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The architecture of procurement in sustainable and zero-emission neighborhood projects—strategic challenges and new realities

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Abstract
As an intermediate layer located between buildings and cities, neighborhoods are considered critical with regard to the transition to low-carbon cities and zero-emission societies. Sustainable and zero-emission neighborhood (ZEN) projects can be characterized as both complex and multi-organizational. However, there is currently only limited research available concerning collaboration among organizations in relation to ZEN projects. In particular, there is a lack of evidence as to how lead organizations arrange procurement for ZEN projects. Using a case study approach, this paper explores the potential of procurement to serve as a system integrator in ZEN projects. Our findings indicate that system integration by means of procurement in ZEN projects is difficult due to several challenges. Among the identified challenges, the most important are the complex ownership structure, the lack of supporting regulations, and the unclear mandate of the procurement department. In light of these findings, we propose a conceptual model that lead organizations could apply to support the realization of ZEN projects.

Keywords Procurement · Zero-emission neighborhoods · Sustainable neighborhoods · Modularity · ZEN

1 Introduction

In response to the challenges associated with achieving sustainability, a growing number of sustainable and zero-emission neighborhoods (ZENs) are being developed worldwide. As an intermediate layer located between buildings and cities, neighborhoods are considered critical in relation to the transition to low-carbon cities and zero-emission societies (Hamdan et al. 2021a, b; Koch et al. 2012; Oliver 2018; Skaar et al. 2018; Wiik et al. 2018, 2021). Providing and coordinating the correct amount and quality of materials and services at the right time plays a pivotal role in achieving the goals of ZEN projects.

A ZEN project is considered to be a complex, long-lived, and multi-organizational endeavor. It involves a group of interconnected building and infrastructure projects, complex sustainability goals, and many actors with different interests and heterogeneous ownership forces. Adding to the collaboration complexity of ZEN projects, compared to more traditional construction projects, is the fact that they are relatively new projects or constitute "uncharted territory". This may raise new issues or exacerbate existing problems associated with traditional construction projects (Hamdan et al. 2021a, b). Project stakeholders consistently face challenges related to interorganizational collaboration when addressing issues related to energy and zero-emissions goals. The additional problems created by focusing on zero-emissions goals interact with other existing problems. An example would be delayed delivery of items, which could lead to more transportation to the construction site and thus increased CO_2 emissions (Chkanikova 2016). Complexity also implies a learning and emergence problem, as many of the items and services being purchased are new to decision makers and have not been adequately practiced by providers (McQuiston 1989). In addition, previous research has shown that more decision-making criteria are involved in sustainable purchasing, as the purchased offering must meet additional parameters compared to conventional offerings (Igarashi et al. 2015). This complexity in ZEN projects often causes project managers and developers to adopt inadequate

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collaborative strategies and practices, which can lead to inefficiency and, in some cases, failure (Canosa Zamora and García Carballo 2018; Gansmo 2012).

The current literature concerning ZENs principally focuses on sustainability principles, energy efficiency, assessment tools, carbon emissions, social housing, user participation, and urban policy. As a result, there is a dearth of research on the nature and dynamics of interorganizational collaboration in ZEN projects. In fact, very little is known about how different types of project procurements coexist or are coordinated within the same project in order to achieve ambitious goals (Hamdan et al. 2021a, b). Moreover, it seems that no attention has been paid to procurement and purchasing management in the prior research on complex projects (Caldwell et al. 2009; Hamdan et al. 2021a, b). This is surprising given that complex construction projects require exceptional organizational and project management skills due to their inherent complexity, with there generally being a high degree of dependence on external suppliers and contractors.

Building on procurement's key role in complex collaboration, the present study frames purchasing management as a system integration issue in the context of ZENs. System integration represents a common approach to managing complexity in multi-project contexts (Davies and Mackenzie 2014). Considering procurement from a system integration perspective can help to better visualize the benefits or challenges associated with collaboration and coordination within a ZEN project supply chain. We question whether system integration by means of procurement at the neighborhood level could serve to foster benefits or buffers able to help reduce the complexity of collaboration in relation to ZEN projects. Such knowledge may prove valuable to lead organizations and developers operating in complex environments, supporting their roles as key drivers of change within the construction industry (Blayse and Manley 2004; van Zoest et al. 2019). In our study of systems integration, we also apply the principles of modularity (Baldwin and Clark 2003) in an effort to understand how ZEN procurement tasks can be connected into a coherent procurement system capable of supporting both system integration and the ZEN mission. In this study, we use the term "lead organization" to describe the organization that initiates the development of a ZEN and then coordinates development efforts between different subprojects and developers.

We extend the procurement literature by lifting the perspective to the neighborhood level and determining how procurement can operate at that level. By analyzing four ongoing high-profile ZEN projects in Norway, we identify several challenges that explain why system integration by means of procurement is difficult in ZEN projects. Among the identified challenges, the most important are the complex ownership structure, the lack of supporting regulations, and the unclear mandate of the procurement department. In light of these challenges, we propose a conceptual model of ZEN procurement that developers as well as project managers and purchasers within lead organizations could use to implement and audit the integration of purchasing tasks and processes, thereby supporting the realization of ZEN projects.

The remainder of this paper is organized as follows. First, after reviewing the relevant literature, we present the theoretical framework for the study in Sect. 2. Then, in Sects. 3 and 4, we describe our empirical setting and set out the findings of the study, respectively. In Sect. 5, we discuss the implications of the findings with regard to the research questions, after which we offer some concluding remarks and suggestions for future research in Sect. 6.

2 Theoretical background

In this section, we will first take a closer look at the complexity of ZENs, describe the procurement process for ZENs, and discuss the logic of applying system integration in relation to ZEN projects. In accordance with the influential work of Baldwin and Clark (2003), we then attempt to conceptualize the integrating role of procurement in ZEN projects.

2.1 ZEN complexity and purchasing

Complex building projects are "often difficult to coordinate and have to devote considerable resources to integration because they have highly differentiated cross-functional structures involving in-house units and multiple parties" (Davies and Mackenzie 2014, p. 774). The ZEN procurement process mirrors this complexity. Depending on the degree of modularization, a ZEN project can be represented as a large and dispersed procurement pyramid (Fig. 1) featuring multiple layers of developers and suppliers (Hobday et al. 2000).

From a system perspective, the structural complexity of a building project can be characterized by the number of differentiated parts, the degree to which those parts are interconnected, and the number of hierarchical levels involved in the project (Davies and Mackenzie 2014; Williams 1999). Project management scholars have added new dimensions to the concept of project complexity by combining structural complexity with uncertainty (Davies and Mackenzie 2014; Williams 1999). In this context, technological uncertainty, poorly defined objectives, and urgency are all examples of internal uncertainties, while environmental politics and stakeholders are examples of external uncertainties. Overcoming both internal and external uncertainties is essential to ensuring a project's stability. Table 1 explains some of the complexities involved in ZEN projects.

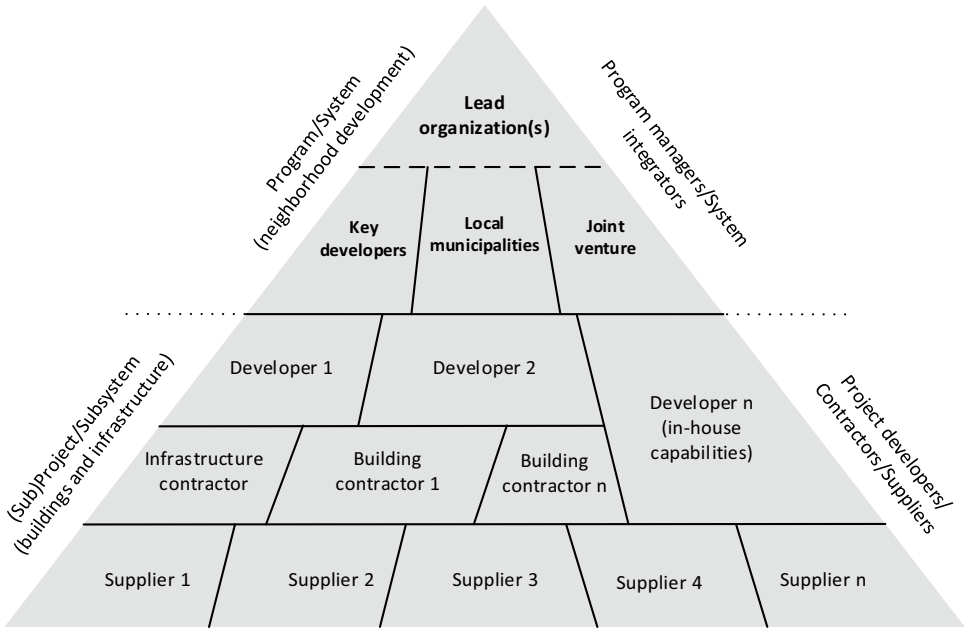

Fig. 1 System integration in ZEN projects (adapted from Davies and Hobday 2005)

