof**	**Brown roof**	**Water roof**	**Green facade**	**Facade garden**
Competing priorities	1,44	1,56	1,78	2,78	4,11	4,11	3,33	3,44	3,56	1,78
Other preferences than ecological gain	1,50	1,67	2,00	2,83	4,33	3,83	3,50	3,00	3,50	1,67
Competing priorities/Other preferences than ecological gain (mean of both)	1,47	1,61	1,89	2,81	4,22	3,97	3,42	3,22	3,53	1,72

L. Map sheets covering Eindhoven, downloaded from the National Height Model of the Netherlands (AHN)

AHN:	Model type, resolution:	Map sheet code:
AHN4	Surface model, 0.5m	R_51GN2
AHN4	Surface model, 0.5m	R_51GZ1
AHN4	Surface model, 0.5m	R_51EZ1
AHN4	Surface model, 0.5m	R_51GN1
AHN4	Surface model, 0.5m	R_51BZ2
AHN4	Surface model, 0.5m	R_51DN1
AHN4	Surface model, 0.5m	R_51DZ2
AHN4	Surface model, 0.5m	R_51DN2

M. Empty GUI of the NID viewer plug-in



N. Checks performed for the NID measures on position 1 in Figure 7

Bat enclosures

- Free facade at SW/NE preferred (≥ 3 m): SW=**8.7 m**, NE=**0.1 m**
- Building height ≥ 4.0 m: **27.4 m**
- Bonus for proximity of public green space/trees applied.

Green facade

- **29.7 m** total free facade (sum of all sides).
- Total exterior facade area ≥ 50 m^2: **282.8 m^2**
- Best oriented free facade (for cooling): SW (south/west) = **8.7 m**
- Solar check (**insolation≥4 h/d**, **irradiation≥1000 Wh/m^2/d**): **both OK**

Insect hotel/stones

- Free facade at SW/SE preferred (≥ 3 m): SW=**8.7 m**, SE=**10.4 m**
- Bonus for proximity of public green space/trees applied.

Nesting stones for birds

- Free facade at NE/NW preferred (≥ 3 m): NE=**0.1 m**, NW=**10.5 m**
- Building height ≥ 3.0 m: **27.4 m**
- Bonus for proximity of public green space/trees applied.

O. Scores table NID viewer plug-in

1. Base checks:

ID	NID option	Roof area ≥30 m² (1=OK)	Roof not glass (1=OK)	high Slope Roofs	low Slope Roofs	flat Roofs	Insolation ≥4 h/day (1=OK)	Irradiation ≥1000 Wh/m²/d (1=OK)	Exterior facade area ≥ 50m2	Free facade ≥3 m (NE)	Free facade ≥3 m (SE)	Free facade ≥3 m (SW)	Free facade ≥3 m (NW)	Height ≥3 m (birds) (1=OK)	Height ≥4 m (bats) (1=OK)
1	Nesting stones for birds on facade	0	0	0	0	0	0	0	0	1	0	0	1	1	0
2	Bat enclosures in facade	0	0	0	0	0	0	0	0	1	0	1	0	0	1
3	Insect hotels in facade	0	0	0	0	0	0	0	0	0	1	1	0	0	0
4	Extensive green roof	1	1	0	1	1	1	1	0	0	0	0	0	0	0
5	Intensive green roof	1	1	0	0	1	1	1	0	0	0	0	0	0	0
6	Nature roof	1	1	0	0	1	1	1	0	0	0	0	0	0	0
7	Brown roof	1	1	0	1	1	0	0	0	0	0	0	0	0	0
8	Water roof	1	1	0	0	1	0	0	0	0	0	0	0	0	0
9	Green facades	0	0	0	0	0	1	1	1	1	1	1	1	0	0
10	Facade garden	0	0	0	0	0	1	1	0	1	1	1	1	0	0

2. Nearby green space bonus

ID	NID option	Nearby green space/tree <5 m (bonus +1)
1	Nesting stones for birds on facade	1
2	Bat enclosures in facade	1
3	Insect hotels in facade	1
4	Extensive green roof	0
5	Intensive green roof	0
6	Nature roof	0
7	Brown roof	0
8	Water roof	0
9	Green facades	0
10	Facade garden	0

