Article

Navigating Approaches to the Use of Pattern Language Theory in Practice

Ruihua Chen [1], Marina Bos-de Vos [2], Ingrid Mulder [3],*, and Zoë van Eldik [4]

[1] Beijing Shangyi Heart Technology Co. Ltd., China
[2] Department of Design, Organisation and Strategy, Delft University of Technology, The Netherlands
[3] Department of Human-Centered Design, Delft University of Technology, The Netherlands
[4] Wageningen Environmental Research, Wageningen University & Research, The Netherlands

* Corresponding author (i.j.mulder@tudelft.nl)

Abstract
Christopher Alexander's Pattern Language Theory (PLT) has been recognized as a valuable methodology to understand complex systems. It has been applied across domains through a variety of different approaches. This article reviews existing approaches to PLT application and reflects upon the differences between them. We find that application generally differs across four components: artefact, activity, roles and tools, informed by practitioners' diverging values and needs. We elaborate on how consciously navigating the dimensions that these components consist of can help to broaden the application of PLT in practice. We report on the development of a set of conceptual tools that aim to support this process. The resulting "activity kit" has been applied in a Dutch housing renovation project to support homeowners in communication and decision-making to illustrate the applicability of our methodology. It can be concluded that the "activity kit" is a promising approach to broaden the use of PLT and contributes to the methodological repertoire of researchers and practitioners to address complexity in today's societal challenges.

Issue
This article is part of the issue "Assessing the Complex Contributions of Christopher Alexander" edited by Michael W. Mehaffy (Sustasis Foundation) and Tigran Haas (KTH Royal Institute of Technology).

1. Introduction

Christopher Alexander's Pattern Language Theory (PLT) has been recognized as a valuable methodology for understanding and designing complex systems. In short, the simple structure of PLT has enabled people without relevant expertise to make decisions for a complex system, such as the urban planning of a community or the design of a service (Alexander et al., 1975, 1977). It has been successfully applied in various (participatory) project contexts including medical service system design (Athavankar, Khambete, Roy, et al., 2014) and policymaking for community dwellings (Palmieri et al., 2021). As PLT has been applied to different domains, changes made to Alexander's original PLT have been part of an ongoing debate (Borchers, 2000; Gamma et al., 1995; Golden,

2009). In short, it can be concluded that even though cases have qualities and characteristics that relate to PLT, oftentimes the approaches taken differ from Alexander's original theory.

However, these differences between PLT approaches and their underlying reasons are often unspecified. This might lead to misunderstanding among researchers and practitioners considering the use of PLT in a new project. Ultimately, it might decrease the effectiveness and diffusion of PLT in practice (Wania & Atwood, 2009). In many cases, PLT is applied in ways that do not (fully) align with the core goals or ambitions of a project. We take the premise that to properly use PLT, decision-making on which PLT approach to use needs to be supported as well as the use of existing approaches must be differentiated. The current work aims to broaden the use of PLT towards

a meaningful application of Alexander's scholarly work in practice. We have reviewed existing applications of PLT to identify similarities and differences among existing approaches. In the following sections, we introduce the methodology of the integrative literature review and elaborate on how the findings have informed the development of three conceptual tools. We present the conceptual tools and illustrate them with an ongoing community housing renovation project in the Netherlands and their value for navigating PLT in practice.

2. Integrative Literature Review

To improve clarity about how PLT is, and can be used in practice, an integrative literature review has been conducted. Integrative literature reviews are suitable for generating new knowledge about mature or new emerging topics by critically reviewing but also synthesizing existing, representative literature in an integrative way (Torraco, 2005). The creative process of synthesis brings together existing knowledge in a new way, for example by looking at it through a specific lens or connecting it to new ideas or conceptualizations of the author (Torraco, 2005). In this way, "new frameworks and perspectives on the topic are generated" (Torraco, 2005, p. 356). Such new frameworks and perspectives, often oriented towards applicability in practice, are of great importance for allowing PLT to be more effectively applied and broadly diffused within the practice.

A literature search was executed by the first author in 2022. The search string consisted of "pattern language" AND ("process" OR "implementation") OR "review." This search string allowed us to find articles that included anywhere in the article the exact phrase "pattern language" and at least one of the words "process," "implementation," or "review." These latter words helped us to find articles that discussed the actual use and application of PLT in practice. The search was performed on Google Scholar, with access to Google Books, Elsevier, Springer, IEEE, ACM digital library, and Wiley online library. The references provided by each document were checked for snowball sampling (Wohlin, 2014) and some relevant documents were added to the sample. After removing duplicates, the titles, abstracts and keywords were checked again to filter and formulate the sample. Articles that were only about PLT theory and not about PLT application were manually excluded by reading the title, abstract, methodology, and conclusions. Similarly, articles that investigated whether PLT was the best approach for a specific project and/or critiqued PLT were excluded as they fell outside the scope of our study. The sample refers to 46 documents reporting a specific case of pattern language application; in addition to *The Oregon Experiment* (1975) by Alexander and colleagues, seven other books or book chapters were included as well as 35 journal and/or academic conference papers, two master theses, and one doctoral dissertation. These documents cover the domains of architecture, urban design, policymaking, business upgrading, sustainability, theatre, software engineering, interaction design, and service design (see Supplementary File for further details).

The literature analysis was done in three stages, which we refer to as "deconstructing," "identifying," and "reconstructing." Each stage contained separate rounds of coding and/or clustering.

1. Deconstructing: This stage is aimed at discovering *components* that different PLT approaches have in common. We first coded information about how PLT has been executed in practice, including the advantages that using PLT was expected to have, and the actions that were taken to ensure these advantages could appear. The detailed coding scheme can be seen in Table 1. The scheme was continuously extended and revised by the first author during the coding process as new information was found relevant or more fitting wording was encountered. A total of 231 codes were generated in this stage.

Table 1. Coding scheme.