Table 1 Project complexities in ZEN projects (adapted from Hamdan and de Boer 2019)

Complexity	Explanation and examples	Challenges to procurement
Structural complexity	The interconnectedness of the ZEN parts goes beyond the traditional technical view to include green spaces, energy exchange, shared renewable energy, shared mobility, and parking. While this reduces the overall carbon footprint of the ZEN, it also increases its complexity	Procurement tasks must reflect this interconnectedness
	Coordination becomes difficult when there are many actors, different interests, and varying degrees of specialization (i.e., resources, knowledge, etc.) involved	Conflicts and misalignments are exacerbated across the project supply pyramid
Uncertainty	Internal uncertainties arise from poorly defined sustainability goals and methods, including a lack of clear guidelines and functional specifications, unsustainable planning, and difficulties in applying sustainable technologies	Abstract specifications and criteria for supplier selection
	External sources of uncertainty stem from and affect the project's environment, such as policies and risks in the housing market. A lack of supportive city policies and building codes could threaten the project's stability and level of aspiration	Suppliers do not deliver on their commitments

Buying a neighborhood is fundamentally different from buying a building, and it is generally beyond the resources of a single organization. It involves multiple procurement tasks associated with development contracts for buildings and infrastructure. Therefore, organizing procurement in relation to ZEN projects requires extensive coordination, as many organizations need to work together to achieve the ambitious goals of such projects. In addition, due to political and investment issues, ZEN projects are usually implemented in stages rather than all at once. As a result, the different actors within the supply chain do not necessarily contribute to the project at the same time. This is referred to in the literature concerning ZENs as temporal uncertainty (Hamdan et al. 2021a, b) and it further complicates the process of procurement. Moreover, procurement in the context of ZENs entails a strong development component, which brings additional influencers into play, namely real estate and property developers (Fig. 1). Development-related issues such as urban planning, public permits, and financing can add both uncertainty and complexity to the process of procurement.

In the current literature on procurement, there appears to be a lack of knowledge as to how best to organize procurement at the urban or neighborhood level. The procurement process associated with ZEN projects seems to deviate from the classic procurement approach described in the mainstream literature, where purchasing organizations typically

rely on project procurement (de Araújo et al. 2017), contracting and subcontracting (Van Weele 2018), green public procurement (Cheng et al. 2018), collaborative procurement (Schotanus and Telgen 2007), commodity and material procurement (Van Weele 2018), and green procurement and supplier selection (Igarashi et al. 2013). This classic procurement approach is well suited to explaining how an organization conducts and tracks purchases at the building and sub-building levels, although it does not seem able to fully capture the complexity of ZENs. Indeed, procurement at the building and sub-building levels is designed to achieve efficiency and does not take into account contextual information (in our case, the nature of a ZEN). For example, procurement for a ZEN is not the same as collaborative procurement. The latter aims to centralize procurement tasks and perform them collaboratively for multiple organizations. Again, a ZEN does not fit the standard "collaborative procurement" approach due to the rivalry between owners or developers. Furthermore, ZEN subprojects serve different purposes and may require different expertise. Yet, procurement in relation to ZENs may involve some collaborative procurement tasks, for example, when multiple developers team up to procure shared infrastructure or a car-sharing service.

Based on the characteristics of ZEN building projects, we see more similarities with the architecture-based purchasing principles found within the complex product systems (CoPS) literature, which appear to better fit the identified purchasing challenges.

2.2 Complex building projects as CoPS

Hobday (1998) identified system integration competencies as critical to the organization and management of CoPS. System integration is concerned with the management, governance, and coordination of temporary stakeholder networks across all phases of a project's life cycle. Complex building projects are "structured as programs and placed under the control of an umbrella organization to coordinate multiple developers and contractors" (Davies and Brady 2016, p. 323). Thus, at the system integration level, an organization must be created to understand the overall system of subsystems, manage external interfaces with multiple stakeholders, and coordinate the various parts of the system (Davies and Mackenzie 2014). This task is often outsourced to organizations that have expertise in program management and system integration (Fig. 1).

The primary reason for lead organizations to use system integration in relation to ZEN projects is the need to ensure coordinated management among an increasing number of stakeholders in order to improve opportunities to achieve complex sustainability goals. We question whether and how procurement can support system integration in ZEN projects. In the following subsection, we apply a modularity perspective (Baldwin and Clark 2003) to examine how various project procurements can function as an integrated whole that supports the achievement of ZEN and zero-emissions goals.

2.3 The integrating role of procurement in ZEN projects

Applying Baldwin and Clark's (2003) logic, the lead purchasing organizations involved in ZEN projects should be able to reduce the collaborative complexity of such projects and achieve modularity benefits through partitioning information into visible design rules and hidden design parameters. In other words, buyers can become less dependent on suppliers -and suppliers less likely to maintain long-term relationships- if they can create standardized interfaces and buy accordingly (Campagnolo and Camuffo 2010; Hoetker et al. 2007). In this context, visible design rules are decisions that affect subsequent decisions at the neighborhood level and fall into three categories, namely architecture, interfaces, and standards. By contrast, hidden design parameters are decisions that do not affect development beyond individual projects. In other words, hidden elements can be understood as decisions that affect individual building projects rather than the neighborhood as a whole. The present study is concerned with the realization of ZENs as a whole and so focuses on visible design rules.

Similar discussions can be found in the CoPS literature. According to Hobday (1998), lead organizations should have a reasonable picture of both the product architecture and the linkages between projects. This picture provides knowledge of the design concepts behind the component projects as well as how they are integrated and interconnected. Lead organizations use this knowledge to make architectural decisions or "decisions about the ways in which components are integrated together to form a coherent whole" (Hobday 1998, p. 694).

This study builds on the concepts of design rules and architectural decisions in an effort to understand how lead organizations might use such knowledge to make decisions tailored to ZEN procurement. That is, the study considers how each of the ZEN procurement tasks can be linked or aligned to form a coherent procurement system able to support system integration and the ZEN mission. Below, we propose a theoretical framework for conceptualizing the integrating role of procurement in ZEN projects (Fig. 2).

First, the architecture describes what components (e.g., schools and housing) will be part of the neighborhood as well as what role they will play in achieving sustainability and zero-emissions goals. This has huge implications for both the supply pyramid and the purchasing structure of ZEN projects. Buying a neighborhood in one piece is unrealistic and beyond the resources of a single organization.

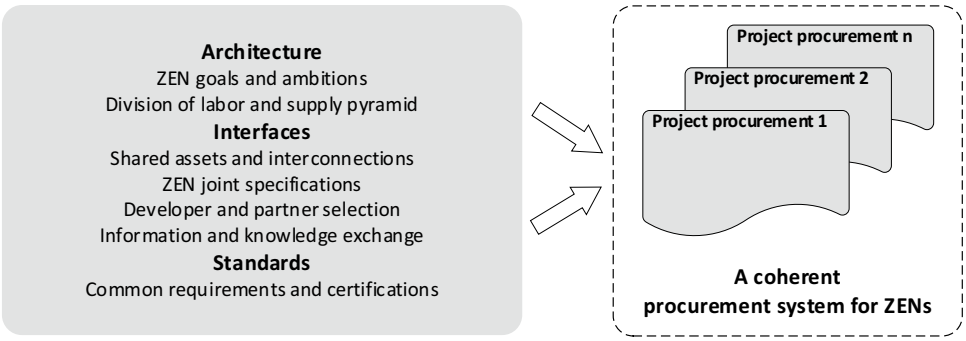

Fig. 2 The proposed integrating role of procurement in ZEN projects (Baldwin and Clark 2003; Hobday 1998)

As a consequence, lead organizations break projects down into individual components (or subprojects) before awarding them to developers and contractors. Thus, it is necessary to define the boundaries of the system and its goals at the beginning of the project. Gadde and Jellbo (2002) stated that the definition of the system is critical to the system buying strategy. Decisions concerning the definition of a ZEN determine the division of the entire neighborhood and the division of labor, which then affect the procurement and supplier selection processes.