3. Multi-functional land use value

ID	NID option	enables Multi-functional LandUse
1	Nesting stones for birds on facade	6
2	Bat enclosures in facade	6
3	Insect hotels in facade	6
4	Extensive green roof	5
5	Intensive green roof	5
6	Nature roof	5
7	Brown roof	5
8	Water roof	4
9	Green facades	6
10	Facade garden	5

4. Effect bonus heat stress, drought and flooding

ID	NID option	cooling	heat Prevention	heat Coping	drought Prevention	drought Coping	flood Prevention	flood Coping
1	Nesting stones for birds on facade	0	0	0	0	0	0	0
2	Bat enclosures in facade	0	0	0	0	0	0	0
3	Insect hotels in facade	0	0	0	0	0	0	0
4	Extensive green roof	2	1	1	0	0	1	0
5	Intensive green roof	4	1	1	1	1	1	0
6	Nature roof	4	1	1	1	1	1	0
7	Brown roof	1	1	0	0	0	1	0
8	Water roof	4	1	1	0	0	0	0
9	Green facades	3	0	1	0	0	0	0
10	Facade garden	1	1	0	0	0	1	0

P. Tool evaluation session

NID viewer tool evaluation

Goal: Assess whether the QGIS “NID viewer” plug-in helps users (i) interpret the right building- and location-specific conditions, (ii) prioritize NID measures with its barriers and (iii) connect outputs to project or policy decisions.

Participants and setting

Participant(s) will be from Brink Management/Advies.

It will be done via a desktop session in QGIS on my laptop with the plug-in installed (on location).

Materials

- QGIS and plug-in;
- Datasets used by the plug-in (BAG3D:lod22 Eindhoven, insolation time and insolation-irradiation rasters, “bomen” and “openbaar groen” Eindhoven);

Measures

- Task completion and remarks;
- Evaluation questions;
- System Usability Scale (SUS) (John Brooke, 1996)

Procedure

0. Intro & consent

- Explain purpose (tool evaluation, not user testing).
- Obtain consent for note-taking/screen recording (if applicable).
- Ask the participant's role and experience with QGIS/NID (1–2 minutes).

1. Brief orientation

- 60-second tour of the UI (where to open the plug-in)
- Remind them: "Please think aloud while you work."

2. Tasks

T1: Run on a single building (or multiple buildings)

1. Select the *BAG3D:lod22 Eindhoven* layer and pick one building.
2. Open NID viewer plug-in and click Run.
3. Which NID measure would you choose and why?

T2: Explore scoring logic

1. Hover over the recommended measures to read the checks; explain what helped or confused you.
2. Toggle the resilience focus (heat/drought/flood) and *describe what changes* and whether that makes sense.

T3: Evaluation questions

1. Is the tool usable and understandable?
2. Are the recommendations/barrier lists perceived as relevant and trustworthy?
3. Do the outputs in the tool fit decision-making processes in existing workflows?
4. Assume this is concept phase. What would you export or copy into your internal decision-making? What is missing?
5. Would you use this in practice, and if not, what would stop you?
6. What was most/least useful?

T4: System Usability Scale (John Brooke, 1996)

Answer on a Likert scale 1-5 (1 = strongly disagree, 5 = strongly agree).