Aspect	Definition	Selection criteria	Examples of codes
Expected benefits	The benefits of PLT which are expected to take place by the practitioners when being applied in the context.	• Advantages or benefits of PLT expected to be achieved in its application. • Mentioned challenges or problems to be solved with PLT. • Research goal or project goal expected to be achieved with PLT.	Bottom-up, transfer of inspiration, participation of end users, communication between different expertise, etc.
Application approach	How PLT is executed, including the design of the application process, the people involved etc.	• Research design. • Application design, such as the activities to perform, the respondents or executors to involve, and/or other agencies involved by design. • Method of using or developing the pattern language or patterns.	Developed by experts, developed by end users, based on experience, based on expectations, etc.

Second, we clustered the codes. To enable easy clustering, all codes were documented in Excel, and imported to Miro as sticky notes. On the Miro board, all codes and corresponding text excerpts were reread carefully to understand which "aspect" of the approach was being decided on in the discussed case. This "aspect" was then included in the name of the code. The code names summarize the codes and excerpts in intuitive and straightforward words or phrases, such as "created by users," "gather from the field," "visionary," or "empirical," etc. Sticky notes with codes describing the same "aspect" were located together on the Miro board. At the same time, similar or ambiguous names were gradually unified. For example, "actions on pattern language" and "activities" were unified into "activities around pattern language." The names of sticky note clusters underwent constant refinement during the process. The clustering finally resulted in five overarching themes, namely "expected benefits," "the pattern language/patterns," "activities around pattern language," "people," and "external tools." The latter four themes represent the main aspects to decide on in applying PLT, and can thus be seen as core components of PLT approaches. For simplicity and ease of referring, the names of these four components were refined into "artefact," "activity," "role," and "tool."

2. Identifying: Since users of PLT also need to know what choices are available in relation to these four components to narrow down their options, our second analysis stage focused on listing the available choices for the different PLT components that were found. The sticky notes of the codes that had been generated and clustered on the scale of a single "component" in the previous analysis stage, were clustered more finely on the Miro board. The codes describing a pair of opposing characteristics were put on two ends of one arrow—which we refer to as "a dimension". For example, a code describing an activity led by medical experts was put opposite to a code about an activity led by an end-user without any medical expertise. Each dimension was given a name to describe the pair of opposing characteristics of the component. For the above-mentioned example, the dimension was named "Activity: bottom-up vs. top-down." A total of seven *dimensions* were generated in this step: three for the artefact component (i.e., user-created vs. professional-created; internally hierarchical vs. externally hierarchical; empirical vs. visionary), two for the activity component (i.e., circular vs. (multi-)linear; bottom-up vs. top-down), and two for the role component (i.e., end-user involved vs. end users not involved; heterogeneous vs. homogeneous). Within the tool component, codes did not show any opposing features, hence no dimension was generated here.

3. Reconstructing: Certain choices for different components fit each other and usually appear together in the PLT application. Describing such associations with a higher-level dimension makes decision-making easier for PLT users. Our third stage of analysis focused on finding such *higher-level dimensions*. First, the seven dimensions generated in the Identifying stage were clustered according to their relevance. For example, whether the activity is bottom-up or top-down is closely related to whether the artefact is created by end users or created by professionals. More specifically, if the artefact is created by end users, at least the development activity of this approach can be taken as bottom-up. Such two dimensions, although respectively for different components, were brought together. In this step, two higher-level dimensions, namely "bottom-up vs. top-down'' and "empirical vs. visionary" were formulated out of five initial dimensions. Two initial dimensions did not show many relations to the others. After finding out "which" choices of components usually appear together, we studied "why" the concurrences often happen. Inspired by the idea that the expected benefits of PLT (Wania & Atwood, 2009) and a value system are always embedded in an approach (Fincher, 1999), we related the two higher-level dimensions to PLT's benefits and values. Using the framework of values by Bos-de Vos (2020), the underlying values of both ends of each higher-level dimension were identified. For example, for the higher-level dimension "bottom-up vs. top-down," the values of "social justice" and "egalitarianism" were identified as being most in line with the bottom-up end, while "efficiency" and "mastery" corresponded with the top-down end. We also related the codes about PLT's benefits (generated in the Deconstruction stage, see Table 1) to the two higher-level dimensions. For example, the high-level dimension "bottom-up vs. top-down" was related to the benefit of PLT enabling "participation of end users."

3. Towards Conceptual Tool Development

This section includes the PLT components and dimensions that were derived from the literature review, as well as the three conceptual tools that were developed based on these components and dimensions.

3.1. Four PLT Components

As mentioned in the previous section, our analysis process revealed four components that characterize PLT application, namely artefact, activity, role, and tool. Each PLT application, regardless of any differences it has from Alexander's approach, consists of these four components. The four components also embody the differences between an approach and the Alexandrian approach.

The artefact component refers to the patterns or pattern language that is/are used in an approach. A pattern or pattern language is itself an artefact, sometimes physical, such as books or cards (Alexander, 1979; Athavankar, Khambete, Doke, et al., 2014), sometimes virtual, such as a pattern language on a website (Experiences—A pattern language for user interface design, n.d.). According to Khambete (2013), a visualized format of pattern language can embody the connections between patterns and make it simpler for users to navigate across them.

The activity component represents the actions around the artefact (pattern language/patterns) in an approach. According to Chen et al. (2007), four activities can be identified in Alexander's pattern language trilogy—i.e., the three books *The Timeless Way of Building* (Alexander, 1979), *A Pattern Language* (Alexander et al., 1977), and *The Oregon Experiment* (Alexander et al., 1975)—including developing a pattern language, and three ways of using pattern language, namely selecting patterns from the pattern language, diagnosing with the patterns, and designing with the patterns.