Next, the design interfaces describe how the subprojects fit together and interact to accomplish the mission of the ZEN. In ZENs, many resources and services are shared, whether by buildings or end users, such as energy, mobility, and parking. Therefore, a clear map of shared assets and connections is essential. It provides developers and contractors with a sense of the project's complexity and helps them to coordinate their development efforts. In addition, design interfaces can form the basis for coordination among ZEN procurement tasks in terms of the bidding sequence, information sharing, joint specifications, and partner selection. For example, developers can team up to perform joint procurements, such as the purchase of a car-sharing service or a centralized energy system. Such coordination efforts make a positive contribution to the overall performance and goals of the project (Eriksson and Westerberg 2011).

Finally, standards are useful for verifying that a given subproject conforms to the design rules as well as for measuring its performance. Thus, lead organizations can adopt a set of procurement-friendly standards, including common requirements and building certifications, to ensure that the various subprojects function as an integrated whole and support the achievement of the ZEN project's goals.

Based on the above design rules (Fig. 2), our theoretical framework suggests that designing the procurement organization as a system integrator can reduce the complexity of the ZEN project and improve collaboration between organizations. In doing so, it can render the benefits or challenges of collaboration more visible. We anticipate that this underlying principle will make it easier for lead organizations and developers to identify and appreciate potential opportunities for collaboration and coordination. In light of this, our case analysis will focus on assessing if there are traces of these principles to be found in current projects and discussing how the further development of these principles can help procurement to contribute to systems integration in ZEN projects.

3 Data and methods

3.1 Data collection and sources

This study forms part of a broader research project titled "The Research Center on Zero Emission Neighborhoods in Smart Cities (ZEN center)," which focuses on the development of ZENs in Norway. According to the ZEN center, a neighborhood is defined as a group of interconnected buildings with associated infrastructure,[1] located within a confined geographical area,[2] and a ZEN aims to reduce and compensate its direct and indirect greenhouse gas (GHG) emissions toward zero over the analysis period, in line with a chosen ambition level (Wiik et al. 2022).

We conducted several case studies (Yin 2018) to investigate how procurement contributes to system integration in ZEN projects. There are currently nine neighborhood developments in Norway that are pursuing ZEN targets. However, in the present study, we are only interested in ongoing developments or projects that are in the planning and implementation stages. As a consequence, only five projects were contacted, four of which agreed to participate in this study. The initial version of this paper was peer-reviewed

[1] Buildings can be of different types, e.g., new, existing, retrofitted or a combination. Infrastructure includes grids and technologies for supply, generation, storage and export of electricity and heat, as well as infrastructure for mobility.

[2] The area has a defined physical boundary to external grids (electricity, heat, and mobility). The system boundary for analysis of energy facilities serving the neighborhood may not be the same as the geographical area.

Table 2 Data collection and sources

Project	Lead organization/municipality	Documents and reports	Interviews
Ydalir	Elverum municipality (ELM)	Lead organization: energy and climate plans/procurement strategy for building projects Project: agreements/public tenders/feasibility studies/research reports/online project website	3* + 1
New City–New Airport	Bodø municipality (BOM)	Lead organization: energy and climate plans/municipal subplan (guide) Project: feasibility studies/research reports/online project information	1*
Sluppen Knowledge Axis	Trondheim municipality (TRM)	Lead organization: energy and climate plans/environmental strategy for building projects/procurement strategy/municipal subplan (for approval) Project: public tenders/research reports/online project information	2* + 1
Oksenøye and Flytårnet	Bærum municipality (BAM)	Lead organization: energy and climate plans/procurement strategy Project: public tenders/research reports/online project website	3

*Group interview

and presented at both the 28th EurOMA Conference 2021 and the EurOMA Publishing Workshop 2021.

We began by collecting and analyzing the available information and documents describing the projects' development and procurement (Table 2). The desk search included strategy documents from the lead organizations and project documents. This allowed us to capture preliminary information about each project's development process, including the sustainability goals, scope and size, key stakeholders, and procurement practices. Moreover, the Norwegian Public Procurement Database (DOFFIN) was used to extract tender information on municipality-led projects and public procurement.

We also conducted semi-structured interviews with key project managers and purchasing professionals from the lead organizations involved in the planning and development of the four selected projects (Table 2). The interviews were intended to determine the role of the lead organizations in coordinating and selecting project partners as well as to uncover the logic involved in procurement for ZENs. The interview questions addressed the following three topics: project architecture and stakeholders, the role of the lead organization, and ZEN procurement and coordination. We focused on the project initiator or lead organization and its role within the broader network and project implementation. Therefore, we limited the interviews with individual organizations to three or four per case, with the exception of the New City–New Airport project. Here, we found that one group interview was sufficient, as the project is still in the strategic planning stage and there has been no major procurement or construction activity. It is also important to note that this interview was limited to the project managers. The purchasing department declined to participate in the study on the grounds that these types of projects are not within their purview or expertise.

Reading the documents concerning planning goals and policies helped us to understand the contexts of these projects and to draw conclusions about the interactions among internal city departments, particularly those among city planning, real estate development, and purchasing. In some cases, this led to additional interviews with city planning department managers so that we could ask questions about the planning process.

3.2 Overview of the projects

This subsection presents four case studies of ongoing ZEN developments in Norway.

3.2.1 Ydalir

The Ydalir project aims to develop a new large residential neighborhood with zero-emissions ambitions. It also aims to be a good place for sustainable living due to the implemented physical solutions, the available meeting places and social arenas, and the stable relationships both between people and between people and place. Ydalir is considered to be an environmental frontrunner project for the city of Elverum. The project began in 2015 and is currently being implemented. The estimated date for completion is 2030, when approximately 1000 housing units (a combination of single-family homes and multi-family homes) will be built around a school and kindergarten. The school and kindergarten buildings have been completed and functional since 2019, while construction of the residential units is still underway.

3.2.2 New City–New Airport

The New City–New Airport project is one of the largest new urban developments in Norway. It aims to develop a new airport and a whole new city district. The redeveloped area is approximately 5,600,000 m^2 in size and is located close to the city center. The former civil and military airport will be replaced by a smaller civil airport located 900 m southwest

of the existing airport. An area of 2,200,000 m^2 will be used for the expansion of the civil airport. The relocation of the airport will free up an area approximately the same size as the current Bodø city center, making room for an entirely new multifunctional urban extension featuring residential and commercial areas. The new expansion will house several dense, mixed-use neighborhoods that will be emission-free and civic-minded. Development work is scheduled to begin in 2026, once the airport relocation project is complete.

3.2.3 Sluppen knowledge axis

The Sluppen Knowledge Axis project aims to transform an existing area into an attractive, zero-emission neighborhood with innovative mobility solutions. Today, the area is mainly a commercial area housing office buildings and logistics companies. The municipality initiated the development of Sluppen with an extensive redevelopment project (demolition and new construction). The new project includes two schools, a multipurpose hall, and a rehabilitation center, which are scheduled for completion in 2023. The private developer, which owns nearly half of the area, has already developed several office buildings with higher environmental standards than current building codes require.

3.2.4 Fornebu

As part of its efforts to become an emission-free city by 2050, the municipality of Bærum has declared Fornebu to be a zero-emission test area. The goal is to make the buildings and surrounding urban structure zero-emission during their lifetime, starting in 2027. Two main projects have been initiated to implement the zero-emission mission: Oksenøya and Flytårnet. Oksenøya is already under implementation and focuses on innovative solutions for sustainable buildings and transportation, while Flytårnet (old control tower) is still in the planning phase, with new planning and design methods being used to lay the foundation for an attractive urban district offering environmentally friendly choices.

4 Findings

The cases show that our theoretical framework does not reflect the full reality of ZEN projects. Table 3 explains how the four projects compare to the design rules and decisions shown in Fig. 2.