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

Q. Answers plug-in evaluation

1. T1, T2 and T3

Task	Question	Participant	Answer
T1	1	1	Groene gevel, deze scoort het beste en aangezien ik het gebouw ken, begrijp ik waarom dit als beste optie naar voren komt.
		2	Geveltuin, insectenhotel of vogelkasten, want deze staan bovenaan en ik weet dat deze mogelijk zijn op dit gebouw. Een groene gevel is wel lastig hier, want het gebouw heeft veel glas op de gevels.
		3	Groen dak, aangezien deze bovenaan staat en ik weet dat dit mogelijk is op dit gebouw.
T2	1	1	Dat de tool 3 vd 4 gevels aangeeft, terwijl het een rijtjeshuis is. Na even bekijken zagen we dat dit kwam door de uitbouw.
		2	De rode en groene checks helpen bij het begrijpen van hoe de tool de scores toekent aan de maatregelen.
		3	Groen/ rode duiding maakt heel snel helder waarom iets goed scoort. Data maakt het direct kwantitatief en objectief. Wat ik verwarrend vind is dat bijvoorbeeld bij de groene gevel wordt aangegeven dat het hoog scoort in verband met het gevel oppervlak terwijl het gevel oppervlak juist bij een rijwoning (die ik had geselecteerd) beperkt is.
	2	1	'Flooding' gekozen. Hierdoor kwam de maatregel geveltuin bovenaan te staan, eerst was dit op plek 2. Dit klinkt zeker logisch aangezien een geveltuin resulteert in minder verharding.
		2	De geveltuin komt nu alleen bovenaan te staan. Dit begrijp ik, want dit houdt als enige optie die bovenaan stond water vast.
		3	Groen dak komt nadrukkelijker naar voren. Dat begrijp ik want dit houdt water vast.
T3	1	1	Zeker, het is natuurlijk wel handig dat je er nu direct bij zit, zodat je nog extra toelichting kan geven en kan helpen met waar ik op moet klikken.
		2	Ja de tool is met uitleg goed te begrijpen. Ik zou wel een A4'tje met begrippenlijst van de maatregelen en barrières toevoegen.
		3	De tool is begrijpbaar. Om het bruikbaar te maken moet nog beter worden onderzocht met welk doel en door wie. Waarom is het nodig om data te gebruiken en is een menselijke blik niet voldoende of toereikend?
	2	1	Recommendations: de voorgestelde maatregelen lijken zeker relevant, aangezien dit veelvoorkomende maatregelen zijn. Omdat het reguliere maatregelen zijn, is het ook 'trustworthy'. Barriers: Ik denk dat de barrières wat moeilijker in te schatten zijn of het echt relevant is. Het is logisch dat politiek invloed heeft op hoeveel maatregelen worden gestimuleerd, maar maakt dit op projectniveau ook echt uit? Ook is het niet duidelijk wat de andere barrières zijn, en of deze dan logischer zijn voor de maatregelen.

	2	De maatregelen zijn duidelijk en een goede optie voor het huis. Allen de maatregel green façade is niet helemaal representatief, die scoort nu hoog terwijl de gevel veel glas bevat. Als er een A4'tje met toelichting is van de barrières is het duidelijker wat er mee bedoeld wordt. Verder wel interessant om te zien wat de barrières zijn.
	3	Ze zijn begrijpbaar maar omdat ze nog vrij hoogover en algemeen zijn, bieden ze (nog) niet veel extra verdiepende waarde.
3	1	Ja, bij veel gemeenten willen ze stappen zetten voor biodiversiteit, maar hebben soms niet helemaal duidelijk hoe ze dit (op gebouwniveau) kunnen uitvoeren. De tool zou een eerste stap kunnen zijn, om inzichtelijk te krijgen wat er überhaupt mogelijk is op hun vastgoed.
	2	Ja het snel inzichtelijk maken van toepasbare materialen op basis van de data die door de tool gebruikt wordt is zeker nuttig om snel beslissingen te maken. Het laat namelijk makkelijk zien wel maatregelen geschikt of niet geschikt zijn en waarom.
	3	Hangt ervan af in welke fase. Als je een portefeuille manager bent met veel bezit die zoekt welke maatregelen het meeste potentie biedt voor zijn of haar portefeuille dan wel.
4	1	Ik zou de maatregelen en de checks meenemen. De informatie is relevant en waardevol. Ik zou ook wel een volledige lijst willen zien van alle mogelijke maatregelen, en waarom bepaalde dan uitgesloten zijn. Ook mis ik wat context, stel ik zou dit helemaal alleen moeten gebruiken, dan zou meer instructies handig zijn.
	2	De rangorde van de maatregelen zou ik gebruiken om keuzes op te baseren. Daarbij zou ik ook alle gegevens die hierbij berekend worden gebruiken. Dus de informatie van het gebouw, het dak, de gevel en de afstand tot groen plus de informatie die bij iedere maatregel staat. De barrières zou ik meer ter informatie of als aandachtspunt meenemen.
	3	Alle uitkomsten behalve de barrières. Die zijn nog te vaag en zou ik daarbij als algemene aandachtspunten meegeven.
5	1	Ja, dit zou ik gebruiken.
	2	Ja ik zou dit gebruiken in de praktijk.
	3	Als het wordt doorontwikkeld om mijn specifieke doel te dienen wel. Bijvoorbeeld om potentie te ontdekken in een gebied of portefeuille.
6	1	Vooral het inzicht in de mogelijkheden, zeker omdat dit direct gecombineerd is met bepaalde voorwaarden die gelden voor natuurinclusieve maatregelen
	2	Het meest handige is de lijst met maatregelen, je krijgt hierdoor snel zicht op wat goed toegepast kan worden en wat niet. Het minst handige is de barrière lijst, omdat deze toch wat toelichting vergt en minder concreet toegepast kan worden. Zoals

	hierboven benoemd zou ik dit meer gebruiken ter informatie of als aandachtspunt.
3	Most: het direct inzichtelijk maken van de data Least: de wat hoogover barrières