With the role component, we refer to the people that are involved in the application of PLT. Drawing upon our analysis of the literature, we classify all roles into three groups: experts, professionals, and end users, in terms of their relative expertise in the domain. In different PLT approaches, these three groups can be selectively involved or excluded as needed. The expert group involves researchers or senior practitioners that have the capacity of extracting methodologies from practices. In Alexander's theory, this group includes Alexander himself, as the advocate of applying pattern language. The experts usually have the highest expertise, but limited influence on the context. The professional group consists of the practitioners in the field, who are making design decisions. For example, the "full-time architects or planners" in *The Oregon Experiment* (Alexander et al., 1975, p. 35), the teachers as the designers and executors of their curricula etc. Professionals are usually criticized for making the results "idiosyncratic" (Alexander et al., 1975, p. 30) when not involving end users. The group of end users consists of the users of the system. This group is traditionally excluded from the design process. For example, in Alexander's theory, the end users of urban planning are the inhabitants who have no idea of how their habitat is designed. In education, the end users are the students who are traditionally not engaged in deciding what and how they should learn. Although end users are most subject to the changes brought by new decisions, they exert the least impact on the decision-making process. However, the end users can be engaged in a bottom-up approach, which is also what Alexander advocates in his PLT trilogy. In such an approach, end users will be able to bring in their insights and regain political power.

The tool component supports the activity component. Some tools can help align stakeholders. In the work of Khambete (2013), researchers use a value system to present end users' goals and standards for a good design. By constantly reflecting on the value system, the researchers make sure the patterns are developed and used in line with end users' needs. In Köppe et al. (2017), a "value-based workshop" was organized to identify stakeholders' common values. This also enables further collaboration in other activities. Another type of tool that is used is for framing or scoping a project. In the study of Athavankar, Khambete, Roy, et al. (2014), a service blueprint was used to decide which touchpoints should be focused on in the project. In addition, prototypes in website design (Dearden et al., 2002), master plans in urban design (Alexander et al., 1975) and storyboards in service design (Dearden et al., 2002) can achieve the same goal. Furthermore, tools for translating knowledge into patterns are often used in different approaches. The pattern format given by Alexander in his trilogy is the most used one.

Figure 1 shows how the four components mentioned above are interrelated. It illustrates how the activity component can be seen as the context of the other three: Without notifying which activity is being discussed, discussions on what artefact (i.e., patterns/pattern language) should be used or produced, which roles should be involved, and what tools should be used, cannot go on. The activity component, therefore, is the primary component to decide on when deciding on an approach for PLT application. There are various relations possible between tools and the artefact (represented with * in Figure 1). For example, in the case of design pattern cards, the cards (tool) serve as the medium for communicating the patterns (artefact), while a service blueprint (tool) helps researchers to frame or scope for the development of the pattern language (artefact; Athavankar, Khambete, Roy, et al., 2014).

3.2. Seven Initial Dimensions

In the identifying stage of the literature review, three components were found to vary across a total of seven dimensions (see Table 2). First, the artefact can be either user-created or professional-created. Since the pattern language used by Alexander was created by his colleagues and himself (Alexander, 1979); their expectations inevitably lay behind the pattern language. Compared to this, patterns created by end-users represent users' dreams and needs (Palmieri et al., 2021). Second, the artefact can be either internally hierarchical or externally hierarchical. The pattern language created by Alexander and his colleagues was internally hierarchical, which means that the connections between patterns naturally exist. Alexander initiated the concept of pattern language as a connected set of patterns, rather than a random set (a random set of patterns is sometimes addressed as a pattern "catalogue" (Salingaros, 2000). In Alexander's way, several lower-level patterns complete each other and form a higher-level pattern. The patterns are collected together
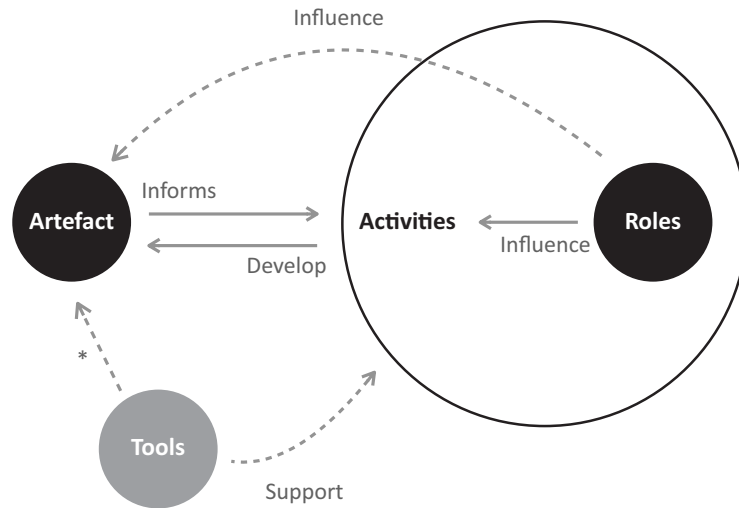
Figure 1. The PLT components and their interrelations.

because when fulfilling one larger pattern, the smaller patterns need to be fulfilled first. Compared to this, an external hierarchy is created by the pattern developer but does not occur naturally. For example, the way Gamma et al. (1995) collect patterns, is by classifying all patterns into three categories (creational patterns, structural patterns, and behavioural patterns), but not directly by the connections between single patterns. In other words, the structure or hierarchy of Gamma et al.'s patterns is imposed by the researchers' preferences rather than by the internal hierarchical relation between patterns. This hierarchy allows users to find a pattern more easily but is "forced" by the developers (Coplien & Schmidt, 1995). Third, the artefact can be either empirical or visionary. Alexander's patterns came from empirical experiences. Patterns can also be visionary. For example, end users could write their ideal living as visionary dwelling patterns (Palmieri et al., 2021). In addition, designers could use patterns as unfinished prototypes (Schön, 1983) which later on can be tested and iterated on through design activities. Fourth, the activities can be either circular or (multi-) linear. *The Oregon Experiment* (Alexander et al., 1975) presents a circular process between developing pattern language and using pattern language. The users who were involved in the design activities were encouraged to improve the