4.1 Challenges limiting the integrating role of procurement

While this discrepancy between our framework and the realities of the four projects was to be expected given the complexity of ZEN projects, our findings also highlight several challenges that explain why taking on the role of systems integration for procurement in the context of ZEN projects is difficult. These challenges are the urban context, the complex ownership structure, the lack of supporting regulations, and the unclear mandate of the procurement department.

4.1.1 Urban development context as a complexity trigger

Neighborhood development in Norway is based on both urban and city planning processes.[3] These processes determine the layout at the neighborhood level, including mixed land use, green spaces, building structure, social infrastructure, energy systems, connections, and means of dealing with existing parts in the case of redevelopment.

Unlike other construction projects, the complexity caused by the external uncertainty inherent in urban development contexts is enormous, especially in sustainable building projects in which many different stakeholders are involved. That is, combining urban planning processes with sustainable building renders the development process even more complex. Or as one informant from Elverum Tomteselskap (ETS) describes the process in the Ydalir project, "The challenge may be that it is not common to do it this way. Usually, you buy land, and you start building. But in Ydalir there is development work, and many are not used to such process as its new for them" (ETS).

In addition, most projects rely on a draft or unfinished version of the municipal sub-plans because the planning processes take too long and are too complex. In the case of the New City–New Airport, Sluppen, and Flytårnet projects, the municipalities are currently working on new municipal sub-plans to integrate the ZEN goals into future land use plans. The lack of a final overarching plan makes physical and functional ZEN divisions disjointed and creates distance between the public and private developers involved, something we observed in Sluppen. Indeed, our informants from the Sluppen case were unsure about the ambitions of the ZEN project or the TRM's role as the lead organization. We find this surprising, as Sluppen is a public-led project

[3] In Norway, urban planning mainly involves municipal and zoning plans. With the municipal master plan, the municipality prepares the area aspect of the municipal plan, which shows the relationship between future social development and land use. The municipality may also prepare sub-plans that cover specific areas or topics, such as zero emissions. There are two types of zoning plans, namely district zoning plans and detailed zoning plans. Municipalities can prepare district zoning plans for multiple properties or large-scale development projects. Private developers may propose detailed zoning plans when seeking to implement development projects in accordance with the main features and boundaries of the higher-level plans.

Table 3 Design rules and decisions in the case projects

Design rules and decisions	Ydalir	New City–New Airport	Sluppen knowledge axis	Fornebu
Develop architecture	Ambitions, goals, and project boundaries are described in a master plan document. The master plan facilitated later decisions regarding the division of labor and the choice of partners	Ambitions and goals are broadly communicated to interested actors through a draft municipal subplan. However, the plan is still under development and is intended only as a guide. This may be due to the early stage of the project	Ambitions and goals are broadly communicated to interested actors through a draft municipal subplan. However, the plan has yet to be approved and lacks information on project boundaries and the division of labor	The first project, Oksenøye, is publicized as a ZEN, although it lacks ZEN ambitions and descriptions for the projects and partners involved. For the second project, Flytårnet, a new municipal subplan is currently being developed
Establish interfaces	Dialog workshops and regular meetings with developers to facilitate information sharing The master plan described joint specifications for future developers and partners, which then formed the basis of project procurements and contracts	Difficult to evaluate, as no major project procurement task has taken place to date. Only one small public tender has been issued to conduct a feasibility study BOM tested new forms of engagement activities, such as the Bylab initiative, a digital participation platform	Strong coordination between public projects resulted in their procurement plans being combined under one large project procurement No procurement-related coordination with private developers operating in Sluppen TRM is involved in dialog and regular meetings with private developers to coordinate the development of the municipal subplan	In Oksenøye, informants reported no coordination among project procurements or developers In Flytårnet, informants reported plans for ZEN joint specifications, including energy exchange between buildings and shared mobility and parking solutions
Apply standards	The master plan and contractual agreements were used to track developer commitments, including greenhouse gas emissions and building certifications	BOM intends to use contractual agreements to track and monitor developers. Green certifications were also mentioned	Except for public projects, follow-up on other projects is outside their purview	Except for public projects, follow-up on others is outside their purview

Table 4 Overview of lead organizations' land ownership

Project	Lead organization and land ownership structure	Influence over developers
Ydalir	ELM: 80%	The high ownership structure allowed the municipality to create a standardized document (master plan) and then to use it as a mandatory condition for developers who want to buy land for residential projects in the area
New City–New Airport	BOM: 100%	The municipality intends to develop airtight development plans and purchase agreements
Sluppen Knowledge Axis	TRM: < 50%	The municipality's current ownership structure has weakened its position vis-à-vis outside developers
Fornebu	BAM: Flytårnet 100%, Oksenøye 66%	The municipality intends to tighten its control over developers in Flytårnet, as the area is still in the land use planning process

initiated by the TRM and anchored by municipal energy and climate plans.

By contrast, in the Ydalir case, ELM decided to compensate for the lack of such a plan. More specifically, in collaboration with interested stakeholders and developers, a master plan was developed that formed the basis for preparing the detailed land use plans and provided guidelines for the implementation of ZEN ambitions in the various development projects. Thus, ELM has taken on another role by assisting private developers in creating smaller development plans that focus on ZEN goals in order to reduce complexity.

4.1.2 Complex ownership structures

The structure of land ownership in a neighborhood affects development and purchase decisions by directly influencing the number of parties involved as well as their interests and the trade-offs associated with them (Table 4). First, the structure of land ownership affects the division of labor and, ultimately, encourages isolated thinking. For example, in Sluppen, although the municipality had adjusted the level of entitlement to the ZEN project, it focused solely on the public portion of the project, which accounted for less than 50% of the land. When we asked the project manager, who was also involved in the public procurement task, about the coordination with other private landowners and developers, he said: "I do not really know anything more than that they are involved in Sluppen" (TRM).

Second, the greater the land ownership, the more influence the lead organization has over purchasing and selecting partners. In Ydalir, two landowners who are also housing organizations own 20% of the project land. One has voluntarily agreed to the master plan and ZEN goals, while the other has rejected them. Nevertheless, the municipality has a relatively large degree of control and influence over the area due to its large land holdings. In the New City–New Airport and Flytårnet projects, the municipalities are the sole owners of the development sites. Informants from these two projects indicated that their organizations intend to enshrine the ZEN goals in land development agreements as well as to maximize their control over private developers.

4.1.3 Lack of supporting regulations

This type of complexity also leads to limitations in terms of system integration in building projects. Our informants reported two different types of regulatory limitations. First, when the lead organization is public, whereas the division of labor is private. This situation prevents the lead organization from imposing ZEN-related requirements. Norwegian municipalities cannot require private developers to meet requirements beyond what is specified in the applicable national regulations: "It is legally very difficult to set the requirements we want. The criteria for particularly climate-friendly construction are stricter than those that may be set by law" (TRM). Such a situation is typical when the municipality outsources land development to private developers. This constraint leaves the lead organization dependent on the voluntary participation of environmentally oriented developers and suppliers.

In Ydalir, the municipality has been able to circumvent this regulatory constraint by outsourcing the coordination and management of development to another organization, the Elverum Land Development Agency (*Elverum Tomteselskap*; ETS). This semi-governmental organization is wholly owned by the municipality, and it aims to facilitate population growth in Elverum by developing land for housing and businesses at reasonable prices. The ETS can be seen as an extension of the municipality that makes up for its lack of coordination and administrative capacity. The ETS has made ZEN goals mandatory in land

development contracts. Yet, it is important to note that the regulatory restriction does not necessarily apply to all portions of the neighborhood, such as public projects. In Sluppen, Ydalir, and Oksenøye, the municipalities have been able to incorporate ZEN-related requirements (e.g., BREEAM,[4] the Passive House Standard, innovative energy systems, and minimized parking) into the public buildings and social infrastructure they own or operate, including schools, kindergartens, and health centers.

Second, further regulatory complications arise due to shared neighborhood solutions. In Sluppen, the municipality is working on two innovative energy systems intended to improve the energy flexibility and performance of buildings. The first system allows power to be exchanged between buildings, while the other reduces heating costs through the use of thermal storage and solar panels. However, to date, electricity exchange is not provided for in the regulations: "Even if it is the same developer who owns both buildings, as long as there are two subscriptions, exchange between buildings is not allowed" (TRM). This reality reduces the legitimacy and attractiveness of shared solutions, which are a prerequisite for a ZEN. It can make interested developers and providers reluctant to invest and participate, which will ultimately reduce the likelihood of developing a ZEN.