2. T4 (SUS)

Participant 1

Question	Answer	Score
1	5	4
2	3	2
3	3	2
4	1	4
5	4	3
6	1	4
7	3	2
8	1	4
9	2	1
10	3	2
	Total:	28

SUS = 2.5 x 28 = 70

Participant 2

Question	Answer	Score
1	5	4
2	2	3
3	3	2
4	2	3
5	3	2
6	2	3
7	4	3
8	2	3
9	4	3
10	2	3
	Total:	29

SUS = 2.5 x 29 = 72.5

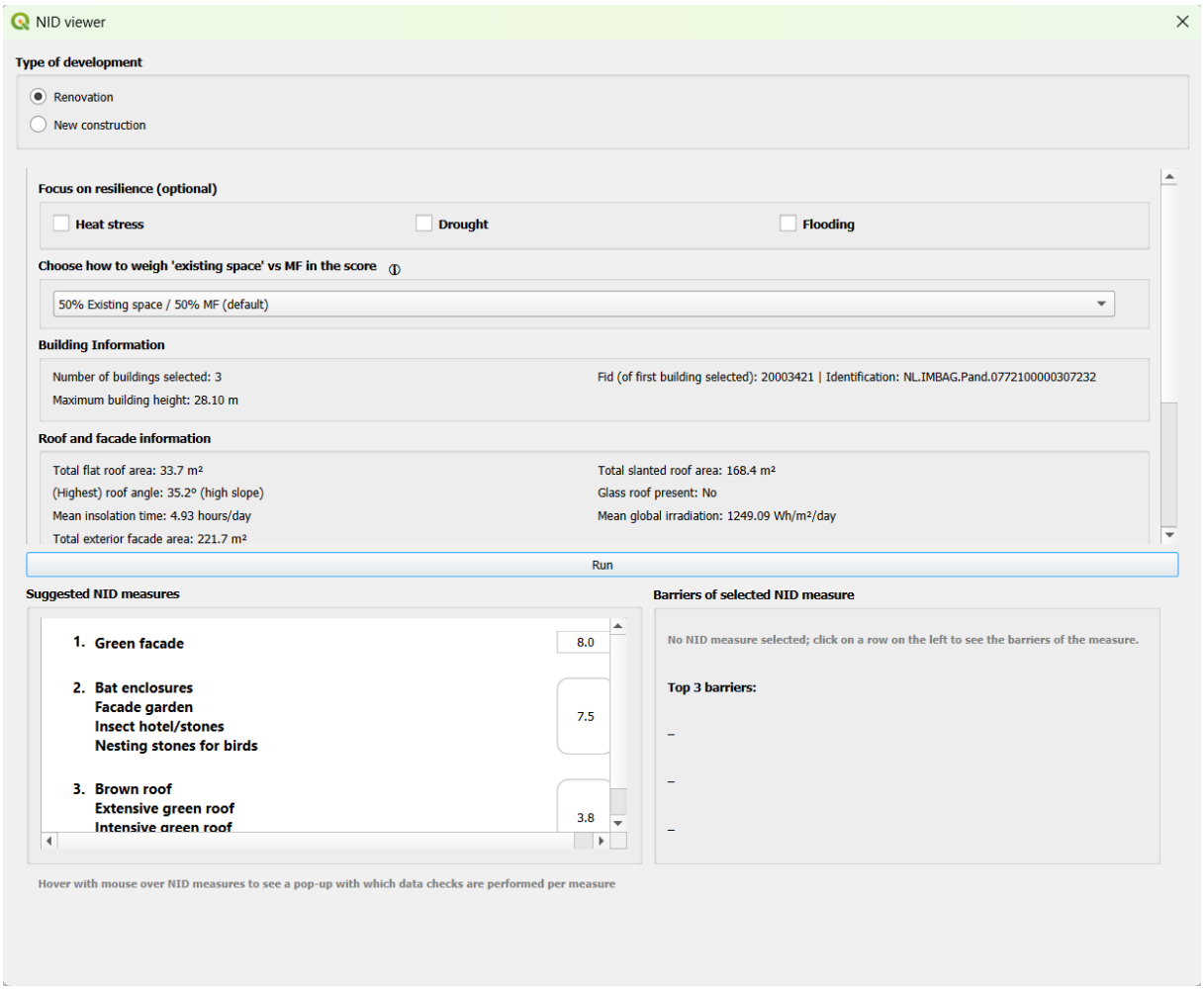
Participant 3

Question	Answer	Score
1	3	2
2	1	4
3	5	4
4	1	4
5	3	2
6	1	4
7	3	2
8	2	3
9	5	4
10	1	4
	Total:	33