patterns according to their new experiences. In turn, the improved patterns gave feedback to improve the design. In comparison, some projects such as those of Zhang et al. (2017) and Ortega-Arjona (2010) followed a linear process, without iterations on pattern language. Fifth, the activities can be either bottom-up or top-down. Alexander argued for a bottom-up approach, in which residents themselves initiate and design a complete project (Alexander, 1979). Yet in other domains, such as education (Köppe et al., 2017), the students were not involved to design the course for themselves. In real life, most cases fall between the two extremes. For example, in *The Oregon Experiment* (Alexander et al., 1975), Alexander presented a complete bottom-up design activity but a top-down pattern development activity. Sixth, for the Roles, the end users can be either involved or excluded. This dimension is similar to the "bottom-up vs. top-down" dimension for activity. Finally, the composition of roles can be more heterogeneous or more homogeneous. This depends on the nature of a project, whether it is multi-disciplinary—such as in service design or interaction design (Athavankar, Khambete, Roy, et al., 2014; Baltzer et al., 2019; Bayle et al., 1998; Borchers, 2000; Khambete, 2013; Pollmann & Ziegler, 2021)—or not—such as in software engineering (Ortega-Arjona, 2010; Zhang et al., 2017; Zhao et al., 2008).

Table 2. Overview of PLT dimensions.

Index	Component	Extreme 1	Extreme 2
1	Artefact	User-created	Professional-created
2		Internally hierarchical	Externally hierarchical
3		Empirical	Visionary
4	Activity	Circular	Linear
5		Bottom-up	Top-down
6	Roles	End users involved	End users not involved
7		Heterogeneous	Homogeneous

3.3. Two Higher-Level Dimensions

The first high-level dimension "bottom-up vs. top-down" was synthesized from three initial dimensions, namely "Artefact: user-created—professional—created," "Practice: bottom-up—top-down," and "Roles: involving end-users—not involving end-users." These three are all about whether a change or a decision-making process is initiated by the end users (grassroots) or by someone with higher authority, such as professionals or experts. In this high-level dimension, "bottom-up" corresponds to PLT's advantage in "engaging end users" (Alexander, 1979; Palmieri et al., 2021) and human values of "social justice" or "egalitarianism" in reference to the framework of values by Bos-de Vos (2020). While "top-down" cases do not necessarily express an "injustice" value. Involving end users is not the first preference, either for efficiency or for business confidentiality.

A second high-level dimension "visionary vs. empirical" was synthesized from two dimensions: "Artefact: visionary—empirical" and "Practice: circular—linear." Both dimensions reflect practitioners' beliefs on whether a better alternative to the current best practice could exist. Or in other words, whether industry revolution/transformation is welcomed. The approaches that use visionary patterns, often use expressions such as "transformative," "challenging," or "transforming," which reflect a departure from what is considered mainstream practice. This is in line with their critiques against Alexander's approach which is "over-focusing on replicability" (Palmieri et al., 2021). Compared to that, approaches using empirical patterns were more inclined to reconfirm the traditional or existing best practices. We use "industry transformation" and "reusing known solutions" to represent the two opposite values.

3.4. Three Conceptual Tools

Three conceptual tools were generated following the results of the integrative literature review results to support use in practice. These tools aim to provide visual and textual understandability and help in differentiating between PLT approaches. More specifically, the tools inform users what aspects of a PLT approach should be decided on and motivate underlying reasons or mindsets that should be reflected when making decisions.

The first conceptual tool, the Approach Axes (Figure 2) contains two tables. Each table details one of the two higher-level dimensions: "bottom-up vs. top-down" and "visionary vs. empirical." The characteristics of and underlying reasons for the two extremes of each dimension are introduced in each table. The characteristics include common expressions, key activity, source of patterns and user of the pattern language. The underlying reasons include the underlying values of the practitioners and their expected benefits of applying PLT. These elements were extracted from the literature.

The second conceptual tool, the "Navigation Panel" (Figure 3) is a combination of the two approach axes. The panel of PLT approaches is divided by the two axes into four areas, each representing one typical approach to using PLT. The four approaches are detailed in Table 3; a third conceptual tool that combines the Approach Axes tables and adds a slogan and a representative example for each approach.

4. Developing a Process to Decide on a PLT Approach

Three workshops with ten practitioners, researchers, and students have been conducted to evaluate the practical usability of the proposed conceptual tools in practice. A first sensitizing activity focused on letting participants think concretely about a concern, worry or difficulty (i.e., a problem) in an ongoing project. Participants were then asked to write down and share this problem with the others. The participants were then introduced to the concept of PLT and the three conceptual tools. After this, participants considered and discussed how PLT could be applied to the problem they had raised, and how the conceptual tools could support this application. Textual and graphical materials were used to facilitate the workshops. The audio of the three sessions was recorded, transcribed, coded and analysed.

In the workshops, the three conceptual tools were found to be helpful in three ways. First, they urged participants to consider and communicate their underlying values in the projects. For example, through working with the navigation panel participants were better able to articulate what they consider important and how they approach the project. This also helped them in aligning with or considering their alignment with other stakeholders in the project, as the quote below shows:

> If you are working with other stakeholders, and have to agree on what it is that you are aiming for with the project, this is a nice way to get on the same page. Because maybe I was making it too hard in my project, I was on a vision-making [visionary knowledge production], but maybe what they want is just decision-making [empirical knowledge production]. So I don't need to make it difficult for myself. (P4)

Second, the conceptual tools were considered helpful for practitioners in choosing their approach to using PLT. For practitioners already applying PLT, the tools can help position their current approach, reflect on whether they are using it in a way that is aligned with their values, and decide for a change when disconformity exists.

Third, the conceptual tools facilitated adopting a long-term perspective towards the project. Even though practitioners may find an approach to align well with their underlying values and purposes, there may exist limitations towards implementing this approach. For example, it may not always be (directly) feasible to involve end-users. In the workshops, quite a few
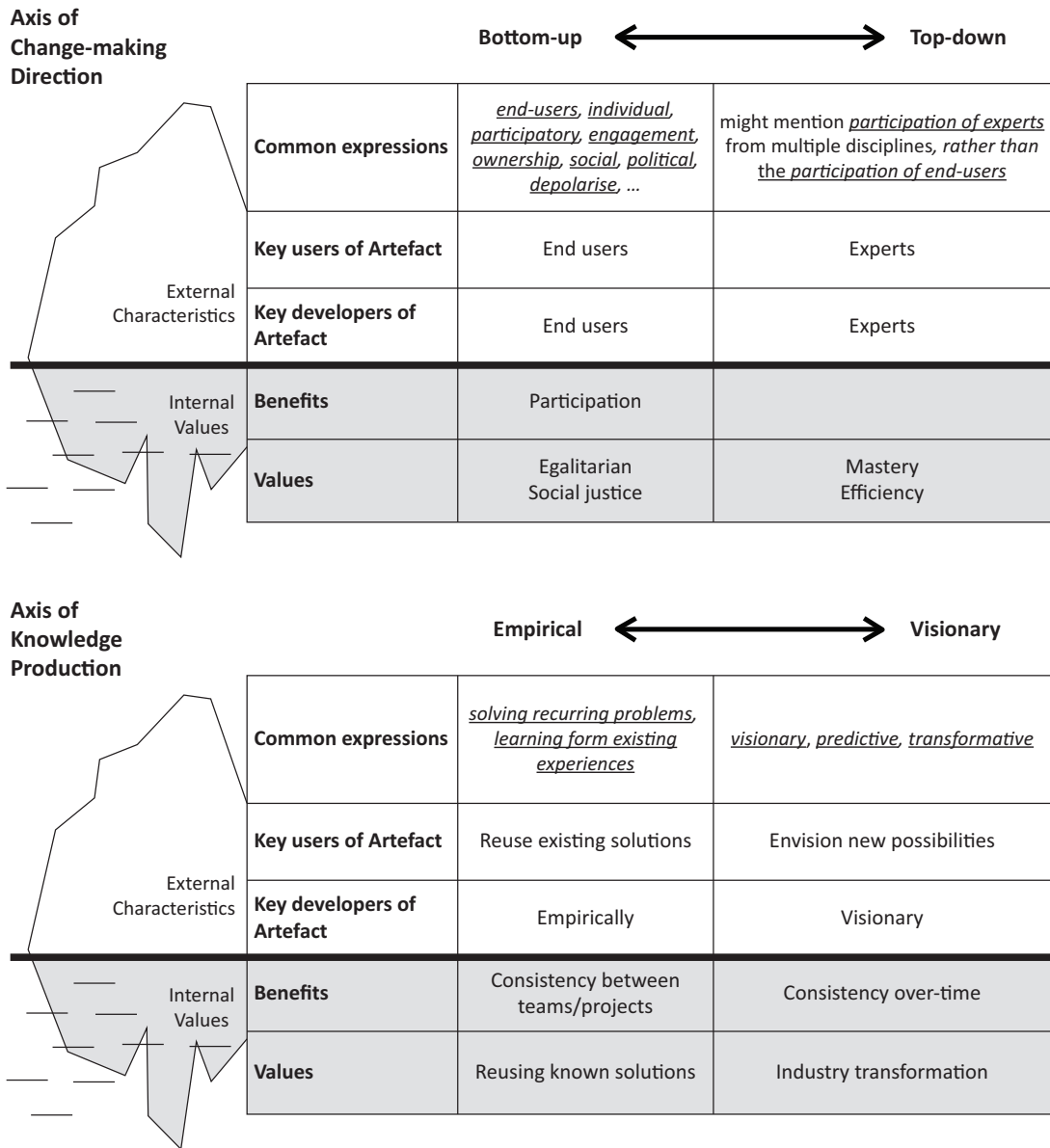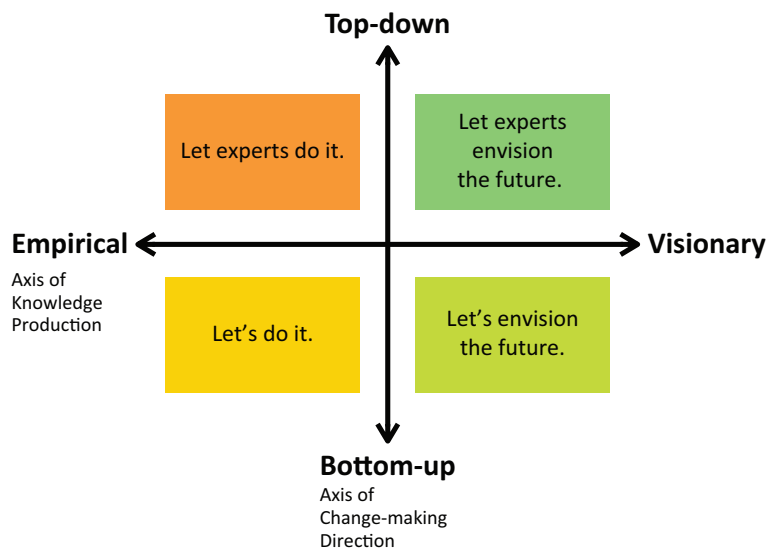
Axis of Change-making Direction

		Bottom-up	Top-down
External Characteristics	**Common expressions**	*end-users*, *individual*, *participatory*, *engagement*, *ownership*, *social*, *political*, *depolarise*, …	might mention *participation of experts* from multiple disciplines, *rather than the participation of end-users*
	Key users of Artefact	End users	Experts
	Key developers of Artefact	End users	Experts
Internal Values	**Benefits**	Participation	
	Values	Egalitarian Social justice	Mastery Efficiency

Axis of Knowledge Production

		Empirical	Visionary
External Characteristics	**Common expressions**	*solving recurring problems*, *learning form existing experiences*	*visionary*, *predictive*, *transformative*
	Key users of Artefact	Reuse existing solutions	Envision new possibilities
	Key developers of Artefact	Empirically	Visionary
Internal Values	**Benefits**	Consistency between teams/projects	Consistency over-time
	Values	Reusing known solutions	Industry transformation

Figure 2. The Approach Axes.

Figure 3. The Navigation Panel.

Top-down

Let experts do it.

Let experts envision the future.

Empirical — *Visionary*

Axis of Knowledge Production

Let's do it.

Let's envision the future.

Bottom-up

Axis of Change-making Direction

Table 3. The Approach detail table.

Dimensions	Bottom-up & visionary	Top-down & visionary	Bottom-up & empirical	Top-down & empirical
Values	Social justice, transformation	Transformation	Social justice, mastery of immediate problems	Mastery of immediate problems
Expected benefits	Participation, consistency over time	Consistency over time	Participation, consistency between projects/teams	Consistency between projects/teams
Slogan	Let's envision the future	Let experts envision the future	Let's do it	Let experts do it
Roles: users	End users	Experts and professionals	End users	Experts and professionals
Roles: developers	End users	Experts and professionals	End users	Experts and professionals
Activity	Envision new possibilities	Envision new possibilities	Reuse existing solutions	Reuse existing solutions
Example cases	Flourishing Foodvalley: Pattern language as a co-design method to approach the transition towards circular agricultural systems in a hybrid landscape (te Duits, 2022)	Towards a pattern language for hybrid education (Köppe et al., 2017)	The PhOCoe Model–Ergonomic pattern mapping in participatory design processes (Silva e Santos, 2012)	A pattern language for designing e-business architecture (Zhao et al., 2008)

participants scribbled the route between their ideal approach and the approach that was feasible at that time on the Navigation Panel, thereby creating a long-term plan towards PLT application. For example, one participant first decided that a bottom-up and vision-making approach would be the best approach for her research project. Yet she admitted that because of the difficulty to access end-users, the project might have to start from a more top-down and decision-making approach. Clarifying her project as following a curved route in the navigation panel gave her a clearer understanding that over time, she should try to involve end-users and shift from using ready-to-use solutions to inventing more radical ones.

Although the conceptual tools were helpful for some activities, participants also encountered issues when trying to use PLT in the workshops. Most importantly, participants did not consider the exact purpose of their project before starting to use PLT. This resulted in overqualified activities that did not directly contribute to their projects. For example, in their first contact with the concept of PLT, most participants immediately considered developing a pattern language for their specific

problems, instead of searching for existing pattern languages that could be reused. Next to the tendency to try to reinvent the wheel, participants often felt rushed to complete a pattern language and sometimes overlooked the importance of non-professionals in developing a pattern language.

To solve the issues described above, we developed a process to decide on a PLT approach. This four-step process provides users with a reminder to consider the purpose of their project before deciding on the PLT approach to use (Figure 4).

The first step of "Understanding PLT" is optional, depending on whether the concept of PLT is new to the user or not. The emphasis is on the second step "Considering Purposes" where practitioners consider/reflect on their own purposes. This was informed by the workshop insights that presenting examples of achievable purposes could help participants take one step back to consider their own purposes:

This part, it's getting me to think about what the purpose of pattern language is and how to use it. So I just briefly gave up making the structure and started to
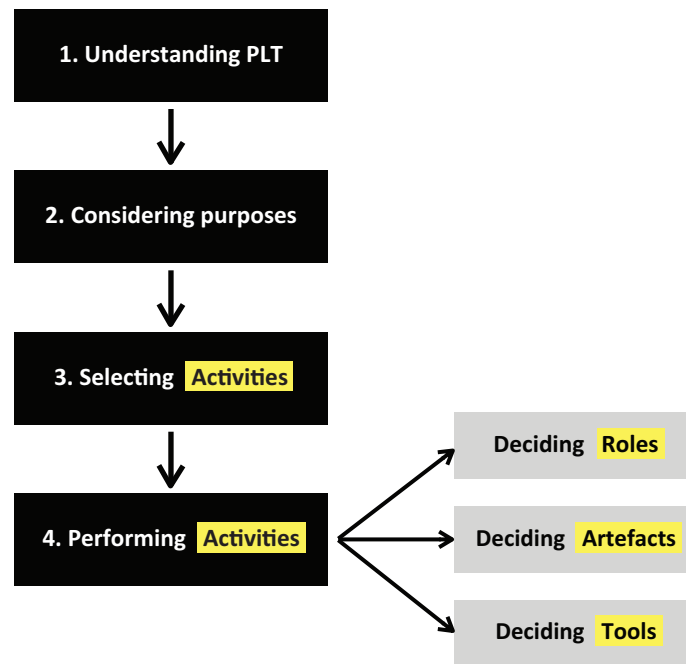
Figure 4. The process to decide on a PLT approach.

think about the purpose….So one step back before making the plan. (P9)

In the literature, we found eight common purposes for which PLT is applied in practice. From simple to more complex, these are: (a) developing an overview of a domain; (b) finding reusable solutions/measurements to diagnose or make decisions for the current situation; (c) creating a toolkit for a participatory (design) project; (d) identifying and externalizing reusable solutions from past project experiences; (e) understanding needs or externalizing knowledge of stakeholders; (f) eliciting vision from stakeholders; (g) identifying future research priorities; and (h) building an ever-growing knowledge database for a domain. With their purpose (this can but does not necessarily need to be one of the listed purposes) clearly in mind, users can begin their decision-making on the PLT approach, corresponding to the third step. To decide on the approach, all four components—artefact, activity, role, and tool—need to be taken into consideration. Among those, the activity component was chosen as the first to decide on, since it directly impacts all the other three components (see Figure 1). Finally, in the fourth step "Performing Activities," decisions on the other three components can be made.

5. Result: The Activity Kit

The three conceptual tools and the Process to decide on a PLT approach have been synthesized into a final toolbox for supporting decision-making on PLT approaches, which we refer to as an "Activity Kit" instead of a toolkit. Activity is the first component to decide on, whereas "tools" represent the agencies in support of activities.

The format of a "kit" was chosen for its practicality and interactive nature allowing customization. The Activity Kit provides a practical guide to using PLT more effectively in accordance with the four-step process (see Figure 4). It consists of an introduction to PLT, including a simple example; as well as the conceptual tools and workshop materials that help to consider the purpose(s) and to select and perform PLT application activities. For each purpose, an activity map with icons shows the recommended activities for reaching that specific purpose. For each activity, cards provide the supporting tools and other important information that enable users to perform the activity (see Figure 5). The Kit also includes an appendix with four representative cases corresponding to the four quadrants of the navigation panel. The cases present an application of pattern language where the actions are well aligned with the purpose. In the next section, we illustrate how the Kit has been used to navigate the complex challenges in a communal housing renovation project.

6. Using the Activity Kit in the Numansgors Project

A PLT approach always depends on the specific context of a project and the values of the stakeholders involved. Therefore, we introduce one specific context of study—the Numangors project—to illustrate the value of the literature insights and corresponding Activity Kit.

Numansgors is a former recreation park in the Netherlands which has been turned into a permanent residential community. The park was designed by the architecture firm Broekbakema in the late seventies and is situated along a wide tidal river. In terms of architectural and landscape aesthetics, not much has

Figure 5. Example of an activity card.

changed since the construction of the park. Many of the houses, however, no longer suffice to current sustainable energy and heating standards and need to be renovated. To coordinate renovation efforts, a voluntary commission was set up. The commission struggled to deal with the differences between households in terms of financial resources and technical knowledge. Moreover, previous individual initiatives to install solar panels and outdoor heat pump installations have been criticized for cluttering the park's unique aesthetic.

The Activity Kit has been used to brainstorm ways to address the complex challenges in Numansgors. It was decided that a top-down approach was first needed to explore different renovation options on a communal level because former individual renovation attempts have led to dissatisfaction among residents. This way, residents can be equally informed about the financial benefits and the potential aesthetic consequences of their decision to renovate.

Following the instructions of the Activity Kit, the Numansgors context serves the purpose of understanding the need and externalizing knowledge of stakeholders to retain the authenticity of these insights throughout the project (purpose 5 in the Kit). Actions connected to this purpose are to align stakeholders by using the right frames (determined by getting stakeholder insights) and writing and curating patterns out of these stakeholder insights (thus developing a pattern language). Following these instructions, a survey was handed out to the residents asking them about basic household information (such as energy labels or current implemented renovation measurements), important values (e.g., the main reason for living in Numansgors), and desirable outcomes of sustainability efforts (like energy cost reduc-

tion and consistency in the technical application of measurements). Consequently, outcomes of the survey were clustered into three subjects (patterns) that recurred in every recollected form. The first was a need for a better technical understanding of sustainability measurements, including the function of these measurements and the application of measurements. The second was a need for better insight into the financial benefits of measurements, including directions to subsidies and considerations in relation to the benefits of collective measurement and individual measurements. The last was to find more consistent and easy ways to communicate.

All subjects were visualized in a pattern language framework. The pattern language framework was handed over to the commission and residents, along with instructions on how to use it. The three main subjects of the PLT frameworks have since been incorporated into a community website. The website offers technical information and financial advice (e.g., how to apply for sustainability loans provided by the local municipality), based on the experiences of residents that have already renovated. Moreover, the website includes a forum in which residents can leave questions or experiences. The commission is key in connecting problem owners to the right solutions.

7. Conclusions

The contribution of the current research is twofold. In the first place, we provide a new lens to examine and differentiate various PLT applications. Both researchers and practitioners can use the conceptual tools developed to reflect on past or ongoing cases or to work on a new application. For example, researchers can use the tools

to examine projects in which PLT is/has been applied to uncover the extent to which underlying values are in line with the characteristics of the PLT approach. In case alignment is lacking, the effectiveness of the PLT application in this project is of particular interest and needs further examination. Second, a practical toolbox named the "Activity Kit" has been generated to support decision-making on PLT approaches; practitioners can choose and perform an appropriate PLT approach in line with their values and needs. In this way, practitioners can use PLT more effectively. The main contribution of the Activity Kit is that it stimulates a broader application of PLT as a necessary first step to further broaden the methodological repertoire of researchers and practitioners needed in addressing complexity in today's societal challenges.

Although the application of the Activity Kit in the Numangors Project was merely meant to illustrate the contribution of our methodology to the application of PLT, the results of our integrative literature review indicate a promising direction to assist researchers and practitioners in navigating options towards applying PLT in practice and thereby further diffusing Alexander's thoughts. We strongly encourage further validation and strengthening of both the theoretical basis and practical use of the Activity Kit. A systematic literature review would be helpful to develop a more nuanced and detailed understanding of PLT application. Also, a thorough evaluation study of the developed Activity Kit across cases in multiple fields would be highly recommended. A unique strength of the developed conceptual tools is that they are quite general and as such applicable to all kinds of design disciplines. Yet, to take into account the unique characteristics of these disciplines, future research could focus on exploring how the contents and application of tools may (or even should) differ to fit best with the practices and norms of the contexts in which they are applied. Furthermore, a more comprehensive discussion on values may require different tools. Currently, the two axes in the navigation panel can cover most initial dimensions with simplicity, but only address several types of values (egalitarianism and mastery). These values are sufficient for discussing PLT approaches, but in many projects also other values are at play.

Acknowledgments

Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

The full overview of reviewed literature is available online as supplementary material in the format provided by the authors (unedited).

References

Alexander, C. (1979). *The timeless way of building* (Vol. 1). Oxford University Press.

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A pattern language: Towns, buildings, construction* (Vol. 2). Oxford University Press.

Alexander, C., Silverstein, M., Angel, S., Ishikawa, S., & Abrams, D. (1975). *The Oregon experiment* (Vol. 3). Oxford University Press.

Athavankar, U., Khambete, P., Doke, P., Kimbahune, S., Devkar, S., Roy, D., & Chaudhary, S. (2014). Exploring cards for patterns to support pattern language comprehension and application in service design. In *Proceedings of the 6th Indian Conference on Human-Computer Interaction* (pp. 112–115). Association for Computing Machinery.

Athavankar, U., Khambete, P., Roy, D., Chaudhary, S., Kimbahune, S., Doke, P., & Devkar, S. (2014). Multidisciplinary team dynamics in service design-the facilitating role of pattern language. In *Proceedings of the 6th Indian Conference on Human-Computer Interaction* (pp. 16–25). Association for Computing Machinery.

Baltzer, M. C. A., López, D., & Flemisch, F. (2019). Towards an interaction pattern language for human machine cooperation and cooperative movement. *Cognition, Technology & Work*, *21*, 593–606.

Bayle, E., Bellamy, R., Casaday, G., Erickson, T., Fincher, S., Grinter, B., Gross, B., Lehder, D., Marmolin, H., Moore, B., Potts, C., Skousen, G., & Thomas, J. (1998). Putting it all together: Towards a pattern language for interaction design: A CHI 97 workshop. *ACM SIGCHI Bulletin*, *30*(1), 17–23.

Borchers, J. (2000). A pattern approach to interaction design. In *Proceedings of the 3rd conference on Designing interactive systems: Processes, practices, methods, and techniques* (pp. 369–378). Association for Computing Machinery.

Bos-de Vos, M. (2020). A framework for designing for divergent values. In S. Boess, M. Cheung, & R. Cain (Eds.), *Proceedings of DRS2020: Volume 1 synergy situations* (Vol. 1, pp. 39–53). Design Research Society. https://doi.org/10.21606/drs.2020.374

Chen, C. T., Cheng, Y. C., & Hsieh, C. Y. (2007). Towards a pattern language approach to establishing personal authoring environments in e-learning. In V. Uskov (Ed.), *Web-based education* (pp. 13–18). ACTA Press.

Coplien, J. O., & Schmidt, D. C. (Eds.). (1995). *Pattern languages of program design*. Addison-Wesley Publishing.

Dearden, A., Finlay, J., Allgar, E., & McManus, B. (2002). Using pattern languages in participatory design. In T. Binder, J. Gregory, & I. Wagner (Eds.), *Proceedings of the Participatory Design Conference (PDC 2002)* (pp. 104–113). Computer Professionals for Social Responsibility.

Experiences—A pattern language for user interface design. (n.d.). *Homepage*. http://www.maplefish.com/todd/papers/Experiences.html

Fincher, S. (1999). Analysis of design: An exploration of patterns and pattern languages for pedagogy. *Journal of Computers in Mathematics and Science Teaching*, *18*(3), 331–348.

Gamma, E., Helm, R., Johnson, R., Johnson, R. E., & Vlissides, J. (1995). *Design patterns: Elements of reusable object-oriented software*. Pearson Deutschland GmbH.

Golden, E. (2009). Helping software architects design for usability. In *Proceedings of the 1st ACM SIGCHI Symposium on Engineering Interactive Computing Systems* (pp. 317–320). Association for Computing Machinery.

Köppe, C., Nørgård, R. T., & Pedersen, A. Y. (2017). Towards a pattern language for hybrid education. In *Proceedings of the VikingPLoP 2017 Conference on Pattern Languages of Program* (pp. 1–17). Association for Computing Machinery.

Ortega-Arjona, J. L. (2010). *Patterns for parallel software design*. Wiley.

Palmieri, T., Huybrechts, L., & Devisch, O. (2021). Co-producing, curating and reconfiguring dwelling patterns: A design anthropological approach for sustainable dwelling futures in residential suburbs. *Design Studies*, *74*, Article 101011.

Pollmann, K., & Ziegler, D. (2021). A pattern approach to comprehensible and pleasant human–robot interaction. *Multimodal Technologies and Interaction*, *5*(9),

Article 49.

Salingaros, N. A. (2000). The structure of pattern languages. *arq: Architectural Research Quarterly, 4*(2), 149–162.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Routledge.

Silva e Santos, M. (2012). The PhOCoe model: Ergonomic pattern mapping in participatory design processes. *Work, 41*(Suppl. 1), 2643–2650.

te Duits, N. (2022). *Flourishing Foodvalley: Pattern language as a co-design method to approach the transition towards circular agricultural systems in a hybrid landscape* [Unpublished Master's thesis]. Delft University of Technology.

Torraco, R. J. (2005). Writing integrative literature reviews: Guidelines and examples. *Human Resource Development Review*, *4*(3), 356–367.

Wania, C. E., & Atwood, M. E. (2009). Pattern languages in the wild: Exploring pattern languages in the laboratory and in the real world. In *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology* (pp. 1–15). Association for Computing Machinery.

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering* (pp. 1–10). Association for Computing Machinery.

Zhang, P., White, J., Schmidt, D. C., & Lenz, G. (2017). Design of blockchain-based apps using familiar software patterns with a healthcare focus. In *Proceedings of the 24th Conference on Pattern Languages of Programs* (pp. 1–14). Association for Computing Machinery.

Zhao, L., Macaulay, L., Adams, J., & Verschueren, P. (2008). A pattern language for designing e-business architecture. *Journal of Systems and Software*, *81*(8), 1272–1287.

About the Authors

Ruihua Chen received a bachelor's degree in architecture from Harbin Institute of Technology (2020) and a MSc degree in Design for Interaction from Delft University of Technology (2022). Currently, she makes use of her human-centered design skillset as a product manager in a fin-tech company in China.

Marina Bos-de Vos has a PhD in Management of the Built Environment and holds an assistant professor position in the Design, Organisation and Strategy department of Industrial Design Engineering, TU Delft. She studies value co-creation processes in complex inter-organizational design projects and how these can be more consciously navigated and improved by designers. Her research is published across various academic disciplines and synthesized into practical methods and tools that students and professionals can use in collaborative design projects.

Ingrid Mulder is an associate professor design for social transformations, Delft University of Technology, and director of the Delft Design Lab Participatory City Making. Her background in policy and organization sciences (MA, University of Tilburg) and behavioural sciences (PhD, University of Twente) reinforces her ongoing transdisciplinary research at the frontiers of systemic design and social change. In her research, she takes the city as a space for design inquiry to study the changing role of design in a transforming society.

Zoë van Eldik has a background in cultural anthropology and development sociology. Currently, she works as a researcher at the Wageningen Environmental Research group at Wageningen University & Research, Wageningen, the Netherlands.