4.1.4 The purchasing department's unclear mandate

The purchasing capabilities of the lead organization do not generally appear to be able to address the complexity of sustainable building projects. When the informants were asked how the various project procurements are coordinated, the answer varied from project to project. Based on the interviews, we learned that in most cases, the central purchasing department in the municipalities has played a limited and unclear role in project development. Moreover, project managers from the real estate and development department have taken on tasks normally assigned to purchasing, such as project procurement. For example, the procurement of public buildings and land development contracts in Ydalir, Sluppen, and Oksenøye was organized and executed by project managers.

When we contacted the buyers from the central purchasing departments of the various municipalities, some of them decided not to participate in this study because they were not involved in the projects or else lacked knowledge about them. Only the purchasers from ELM and BAM were willing to be interviewed. This is indicative of the unclear and confusing role that the procurement function plays in the context of complex building projects. Although the municipalities referred to their projects in the strategy documents, no procurement system or strategy was found to support the complex organization and implementation of these projects. However, an exception was identified in ELM, where a procurement strategy for sustainable building projects was applied. Although project managers organized the procurement for building projects, this document was the result of interdepartmental collaboration between the purchasing manager and the project manager responsible for municipal buildings. Yet, the document focuses on individual buildings and ignores their context, that is, whether or not they form part of a larger neighborhood project.

5 Discussion

In this paper, we adopted as a starting point the assumption that lead organizations can mobilize their purchasing capabilities to support system integration processes in relation to ZEN building projects. However, the realities of the case projects revealed a different picture. In what follows, we will first discuss how the above-mentioned challenges affect the project design rules and what it means for procurement. We will then propose a conceptual model for ZEN procurement that lead organizations could use to support the delivery of complex ZEN building projects.

5.1 Challenges and implications with regard to ZEN procurement

Building on our findings, this section will expand the discussion of the identified challenges and explain some of their key implications for procurement decisions (Table 5).

First, all urban development projects go through lengthy processes of land use and zoning planning in multiple arenas that affect both the goals and the physical boundaries of the projects as well as the different time perspectives associated with the positions and interests of the different stakeholders (Gustavsson and Elander 2016). These lengthy area delineations and long processing times exacerbate the temporal uncertainty and time gaps between projects, rendering the coordination of project procurement and operations challenging. In addition, our results suggest that these upstream planning activities and the subsequent procurement tasks may be interrelated. In other words, decisions made during neighborhood planning impact procurement, which means that lead organizations should also think about purchasing when coordinating such activities.

Second, complex ownership affects the lead organizations' system integration and reduces their influence over both developers and partner selection. One would expect

[4] BREEAM stands for Building Research Establishment's Environmental Assessment Method. BREEAM is an international scheme that provides independent third-party certification of the assessment of the sustainability performance of individual buildings, communities and infrastructure projects.

Table 5 Challenges and implications concerning ZEN procurement decisions

Challenge	Impacted design rule	Implications for procurement decisions
Urban development context as a complexity trigger	Architecture, Interfaces	Lengthy planning processes impair ZEN system partitioning, cause isolated thinking and time gaps, and promote fragmentation and misalignment of procurement tasks
Complex ownership structure	Interfaces, Standards	Lead organizations' ability to enforce ZEN joint specifications, influence partner selection, and track procurement outcomes is undermined
Lack of supporting regulations	Interfaces, Standards	Lead organizations' reliance on voluntary participation by developers and private contracts to anchor ZEN requirements is increased. This also reduces the legitimacy and attractiveness of common features, such as energy exchanges
The purchasing department's unclear mandate	Architecture, Interfaces, Standards	Unclear participation in project development encourages fragmentation and isolationist thinking in relation to ZEN procurement tasks and makes it difficult to incorporate ZEN goals into the various procurement processes

the municipality to assume the lead organization role, as it is the initiator and main driving force behind the ZEN goals. However, operating in a loose interorganizational context takes away much of its control and influence. The municipality will always perform a (small) part of the project work with its staff and capacity, leaving the rest of the work to the private sector. This represents one way of spreading risk and mitigating risk in an unstable housing market. Yet, it raises questions regarding the legitimacy of the lead organization and the alternative approaches it could use to coordinate common ZEN specifications and track procurement outcomes when it has little outsourcing power. Although the issue of ownership has been addressed in prior studies (Gansmo 2012; Oliver and Pearl 2018; Zhan and de Jong 2018), it has not previously been discussed in relation to procurement, which means that it warrants further investigation.

Third, the lack of supporting regulations forces lead organizations to rely more on the voluntary participation of environmentally oriented developers or private contracts when it comes to achieving the ZEN goals. This challenge has been described as a general challenge for ZEN development (Hamdan et al. 2021a, b; Shi et al. 2016), and it affects both municipal planning and procurement processes. Lead organizations cannot bring in more than is allowed under current regulations. In some cases, for example, in Ydalir, the lead organization relies on another project organization to circumvent certain regulations, although this can lead to additional layers within the supply pyramid. In addition, lagging regulations reduce the legitimacy of shared development functions, including energy exchange between buildings, rendering such solutions less attractive and making them appear to be risky investments.

Finally, the unclear purchasing mandate encourages both the fragmentation and disintegration of ZEN projects. Complex building projects require greater buyer participation as well as more robust purchasing capabilities and activities (Caldwell et al. 2009; Davies and Brady 2000). With regard to ZEN projects, this means standardizing ZEN goals, coordinating multiple procurement and supplier selection tasks, tracking an extensive supplier base, and updating procurement as new challenges and opportunities arise. Similar findings have been reported in other contexts. For instance, complex product development projects require greater buyer involvement and increased purchasing activities (Lakemond et al. 2001), which implies the need for a sophisticated purchasing system in ZEN projects.

It is worth mentioning that although these cases are context-specific as all of them are case projects in Norway, we believe that the challenges addressed are general and can be related to other countries. In the context of sustainable urban development different countries share much of the same issues since these challenges are embedded in the building and construction industry (Hamdan et al. 2021a, b; Shi et al. 2016). Therefore, these challenges can be of value for the general procurement practice in other countries as well, such as European countries and China, and in particular insights to procurement at the strategic level.

5.2 Toward a new procurement reality in complex ZEN building projects

Our findings confirm that the classic procurement approach is inappropriate for use in the novel context of ZENs. A ZEN procurement must be organized so as to be more strategic. This subsection presents a conceptual model of procurement that lead organizations could use to support the realization of ZEN projects. Table 5 shows how the four identified challenges partially paralyze ZEN procurement tasks and render

them ineffective in relation to coordination and systems integration. However, we believe that this paralysis can be addressed by creating a new procurement reality that reflects the complexity of ZEN building projects.

This study highlights a neglected area of procurement research as well as a practical problem associated with complex building projects. A complex building project includes several interrelated buildings that can be developed through one procurement task or divided into several individual procurement tasks. The single procurement task approach corresponds to what are known in the construction industry as alliance and partnership contracts. An alliance contract exists when multiple stakeholders enter into a cooperative agreement and jointly procure the entire project (Davies and Mackenzie 2014). Yet, in the context of ZEN projects, an alternative reality is required to reflect the nearly decomposable or modular nature of neighborhoods. In this alternative form, the various procurement tasks should simultaneously support local building-level conditions and neighborhood-level interactions. In other words, the various procurement tasks associated with ZEN development need to reflect both hidden and visible rules in order to reflect the complexity of a ZEN. The cases revealed that visible design rules are not used to the same extent as hidden design parameters. Figure 3 distinguishes between two realities in terms of individual building and neighborhood projects. A reductionist reality prevails when the focus is on hidden parameters, whereas a holistic reality calls for visible and hidden rules simultaneously (Fig. 3). This requires a somewhat looser version of system integration to create channels for visible information and interaction while hiding project-internal specifications (Fig. 4).

The above discussion suggests that ZEN projects require a holistic procurement reality that is both decomposable and interrelated. In other words, a modular reality. In this context, the term "decomposable" implies that procurement encompasses multiple procurement tasks that reflect the various building and infrastructure projects. Moreover, the term "interrelated" means that there must be some degree of interrelationship between the various procurement tasks in order to reflect the ZEN mission. Building on the identified challenges and implications (Table 5), we propose several procurement-related design rules that can represent what we refer to as a holistic procurement reality (decomposable and interrelated) and, further, that can help to enhance the procurement function and allow it to work optimally (Table 6).

The first design rule states that the architecture, ZEN systems definition, and partitioning should all be developed with procurement in mind. Clear boundaries and modular ZEN goals facilitate the various procurement tasks that are both decomposable and interrelated. This should not surprise us, as ZENs are rooted in the urban planning tradition. Factors such as complex land ownership, zoning, development

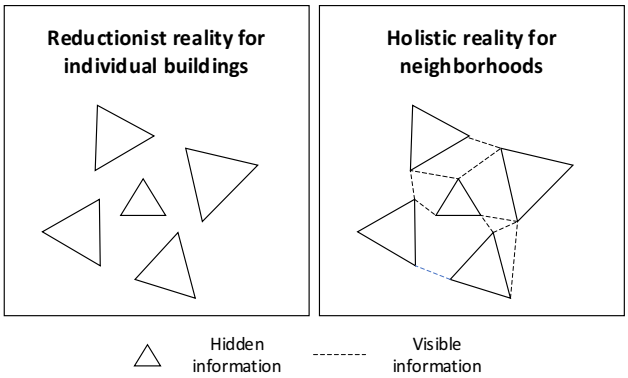

Fig. 3 Different realities in terms of buildings and neighborhoods

plans, and local housing policies impact ZEN allocation and the division of labor, rendering the ZEN development process more dispersed and decentralized. The challenge is to infuse ZEN-related system-wide knowledge into each ZEN sub-procurement task. This may require new procurement practices. For example, Kuronen and Vaara (2013) stated that procurement market dialogs can represent a way to develop different potential configurations for dividing the procurement or defining what will be included in the outsourcing strategy. Our findings from the cases are consistent with this statement. In addition, the division of labor must consider the merging of the various subprojects during the final assembly of the ZEN.

It was also expected that the purchasing department would play an important role during this phase. The intermediate position of buyers involved between planning and implementation can ensure the feasibility of ZEN ambitions. Gray (1989, p. 89) emphasized that "implementers should be involved as early as possible." In fact, involving buyers can improve the transfer of information to project implementers and suppliers. This notion is in line with the findings of Sporrong and Kadefors (2014), who investigated how the working conditions of and relationships between technical functions and procurement functions influence project procurement practices.

Finally, a useful outcome of the architecture could be a master plan that describes the ZEN definition as well as the associated goals and workable specifications that buyers can use and refer to. An ideal scenario would involve integrating the ZEN goals into the land use plan, something we observed in relation to the New City–New Airport and Flytårnet projects. The respective municipalities are currently developing their municipal sub-plans to ensure the implementation of ZEN and other sustainability criteria at the zoning level, which will make it easier to integrate ZEN requirements at the lowest levels and in the various procurement tasks. Ideally, such a zoning plan will impact subdivision and detailed

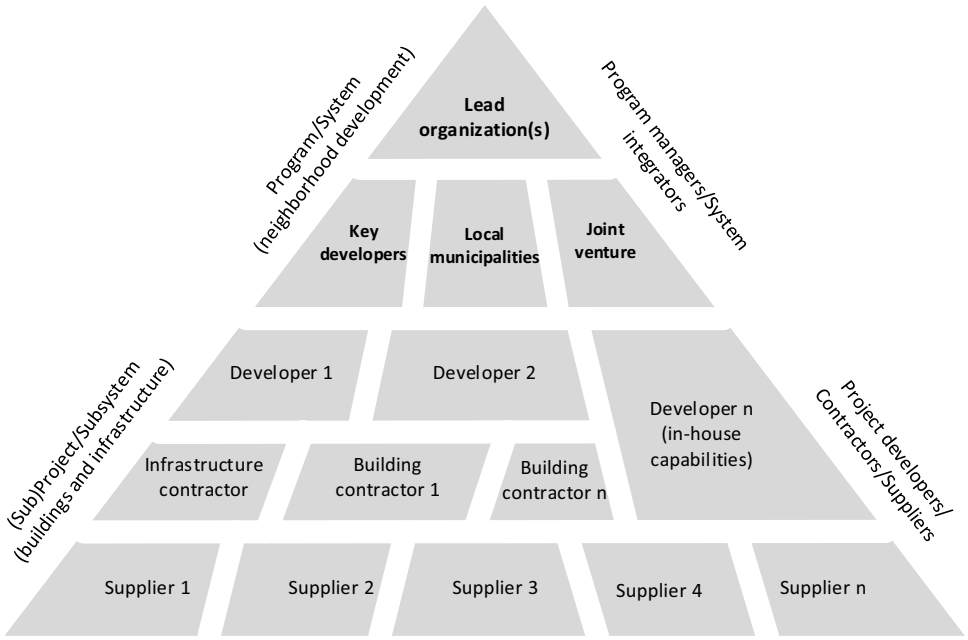

Fig. 4 (Re-imagined) system integration in ZEN projects

zoning within the boundaries of the planned neighborhood, thereby also exerting a strong influence on future developers.

The next design rule refers to the interfaces between ZEN procurement tasks. To create useful standardization and encourage the use of common concepts, purchasers must define modular ZEN goals and specifications and then incorporate them into the various procurement tasks. For example, a ZEN project must rely on greenhouse gas (GHG) accounting to formulate procurement requirements and goals. The selection of partners and suppliers must consider the ZEN master plan and mission. Suppliers must qualify to work on ZEN projects. For example, project buyers can use the ZEN mission to determine if suppliers qualify. Interfaces indicate coordination. Dynamic coordination should be ensured between different procurement tasks to avoid time gaps, duplicate processing, and other problems caused by time-sensitive issues. Furthermore, lead organizations need to promote joint initiatives at the neighborhood level in order to initiate common procurement tasks as well as a long-term plan for dialog and information sharing among all involved partners and suppliers. In addition, interfaces bring new implications to the supplier relationship management. A supplier may want to share as little as possible with other neighboring suppliers in the neighborhood project in order to maintain its advanced position, while share more for shared activities at the neighborhood level. This will lead to weak ties between buyers and suppliers and between suppliers themselves. In a high modularity scenario, suppliers can benefit from autonomy and buyers can evaluate the progress of suppliers without the need to consider a web of interactions and relationships (Hoetker et al. 2007).

The final design rule, namely standards, creates a framework for tracking the various procurement tasks throughout the life cycle of a ZEN project. In this sense, standards refer to a set of procurement-friendly criteria, requirements, key performance indicators (KPIs), certifications that the project adopts based on voluntary basis and can be integrated in the procurement process, making the lead organization able to verify and follow-up on suppliers' commitment. Standards can be derived based on different assessment criteria, including emission reduction, energy efficiency in buildings, life cycle costs, and certification rating (Wiik et al. 2022). To do this, the procurement department must distinguish between building- and neighborhood-level supplier engagement. For instance, the neighborhood level requires different tracking programs and assessment tools, such as GHG accounting, LEED-ND,[5] and BREEAM communities. Lead organizations, including major developers and property owners, may need to add incentives and motivational programs to their procurement missions (Krangsås et al. 2021), especially if the gap between policies and regulations is wide. A good example of an incentive program is found in the Sluppen case. An informant from the planning department mentioned the municipality's plan to implement a non-mandatory environmental incentive program to incentivize developers to use more collaborative solutions such as shared energy networks, parking, and mobility. The incentive program awards points to developers

[5] LEED for Neighborhood Development (LEED-ND), where "LEED" stands for Leadership in Energy and Environmental Design. LEED is a United States-based rating system and green building certification.

Table 6 A holistic procurement reality in ZEN projects

Visible design rule	ZEN procurement
Develop a rough but explicit architecture	A strategic document that describes the ZEN definition and its associated goals and joint specifications ZEN goals and specifications should be formulated to support modular behavior Purchasers play an intermediate role between planning and implementation
Establish interfaces	Modular goals and specifications enable standardization and the use of common concepts Dynamic coordination between different procurement tasks Influence developer and partner selection and facilitate collaborative procurement tasks A long-term plan for dialog and information sharing among partners and suppliers
Apply standards	Different tracking systems and assessment tools are required Incentives and motivational programs to bridge the gap between policy and regulations

based on whether they are willing to go beyond the minimum requirements of current regulations. The more they do, the more points they receive. Finally, follow-up systems must take into account the temporal aspects or temporal uncertainty of ZENs, as things are not immutable and may change over time. For example, the actors involved may change or reconsider their commitment (Hamdan et al. 2021a, b).

It should be noted that the above model requires some support from two key entities, namely the lead organization and the procurement department. The first issue has to do with both legitimacy and outsourcing power. Weak lead organizations have little influence over the various procurement channels, which leads to misalignment and fragmentation. Increased land ownership allows lead organizations to create superior procurement positions and arrangements. For example, by embedding ZEN goals into each step of the procurement process. The role of lead organizations in ZEN projects can be confusing and complex. They often play multiple roles simultaneously or change their involvement (Hamdan et al. 2021a, b). Similar findings regarding the confusing role of clients have been reported in relation to megaprojects, a famous form of complex project (Denicol et al. 2021). The second issue concerns upgrading the purchasing function and making the most of it with regard to ZEN projects. In our view, the "unclear purchasing department mandate" challenge is by far the most critical constraint faced by lead organizations and ZEN projects. Lead organizations with advanced purchasing capabilities could potentially enforce a new procurement reality that matches the level of complexity of ZEN projects. In particular, it is vital that purchasing specialists become better at arranging contracts and managing conflicts (de Boer et al. 2003).

6 Conclusions

The findings of this study provide a better understanding of how procurement can help to create a form of order and reduce complexity in relation to ZEN projects, which should also help to reduce the likelihood of waste/mistakes, a major historical problem within the construction industry. This study also contributes to research on the procurement of non-standard goods or services as well as to research on urban development-related procurement (Kuronen and Vaara 2013), fields that are still in their infancy.

This study both examines the current integrating role of purchasing in terms of ZEN projects and also seeks to address shortcomings that could potentially be remedied using a system integration perspective. In reviewing the CoPS and modularity approaches to project management, we identified several design rules and decisions that can help organizations to design ZEN procurement and create better conditions for collaboration during complex ZEN building projects. We recognize the findings and the potential of the perspective in several other procurement contexts in which the standard boilerplate approach to purchasing management is associated with shortcomings. Projects outside the ZEN context that involve several stakeholders and a considerable amount of innovation and learning include innovative shipbuilding, where several new technologies need to be integrated among stakeholders who lack insights into each other's capabilities (Alves et al. 2021), and procurement in relation to megaprojects (Brahm and Tarziján 2015; Flyvbjerg 2021).

However, the cases have also shown that our theoretical framework does not reflect the full reality of ZEN projects. Indeed, the cases highlight several challenges that explain why it is difficult to assume the role of systems integration for procurement in ZEN building projects. These challenges are the urban context, the complex ownership structure, the lack of supporting regulations, and the unclear mandate of the procurement department. Based on our findings, we proposed a holistic procurement model to capture the complexity of ZEN projects. The various ZEN procurement tasks need to reflect both hidden and visible information in order to account for local building-level conditions and neighborhood-level interactions, respectively. The model should not only prove useful to researchers by filling the

observed knowledge gap in this area, but can also be used by developers as well as project managers and purchasers within lead organizations to implement and audit the integration of procurement tasks and processes and to support the implementation of complex ZEN building projects.

Our findings suggest several avenues for future research. First, a better understanding of the role of procurement in complex urban development projects is required. To date, the purchasing literature appears to paint only an incomplete picture of procurement practices in urban and complex building projects. For example, Kuronen and Vaara (2013) noted that "procuring units are often centralized in public organizations" (p. 268), which does not appear to be the case in ZEN or even conventional neighborhood projects. The role of technology in ZEN also needs to be explored in future research. Advanced technology integrated in urban forms such as smart sustainable cities and ZENs can be used to manage the complex interfaces between buildings and services (Taveres-Cachat et al. 2019). However, while smart and intelligent systems using IoT (Internet of Things), real-time monitoring, and predictive analytics can help achieve zero-emission goals (Ghaffarianhoseini et al. 2017; Mofidi and Akbari 2020), they also increase procurement complexity. Second, more studies are needed to examine the issue of land ownership and its potential impact on procurement practices and project development. In addition, our study highlights the need for a better understanding of public sector involvement in complex urban projects. ZENs are often initiated by municipalities in response to both national and regional sustainable policies. For the public sector, this can be seen as an opportunity to support innovation and create new markets (Lember et al. 2011). We assume that due to the nature of urban planning and development, the public sector will also play a role in privately led ZENs. It would be interesting to know what role the purchasing department would play, assuming that the public sector is sufficiently involved.

In terms of its practical implications, our study highlights the need for interdepartmental coordination within the lead organization. Prior studies have reported on silo thinking (Nielsen et al. 2019), although none have discussed the role of the purchasing department or the project experts performing purchasing tasks. Additional interdepartmental coordination is needed within the lead organization. More specifically, it is required between the city planning, real estate development, and purchasing departments. Procurement should be assessed not only as a contracting strategy, but also in terms of leadership, policy, culture, and management (Walker and Rowlinson 2007). Cross-departmental collaboration and coordination within lead organizations protect ZEN projects from simplistic procurement practices that only inadequately address complex goals and fail to recognize the expertise of both developers and partners (Sporrong and Kadefors 2014).

Finally, this study was solely conducted in Norway, which imposes some limitations in terms of transferring the results to other countries. International case studies would have allowed the comparison of different urban planning and procurement practices. Studying different urban planning and procurement practices from other countries could have benefited the current research with even more challenges and implication about the procurement process. The methodology used in this study could serve as the basis for further research at the international level, for example, in European Union (EU) countries, as Norwegian building laws and related policies are generally considered to be strict with regard to sustainability and climate issues. Moreover, public procurement processes in Norway follow EU directives and, therefore, should be quite similar to those in EU countries.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

Alves AC, Vonortas NS, Zawislak PA (2021) Mission-oriented policy for innovation and the fuzzy boundary of market creation: the Brazilian shipbuilding case. Sci Public Policy 48:80–92. https://doi.org/10.1093/scipol/scaa059

Baldwin CY, Clark KB (2003) Managing in an age of modularity. In: Garud R, Kumaraswamy A, Langlois RN (eds) Managing in the modular age: architectures, networks, and organizations. Wiley, Hoboken, pp 84–93

Blayse AM, Manley K (2004) Key influences on construction innovation. Constr Innov 4:143–154

Brahm F, Tarziján J (2015) Does complexity and prior interactions affect project procurement? Evidence from mining mega-projects. Int J Project Manag 33:1851–1862. https://doi.org/10.1016/J.IJPROMAN.2015.08.005

Caldwell ND, Roehrich JK, Davies AC (2009) Procuring complex performance in construction: London Heathrow Terminal 5 and a private finance initiative hospital. J Purch Supply Manag 15:178–186. https://doi.org/10.1016/j.pursup.2009.05.006

Campagnolo D, Camuffo A (2010) The concept of modularity in management studies: a literature review. Int J Manag Rev 12:259–283

Canosa Zamora E, García Carballo Á (2018) The failure of eco-neighborhood projects in the city of Madrid (Spain). Urban Sci 2:111. https://doi.org/10.3390/urbansci2040111

Cheng W, Appolloni A, D'Amato A, Zhu Q (2018) Green public procurement, missing concepts and future trends—a critical review. J Clean Prod 176:770–784. https://doi.org/10.1016/j.jclepro.2017.12.027

Chkanikova O (2016) Sustainable purchasing in food retailing: inter-organizational relationship management to green product supply. Bus Strategy Environ 25(7):478–494

Davies A, Brady T (2000) Organisational capabilities and learning in complex product systems: towards repeatable solutions. Res Policy 29:931–953. https://doi.org/10.1016/S0048-7333(00)00113-X

Davies A, Brady T (2016) Explicating the dynamics of project capabilities. Int J Project Manag 34:314–327. https://doi.org/10.1016/j.ijproman.2015.04.006

Davies A, Hobday M (2005) The business of projects: managing innovation in complex products and systems. Cambridge University Press, Cambridge

Davies A, Mackenzie I (2014) Project complexity and systems integration: constructing the London 2012 Olympics and Paralympics Games. Int J Project Manag 32:773–790. https://doi.org/10.1016/j.ijproman.2013.10.004

de Araújo MCB, Alencar LH, de Miranda Mota CM (2017) Project procurement management: a structured literature review. Int J Project Manag 35:353–377. https://doi.org/10.1016/j.ijproman.2017.01.008

de Boer L, Holmen E, Pop-Sitar C (2003) Purchasing as an organizational design problem: the case of non-product-related items and services. Manag Decis 41:911–922. https://doi.org/10.1108/00251740310500903

Denicol J, Davies A, Pryke S (2021) The organisational architecture of megaprojects. Int J Project Manag 39:339–350. https://doi.org/10.1016/j.ijproman.2021.02.002

Eriksson PE, Westerberg M (2011) Effects of cooperative procurement procedures on construction project performance: a conceptual framework. Int J Project Manag 29:197–208. https://doi.org/10.1016/j.ijproman.2010.01.003

Flyvbjerg B (2021) Make megaprojects more modular. Harvard Business Review, Brighton, pp 1–16

Gadde LE, Jellbo O (2002) System sourcing: opportunities and problems. Eur J Purch Supply Manag 8:43–51. https://doi.org/10.1016/S0969-7012(01)00013-2

Gansmo HJ (2012) Municipal planning of a sustainable neighbourhood: action research and stakeholder dialogue. Build Res Inf 40:493–503. https://doi.org/10.1080/09613218.2012.676319

Ghaffarianhoseini A, Tookey J, Ghaffarianhoseini A, Naismith N, Azhar S, Efimova O, Raahemifar K (2017) Building Information Modelling (BIM) uptake: clear benefits, understanding its implementation, risks and challenges. Renew Sustain Energy Rev 75:1046–1053

Gray B (1989) Collaborating: finding common ground for multiparty problems. Jossey-Bass, San Francisco

Gustavsson E, Elander I (2016) Sustainability potential of a redevelopment initiative in Swedish public housing: the ambiguous role of residents' participation and place identity. Prog Plan 103:1–25. https://doi.org/10.1016/j.progress.2014.10.003

Hamdan HAM, de Boer L (2019) Innovative public procurement (IPP)—implications and potential for zero-emission neighborhood (ZEN) projects?. In: IOP Conference Series: Earth and Environmental Science. IOP Publishing Ltd, Bristol. https://doi.org/10.1088/1755-1315/352/1/012013

Hamdan HAM, Andersen PH, de Boer L (2021a) Stakeholder collaboration in sustainable neighborhood projects—a review and research agenda. Sustain Cities Soc 68:102776. https://doi.org/10.1016/j.scs.2021.102776

Hamdan HAM, de Boer L, Baer D (2021b) When green procurement meets complexity: the case of sustainable neighborhood projects. Sustainability 13:2116. https://doi.org/10.3390/su13042116

Hobday M (1998) Product complexity, innovation and industrial organisation. Res Policy 26:689–710. https://doi.org/10.1016/S0048-7333(97)00044-9

Hobday M, Rush H, Tidd J (2000) Innovation in complex products and systems. Res Policy 29:793–804. https://doi.org/10.1016/s0048-7333(00)00105-0

Hoetker G, Swaminathan A, Mitchell W (2007) Modularity and the impact of buyer-supplier relationships on the survival of suppliers. Manag Sci 53:178–191

Igarashi M, de Boer L, Fet AM (2013) What is required for greener supplier selection? A literature review and conceptual model development. J Purch Supply Manag 19:247–263. https://doi.org/10.1016/j.pursup.2013.06.001

Igarashi M, de Boer L, Michelsen O (2015) Investigating the anatomy of supplier selection in green public procurement. J Clean Prod 108:442–450

Koch A, Girard S, McKoen K (2012) Towards a neighbourhood scale for low- or zero-carbon building projects. Build Res Inf 40:527–537. https://doi.org/10.1080/09613218.2012.683241

Krangsås SG, Steemers K, Konstantinou T, Soutullo S, Liu M, Giancola E, Prebreza B, Ashrafian T, Murauskaitė L, Maas N (2021) Positive energy districts: identifying challenges and interdependencies. Sustainability 13:10551. https://doi.org/10.3390/su131910551

Kuronen M, Vaara P (2013) Procurement clinics in public procurement and urban development. Proc Inst Civil Eng 166:265–270. https://doi.org/10.1680/muen.12.00045

Lakemond N, van Echtelt F, Wynstra F (2001) A configuration typology for involving purchasing specialists in product development. J Supply Chain Manag 37:11–20. https://doi.org/10.1111/j.1745-493X.2001.tb00108.x

Lember V, Kalvet T, Kattel R (2011) Urban competitiveness and public procurement for innovation. Urban Stud 48:1373–1395. https://doi.org/10.1177/0042098010374512

McQuiston DH (1989) Novelty, complexity, and importance as causal determinants of industrial buyer behavior. J Mark 53:66–79

Mofidi F, Akbari H (2020) Intelligent buildings: an overview. Energy Build 223:110–192

Nielsen BF, Baer D, Lindkvist C (2019) Identifying and supporting exploratory and exploitative models of innovation in municipal urban planning: key challenges from seven Norwegian energy ambitious neighborhood pilots. Technol Forecast Soc Change 142:142–153

Oliver A (2018) Lessons learned from eco-district pilot projects: the importance of stakeholder relations. Ph.D. thesis, Faculty of Environmental Design, University of Montreal

Oliver A, Pearl DS (2018) Rethinking sustainability frameworks in neighbourhood projects: a process-based approach. Build Res Inf 46:513–527. https://doi.org/10.1080/09613218.2017.1358569

Schotanus F, Telgen J (2007) Developing a typology of organisational forms of cooperative purchasing. J Purch Supply Manag 13:53–68. https://doi.org/10.1016/j.pursup.2007.03.002

Shi Q, Yu T, Zuo J, Lai X (2016) Challenges of developing sustainable neighborhoods in China. J Clean Prod 135:972–983. https://doi.org/10.1016/j.jclepro.2016.07.016

Skaar C, Labonnote N, Gradeci K (2018) From zero emission buildings (ZEB) to zero emission neighbourhoods (ZEN): a mapping review of algorithm-based LCA. Sustainability 10:2405

Sporrong J, Kadefors A (2014) Municipal consultancy procurement: new roles and practices. Build Res Inf 42:616–628. https://doi.org/10.1080/09613218.2014.900260

Taveres-Cachat E, Grynning S, Thomsen J, Selkowitz S (2019) Responsive building envelope concepts in zero emission neighborhoods and smart cities—a roadmap to implementation. Build Environ 149:446–457

Van Weele AJ (2018) Purchasing and supply chain management, 7th edn. Cengage Learning EMEA, Boston

van Zoest S, Volker L, Hermans M (2019) Implementing a new procurement strategy: the case of social housing associations. Int J Manag Proj Bus 13:409–425. https://doi.org/10.1108/IJMPB-09-2018-0189

Walker D, Rowlinson S (2007) Procurement systems: a cross-industry project management perspective. Routledge, New York

Wiik MK, Fufa SM, Kristjansdottir T, Andresen I (2018) Lessons learnt from embodied GHG emission calculations in zero emission buildings (ZEBs) from the Norwegian ZEB research centre. Energy Build 165:25–34. https://doi.org/10.1016/j.enbuild.2018.01.025

Wiik MK, Fjellheim K, Krogstie J, Ahlers D, Wyckmans A, Driscoll PA, Brattebo H, Gustavsen A, Fufa SM, Lien SK (2021) Zero emission neighbourhoods in smart cities: definition, key performance indicators and assessment criteria: version 2.0. ZEN Report No. 32. Research Centre on Zero Emission Neighbourhoods in Smart Cities, Trondheim

Wiik MK, Fjellheim K, Vandervaeren C, Lien SK, Meland S, Nordström T, Cheng CY, Brattebø H, Thiis TK (2022) Zero emission neighbourhoods in smart cities: definition, assessment criteria and performance indicators: version 4.0—ZEN Report No. 45. Research Centre on Zero Emission Neighbourhoods in Smart Cities, Trondheim

Williams TM (1999) The need for new paradigms for complex projects. Int J Project Manag 17:269–273. https://doi.org/10.1016/S0263-7863(98)00047-7

Yin RK (2018) Case study research and applications: design and methods, 6th edn. SAGE Publications Inc, Los Angeles

Zhan C, de Jong M (2018) Financing eco cities and low carbon cities: the case of Shenzhen International Low Carbon City. J Clean Prod 180:116–125