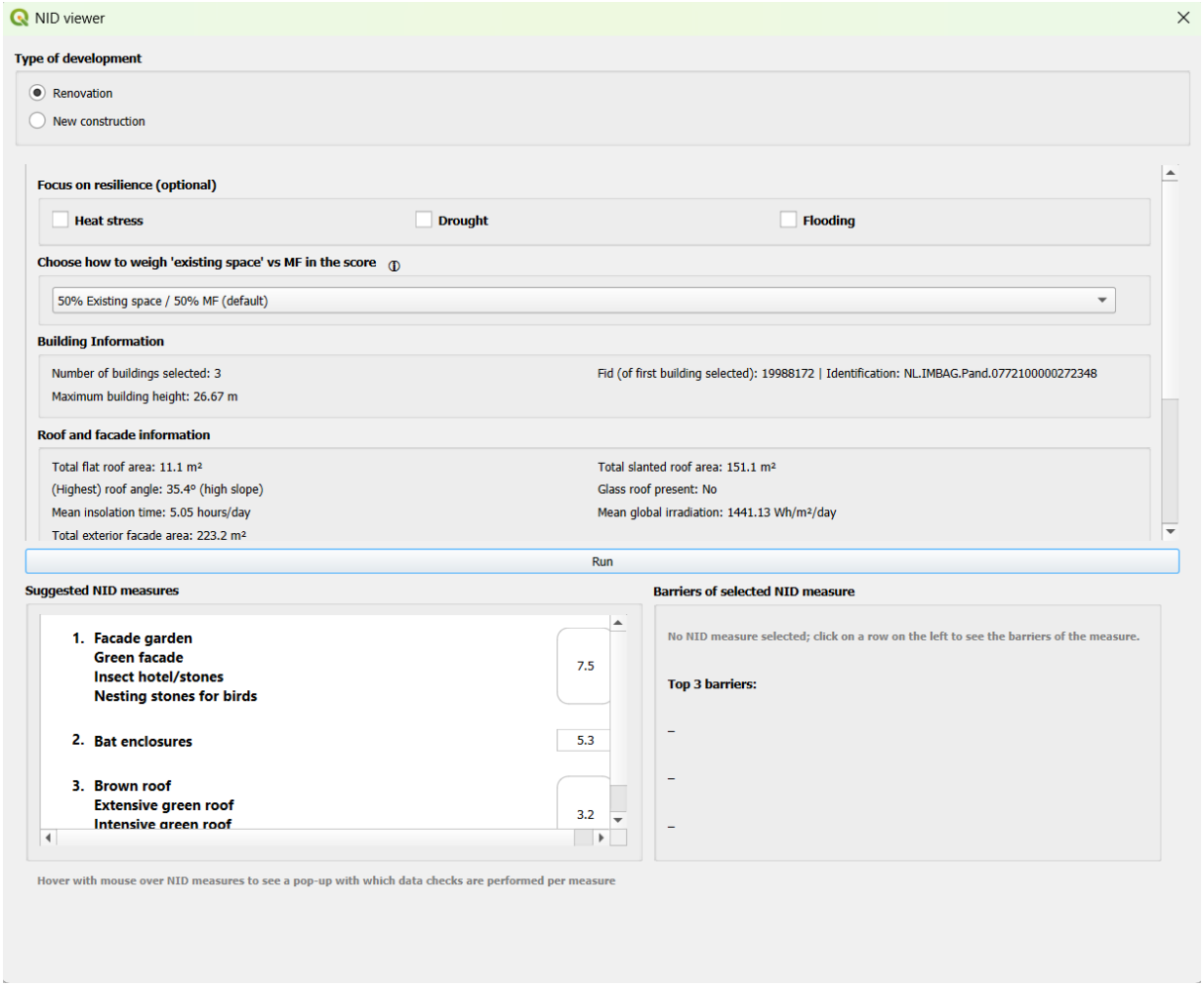
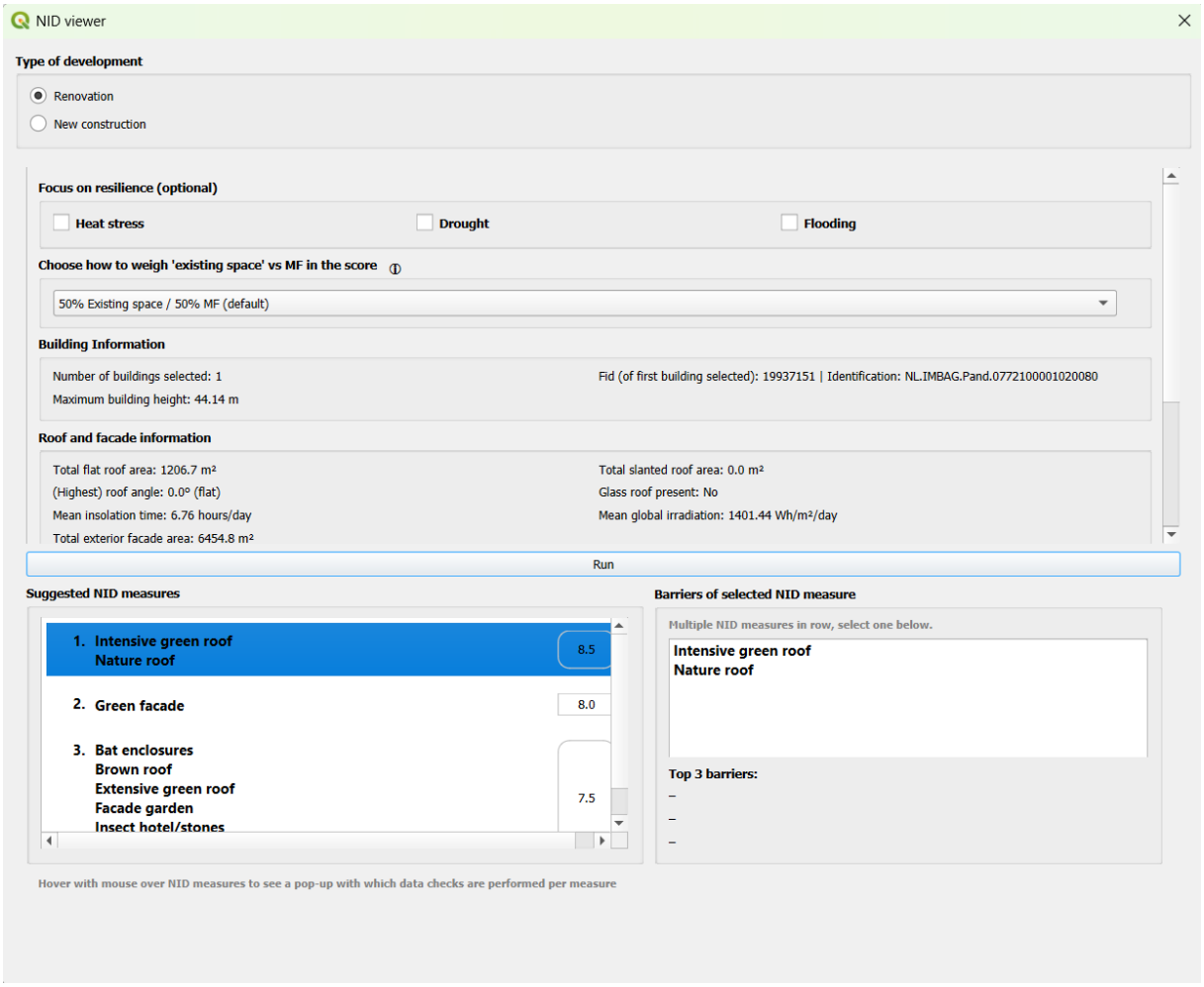
SUS = 2.5 x 33 = 82.5

R. GUI of the NID viewer plug-in containing the first run of each participant

Participant 1:



Participant 2:



Participant 3: