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Temporal challenges of building a circular city district through living-lab experiments

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Abstract

Urban living lab (ULL) experiments are expected to create grounds for circular city transitions but their temporal dynamics remain understudied. This study investigates the linkages of a particular sanitation experiment to a long-term urban development trajectories in the Hiedanranta ULL in the City of Tampere, Finland. The ethnographical study focuses on the temporal matches and mismatches of three interrelated timescales affecting the transformative potential of the experiment: 1) the experiment's life cycle, 2) the brownfield ULL and 3) the formal land-use planning of the future city district. Temporal analysis showed that the creation of transformative capacity requires a long development trajectory beyond a single experiment. In this case, the long-term development of R&D networks and the persistence and maturation of the ULL with its variety of co-developing experiments enabled experiment implementation; changed the city's sustainability discourse; and nurtured prominent cross-sectoral initiative of a super block. However, further implementation of ULL innovations in urban planning has proven to be difficult without a clear orchestrator. Practical recommendations highlight the need to clarify the strategic role of the ULL in experimental governance, transparent ULL processes that support learning, and overcoming transition barriers in the rigid infrastructure sector.

Keywords: experiment, urban living lab, formal land-use planning, timescales, circular city, new sanitation

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1 Introduction

Due to the fast urbanisation and growing consumption seen over the past decades (McKinsey Global Institute, 2016), the twofold negative impact affecting urban resource flows is becoming more evident. First, cities consume scarce resources from regional and global hinterlands; second, consumption of natural resources and waste disposal causes severe environmental effects (Agudelo-Vera et al., 2011). Subsequently, cities are facing increasing political pressure to promote sustainable resource use and enhance the circular economy (CE) (European Commission, 2018). A new term—the circular city—has emerged to describe the cities adopting the principles of a CE in urban development (Gravagnuolo et al. 2019). Closing the resource loops in cities requires innovation, participation and wide collaboration focusing on the interlinkages between resource streams, actions and sectors (Gravagnuolo et al. 2019, Paiho et al. 2021).

The research on sustainability transitions agrees that the reorganisation of urban infrastructures, which conduct flows of resources through cities, plays a central role in the transformation to circular cities (Frantzeskaki & Loorbach, 2010; Hodson et al., 2012; Paiho et al. 2021). A fundamental change is required both in the physical urban infrastructure and the institutions managing it (Frantzeskaki & Loorbach, 2010). The current study relates to the sanitation sector, where a paradigm shift is required to close the cycles of nutrients, energy and water (Drangert et al., 2018; Metson et al., 2018; Skambraks et al., 2017). New sanitation is a prominent paradigm for the management of nutrient-rich waste, with the aim to recover and reuse resources locally (Särkilahti et al., 2017; Wielemaker et al., 2018). Technical solutions vary, but usually, initiatives include the source separation of kitchen waste, black water (faeces and urine), grey water (washing) and/or urine (Wielemaker et al., 2018).

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In the Global North, renewing sanitation infrastructure contradicts path-dependent large investments (Metson et al., 2018) and the traditional boundaries between the water, energy and waste sectors (Skambraks et al., 2017). Renewing the infrastructures is going to be a slow process (Frantzeskaki & Loorbach, 2010) characterised by complex temporal dynamics (Quezada et al., 2016). Studies in the energy sector, which also has a long life-time infrastructure, have shown that multidecade shifts are needed in systemic transitions (Bento & Wilson, 2016). Taking into account the stability of the urban infrastructure systems, a crucial question is how the transition towards a circular city could happen, who leads it and what kind of social and governance processes can facilitate it (Hodson et al., 2012). To support urban infrastructure transition, strategies to increase flexibility, variety, innovative capacity and adaptability, along with a new governance approach fostering cross-organisational experimentation, are suggested (Frantzeskaki & Loorbach, 2010).

Since the late 1990s, socio-technical experiments have been practised and studied as promising seeds to the sustainability transition (Sengers et al., 2019). Lately, urban living labs (ULL) have been introduced as sites for socio-technical experimentation in cities and as novel instruments for collective urban planning (von Wirth et al., 2019; Voytenko et al., 2016). In experimental governance (Kronsell & Mukhtar-Landgren, 2018), cities facilitate ULL experimentation to create grounds for sustainability transition in urban development. In the field of new sanitation, several large-scale urban pilot areas have been planned and implemented in Northern Europe over the past decade (Skambraks et al., 2017). The idea of experimentation is that learning contributes to wider sustainability transitions (Sengers et al., 2019). However, there is little evidence of such a diffuse impact in urban infrastructure regimes, and the ability of local experiments to induce changes in complex and path-dependent urban infrastructures has been questioned (Naess & Vogel, 2012). The tension between project based governance attempts and long-term transition has been recognised (Munck af Rosenschöld & Wolf, 2017). However, this dominant view leaves important timescales,

such as the connection between ULLs and urban planning (von Wirth et al., 2019), and the connection between experiments and institutional change (Kivimaa et al., 2017) , understudied.

The present study analyses the overlooked complex temporal dynamics of experimental governance in the renewing of infrastructures. Using an ethnographical approach, the researchers closely followed a dry toilet (DT) experiment promoting new sanitation in Hiedanranta ULL, in the City of Tampere, Finland. Hiedanranta is a former industrial area that is going to be transformed into a new circular city living district. Therefore, ULL and experiments located there have a direct opportunity to transform urban development paths. Bulkeley et al. (2019) have categorised living labs according to the level of top down steering and time-scale into three categories. In this typology, the Hiedanranta living lab, as a long-term test-bed for novel circular city solutions, can be primarily understood as a civic urban living lab. It is steered and governed by municipal authorities with long-term urban development goals, and at the same time, it evolves according to the priorities of local companies and research organisations. This makes it a particularly interesting case to study the temporalities in experiment-driven socio-technical change. As Quezada et al. (2016) point out, new city districts free from existing infrastructures and associated incumbent institutions are potential sites for actors to co-design alternative infrastructure.

The three-dimensional structure of the experimental governance in the Hiedanranta case was distinguished: 1) the DT experiment, 2) ULL and 3) formal land-use planning of the city district. Each dimension forms its own timescale and subsequent temporal matches and mismatches within and between the timescales. It is hypothesised that the synchronisation of the timescales shapes the DT experiment and determines its success in producing transformative capacity, which here is understood as the collective ability of actors to realise changes in the urban environment in the long run (eg. Castán Broto et al. 2019). The research questions are as follows: How do the three studied

timescales evolve interrelatedly? What kind of temporal matches and mismatches occur between and within the timescales? How do matches and mismatches contribute to the creation of transformative capacity?

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2 Theoretical background

Experimentation in urban living labs

Socio-technical experiments take place in unpredictable conditions, often within ULL, where 'society is itself a laboratory and a variety of real-world actors commit to the messy experimental processes tied up with the introduction of alternative technologies and practices in order to purposively re-shape social and material realities' (Sengers et al., 2019). The innovative power of urban socio-technical experiments is often considered to be in their flexible, bottom-up organisation, which makes it possible for different stakeholders to engage in experimentation. The downside of non-hierarchical organisation is the constant need to negotiate between different goals, to keep participants engaged throughout the process and to mobilise the needed resources to run the experiments. Because these experiments are conducted outside formal governance structures, the experiments may remain marginal and do not necessarily produce cumulative knowledge, sustaining practices or durable socio-material structures (Bulkeley & Castán Broto, 2013).

The term ULL has emerged through new research focuses; for example, a number of EU projects frame experimental sites in European cities as ULLs (Sengers et al., 2019). Properly managed ULLs can also work as mediators between self-organised groups and city developers (Juujärvi & Lund 2016). The life cycle of a ULL depends on its position in the urban governance system. Marvin and Silver (2016) found that 70% of the studied 100 ULLs were long-term, with well-defined functions, established funding and a well-embedded role in the wider city, while the rest were temporary and short-term interventions with an uncertain future. ULLs can be steered by various actors. Bulkeley et al. (2019) propose that the ideal types of ULL are 1) strategic, steered by the national state or regional authorities, 2) civic, with a focus on the priorities of municipal governments, universities and local companies and 3) organic, when the key actors are urban civil society and nonprofit

groups. Kronsell and Mukhtal-Landgren (2018) highlight the role of municipalities in ULLs, arguing that municipalities are deeply involved in ULLs as promoters, enablers and partners with the capacity to organise funding, initiate and occasionally govern collaborations.

Temporal ascpects of ULL based urban development

Even though temporal issues are seldom explicitly studied, their high relevance can be inferred from previous ULL research. First, as ULL can be characterised as a multi-actor process, place or open system in which co-creation and various experiments emerge (Puerari et al., 2018), it is reasonable to assume that ULL and its experiments shape each other and develop side by side. Second, experiments within ULL can grow differently along their project-internal trajectories and have their own life cycle. They can undermine or reinforce each other in synchronic ways, even make the ULL effect beyond its initial boundaries (von Wirth et al., 2019). Third, while ULL is increasingly used as a governance tool for urban development, its relationship with formal institutions like land-use planning may be highly controversial. Land-use planning has often a conflicting time schedule with a temporary ULL, even though the latter can serve planning by contributing to transformative place-making (von Wirth et al., 2019).

Because of the powerful role of formal land-use planning, its interrelations to ULL experiments largely determine the ability of these experiments to constitute long-term transformative capacity in the city. The potential barrier or enabler for experimental governance is the formal and informal understanding of the types of policies included in the municipal area of responsibility and jurisdiction (Kronsell & Mukhtal-Landgren, 2018). Puerari et al. (2018) propose that urban policy makers should consider ULLs more strategically as mechanisms for systemic and institutional change, in order to escape unsustainable and path-dependent urban-development processes. Previous research has shown that knowledge transfer between different actors of experimental

governance is poor. ULLs tend to focus on running experiments instead of translating societal learning from experiments into wider sustainability transitions (Bulkeley et al., 2019) and formal planning tends to leave no space for what first seems to be unproductive reflection, reconsideration and learning (Nevens et al., 2013). Wolfram (2018) argues that transition management cannot be performed within existing urban planning institutions because it questions many of their constitutive assumptions, such as spatial orientation and democratic legitimacy, and instead highlighs sustainability orientation, bottom-up processes, the selective involvement of forerunners and the role of academia.

Transformative capacity

Sustainability transition studies suggest that there are various mechanisms for creating long-term transformative capacity in experimental governance (eg. Castán Broto et al. 2019). ULL experiments can constitute transformative capacity via *embedding*, which refers to the adoption and integration of the experiments' design, approach or outcomes into existing local structures, such as institutions, regulations, planning and/or communities of practice. Another mechanism is *translation*, which refers to the replication and reproduction of the experiment elements elsewhere. *Scaling* refers to an experiment growing bigger in terms of spatial, content, actor and resource scaling (von Wirth at al., 2019). Mechanisms to create transformative capacity by intermediary organisations include documentation and dissemination of experiment results, removal of administrative barriers for initiatives and promotion of inspiring "real-life examples" (Matschoss & Heiskanen 2017). Previous research on climate governance shows that socio-technical experiments can generate changes in discourse; technology; built environment and infrastructure; policy and institutions; business practices; the market; and citizen practices (Kivimaa et al., 2017). Different types of learning take place during experiments. Firstly, techno-scientific, cognitive learning can answer the questions: What works where, when, how and why? Secondly, situated learning creates new identities and

practices by enhancing skills and confidence, reshaping roles and professional profiles, building new networks and inspiring. Oftentimes, situated learning can be the main outcome of experimenting in 'enthusiastic but fragmented experimentation scene of Finland' (Heiskanen et al., 2017).

3 Materials and methods

3.1 Case Hiedanranta

Tampere is the third largest and rapidly growing city in Finland, with 235,000 inhabitants in 2018. The case area of this study, Hiedanranta, is a brownfield area that will be developed into a new city district of 25,000 residents and 10,000 workplaces.

Urban living lab Hiedanranta

Momentum towards the circular city district of Hiedanranta was initiated when the City of Tampere procured the brownfield area in 2014 and established the Hiedanranta development program in 2015 to coordinate the development using an open and collaborative approach (City of Tampere, 2018). In 2016, the gates of the former industrial area were opened for the public, and some old industrial buildings were taken into use. In three years, 2016–19, Hiedanranta has become an attractive platform for culture, research and development (R&D), start-ups and co-creation; in other words, the Hiedanranta ULL has started to form. The ULL has hosted about 40 R&D projects and experiments that promote smart technology, sustainability and circular economy solutions, all of which are expected to make life smoother for future city dwellers (City of Tampere, 2020) (Figure 1). Using the terms of Bulkeley et al. (2019), Hiedanranta ULL is a civic ULL, where the city has the leading role, and universities and local companies are important partners. The objectives of civic ULLs are typically 'transfer of research into demonstration, the development of first-mover advantage, and innovation and economic development and/or accelerated transition within an infrastructure' (Bulkeley et al. 2019), which fit into the Hiedanranta context.

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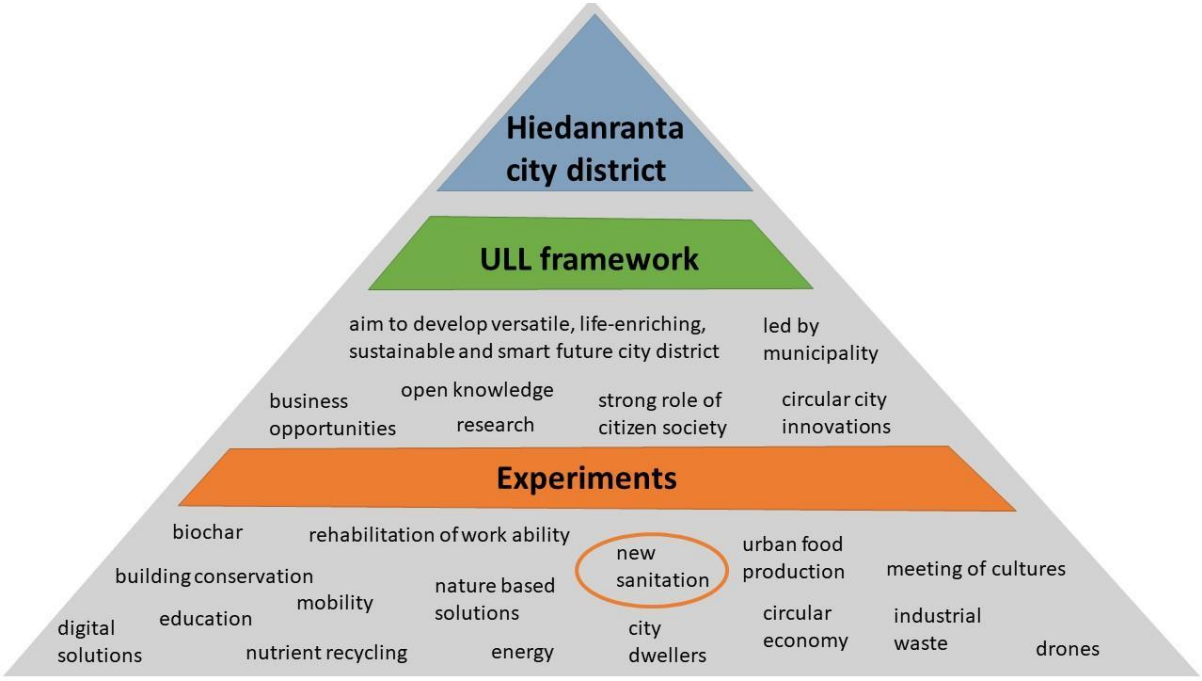

Figure 1. Framework of Hiedanranta ULL (City of Tampere, 2018; Lehtovuori et al., 2016; Solved Cleantech Network, 2016) and the topics of the experiments (City of Tampere, 2020)

Dry toilet experiment

In the current study, the DT experiment is used as an example of the experiments in the studied ULL to allow an in-depth analysis of the timescales that have evolved during experimentation. The DT experiment was initiated by stakeholders when the Hiedanranta development program was seeking ideas for a circular city. Along with the circular city and new sanitation ideating, there was a practical need for toilets in the Hiedanranta area, because one of the old industrial halls without a sewage connection was going to be renovated into a cultural centre. In a short time, an experimental network managed to ideate and implement a large-scale DT system (Figure 2) that serves up to 1,000 visitors in the cultural centre of Kuivaamo. Soon after the collection system, a treatment system for feces was developed. Urine was used in various R&D projects focusing on nutrient

recycling. Apart from a successful implementation within a tight schedule, the DT experiment was characterised by conflicting interests and undefined relations to formal land-use planning, making it a rich study case.

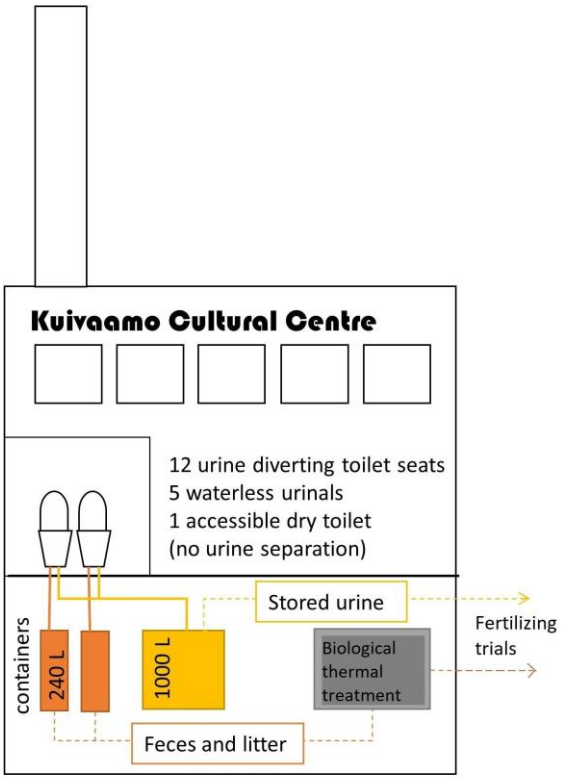

Figure 2. DT experiment set-up

Formal land-use planning of the new city district

Along with ULL experimenting, formal land-use planning began with an international idea competition in 2016. The preparation of a master plan commenced in the spring 2017 with a process involving the city residents. The first phase of the master plan—the structure plan—was approved by the end of 2017. The master plan of Hiedanranta district is soon to be completed in 2020, after which more detailed city planning will begin. Construction of the houses is expected to start in the early 2020s. Planning and construction will continue until 2045 (City of Tampere, 2020).

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Interrelated timescales of experimental governance

Hiedanranta was selected as a case for an in-depth analysis of timescales because circular city experimenting in an emerging ULL and the formal land-use planning of a new city district are taking place there at the same time (Figure 3). Simultaneous processes put pressure on experiments to produce and for planners to adopt novel solutions in a narrow time frame before building of the infrastructure and houses begins. The current study covers years 2016–19; most of the DT experiment activities took place in 2016.

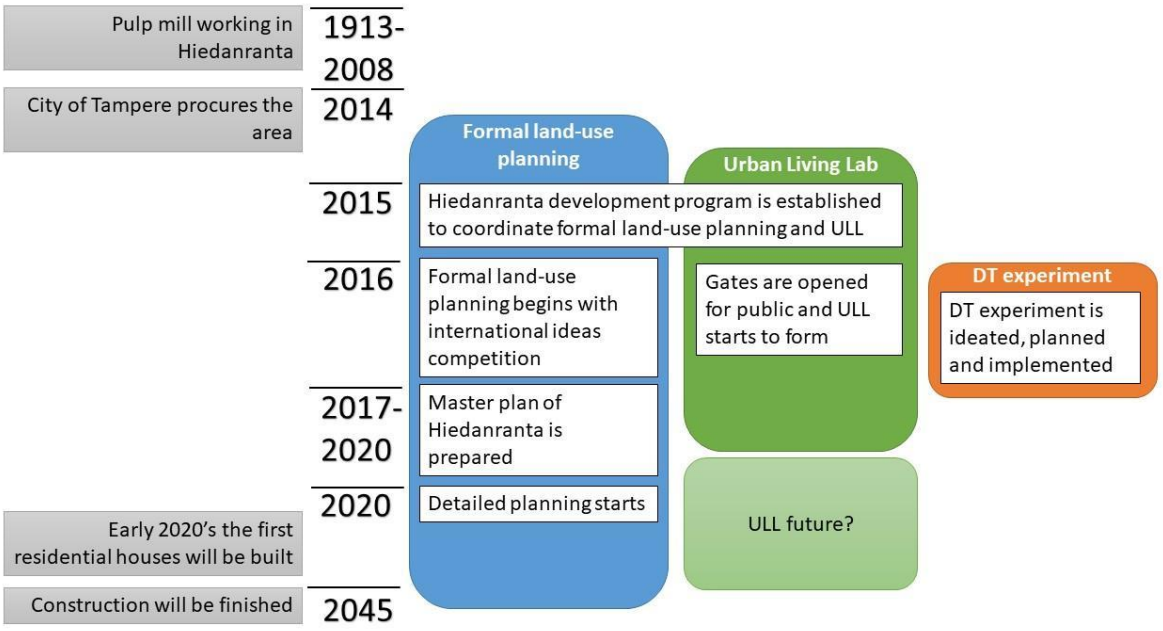

Figure 3. Case Hiedanranta: Interrelated timescales of the ULL, DT experiment and formal land-use planning of the new district.

3.2 Research data

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The research data consist of the three data sets: interviews of experiment actors, guiding documents of the Hiedanranta district's development and notes by one of the authors who participated in the experiment and also followed the general development of the area in 2016-2020.

First, the DT experiment actors (Table 1) were interviewed from August–September 2016, right after the DTs were taken into use in Hiedanranta. The interviewees were selected based on their roles and impact on the DT experiment. The group was broadened up to 13 due to the recommendations by the first interviewees. Prior to the interviews, a timeline of experiment events (Figure 4) was constructed, and it was discussed, completed and corrected during the interviews. In addition, an interview frame was prepared, including the following themes: 1) The progress of the experiment and role of the actor, 2) contacts, cooperation, conflicts, critical actors and turning points, 3) further improvement needs of the DT system, 4) impact of the experiment and 5) future prospects for new sanitation in Hiedanranta. In addition, topics related to each actor's expertise and DT experiences from former projects were discussed. The interviews took from one to one and half hours, and they were recorded and transcribed. Mostly, the informants were interviewed individually and face to face, while one group interview and one e-mail inquiry took place, as indicated in Table 1.

Table 1. The interviewees, their organisation and their expertise in assessing the DT experiment

Interviewees	**Organisation**	**Expertise**
Hiedanranta Project Development Director (later Hiedanranta Project Director)	City of Tampere	Urban planning, interaction and environmental policy
Environmental expert	City of Tampere	Environmental issues and local actors
Building supervisor	City of Tampere	Planning permission-related piping issues
Manager	Waste utility	Infrastructure development
PR	Waste utility	Waste information, stakeholder relations
Customer service[1]	Waste utility	Coordination, supervision, invoices
Sanitation services[1]	Waste utility	Event sanitation, sanitation services for sparsely populated areas
Waste management[1]	Waste utility	Hiedanranta solid waste management, orders
DT expert	DT NGO	DT solutions, projects, actors

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DT planner	DT enterprise	DT planning, implementation
Superintendent of (DT) construction	Property management/ development company	Hiedanranta area and actors, property management and development
HPAC contractor	Repair and construction company	Ventilation and piping supplier
Kuivaamo cultural event organizer[2]	Music & Art Collective	Kuivaamo space, customers and events

[1] group interview

[2] e-mail

Figure 4. Timeline of the DT experiment from visioning to implementation

Second, the guiding documents of the Hiedanranta development program (Table 2) were analysed. The focus of the analysis was to look at the synchronisation of circular city aims in the documents and in practice, as well as the transition of new elements into formal documents.

Table 2. Guiding documents of the Hiedanranta development program, their publishing year and their relationships to each studied timescale

Document	**Description**	**Use in timescale analysis**
Development vision for Hiedanranta: Densely-built and intensively green Tampere City West (Lehtovuori et al. 2016)	Produced when the City sought ideas for circular city from external experts. Early and unofficial documents that contain concrete ideas for circular city. These ideas were important for Hiedanranta ULL	DT experiment ULL Formal land-use planning

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Hiedanranta Circular Economy Concept (Solved Cleantech network, 2016)	formation and experiments in the beginning. Gave input to the international idea competition.	
Hiedanranta Structure Plan (City of Tampere, 2017)	The structure plan already reflects the connection between ULL outputs and those of the more established urban planning institutions, that is, transformative capacity.	Formal land-use planning
From ideas competition to citizen's visions. Planning Hiedanranta in follow-on workshops (Alatalo et al., 2017)	Workshop reports connect the results of the international idea competition to the ULL.	ULL Formal land-use planning
Hiedanranta development program plan (City of Tampere, 2018)	The guiding document of the Hiedanranta development program and ULL within it. It is accepted in the political decision-making process, hence strongly shaping the ULL's future development. However, it did not exist at the time of the DT experiment construction.	ULL Formal land-use planning

Third, in addition to the interviews and guiding documents, field notes and the research diary of the first author, offer the background knowledge for the study. The first author participated in Hiedanranta vision (Lehtovuori et al. 2016) writing and had an intermediating role in promoting new sanitation. The background data was collected in 2016-20 in formal and informal Hiedanranta meetings, seminars and conversations, where the DT experiment was ideated and learning from the experiment took place (Table 3).

Table 3. The main events and forums participated and observed

Event/forum	**Time**	**Organiser**	**Participants**	**Author's role**
Idea group to develop solutions for circular city	Regular meetings in 2016-17, few times in 2018-20	City of Tampere and Tampere University	City of Tampere, researchers, NGOs	Intermediator
Hiedanranta development group	Regular meetings 2017-2020	City of Tampere	ULL project managers	Participant
Hosting visitor groups in ULL and sanitation experiments	2016-20	City of Tampere, ULL projects	Students, researchers, City of Tampere	Guide

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Workshop: Nutrient recycling in Future Hiedanranta	13.3.2017	City of Tampere, ULL project	City of Tampere, Water utility, Tampere University, local companies	Organiser
6 th International Dry Toilet Conference – Dry Toilet Goes Circular	20.-24.8.2018	DT NGO, Tampere University	Universities, local companies, City of Tampere	Organiser
Seminar and workshop: Evaluation of nutrient recycling experiments	30.10.2019	ULL projects	City of Tampere, Tampere University	Organiser
Source separating sanitation and nutrient recycling - virtual excursion to Sweden	20.1.2020	ULL project	Hiedanranta Development Company, City of Tampere	Organiser
Nutrient recycling in Hiedanranta - webinar	30.4.2020	ULL project	Hiedanranta Development Company, City of Tampere	Organiser
Workshop: Hiedanranta nutrient recycling, partnership discussion	18.11.2020	ULL projects	City of Tampere, Hiedanranta development company, local companies	Organiser

3.3 Analytical frame

To grasp the potential of the DT experiment to gain transformative capacity regarding the existing infrastructure regime, an analytical framework (Figure 5) was built that drew on recent sustainability transition studies (Bulkeley et al., 2019; Frantzeskaki et al., 2018; Heiskanen et al., 2017; Kivimaa et al., 2017; Matschoss & Heiskanen, 2017; von Wirth et al., 2019), here with a focus on the role of temporalities. First, the data from the interviews, guiding documents and field notes were categorised according to the three timescales characterising the study case: ULL, DT experiment and formal land-use planning. Second, the interrelatedly evolving timescales were analysed in relation to how the DT experiment was made, how it was embedded in the Hiedanranta context and what kind

of temporal matches and mismatches were created during the experiment. Third, transformative capacity was analysed by comparing the experiment's achievements to formal land-use planning and by searching for the processes and initiatives of change, such as embedding, translating and scaling (von Wirth et al., 2019; Matschoss & Heiskanen, 2017), cognitive and situated learning (Heiskanen et al., 2017) and changes made to socio-technical structures (Kivimaa et al., 2017).

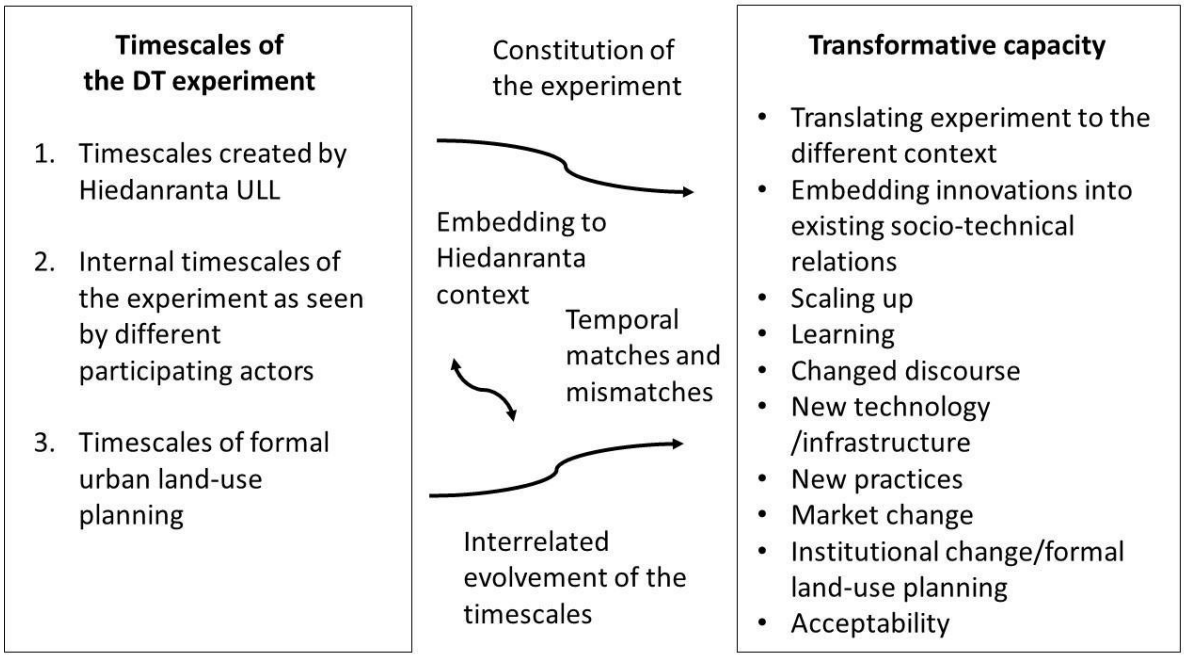

Figure 5. Analytical framework of the ethnographical study: formation of long-term transformative capacity from the three interrelated timescales.

This kind of ethnographical approach is fruitful in showing the actual practices of experimentation, achieved structural changes and the subsequent role of experimentation in the broader transition process (Sengers et al., 2019).

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4 Results

4.1 Co-development of the DT experiment and Hiedanranta ULL

This section presents the internal timescales of the DT experiment (Figure 4, Section 3.2), which range from a long-term interest in developing a circular city to the urgent need for introducing sanitation for the brownfield cultural centre. Furthermore, the DT experiment serves as an example of the intertwined development of the ULL and its experiments in Hiedanranta.

History of the DT experiment

The roots of the DT experiment were in a 'alternative sanitation cluster' with a 15-year history in the Tampere area. Local universities have programs of environmental engineering, where resource (including nutrients) recovery is ever more important. Another important actor is the Global Dry Toilet Association of Finland (DT NGO), which was established in 2002 in Tampere. The DT NGO and the local universities have, for example, organised an International Dry Toilet Conference every third year since 2003. This cluster has promoted sustainable sanitation, especially in rural context, and development cooperation. The DT experiment was a continuation of the R&D cooperation of the local actors, who used the momentum of Hiedanranta ULL to reframe alternative sanitation as 'new sanitation' (Wielemaker et al., 2018) focusing on nutrient recycling in the urban context.

Ideating of the DT experiment

In January 2016, as part of seeking the latest trends in sustainable urban development, the Hiedanranta project director formed an idea forum by inviting local universities and NGOs to

develop ambitious solutions for a ‘circular city’. The researchers who moderated the idea forum together with the Hiedanranta project director managed to create a discussion arena that supported idea sharing and legitimated new ideas with scientific knowledge. Also, other network actors had the crucial capacities to enhance experimentation; for example, DT NGO had extensive experience running practical experiments and broad networks with business actors, including DT planner.

In March 2016, the idea forum produced ideas for circular city, including the new sanitation experiment in the Kuivaamo cultural centre. In the ideating phase, the experiment was seen as an opportunity to test and promote new sanitation and related nutrient recycling, which could become part of future Hiedanranta circular city district. At that time, not only DTs, but also other new sanitation technologies such as vacuum toilets, were considered.

Temporal mismatches

Along with the idea forum discussions, activity in the Hiedanranta ULL was increasing, the Kuivaamo cultural centre opening was approaching, and toilets were needed urgently. Putting the DT experiment into action required reorganisation of the experiment network. To run the DT experiment smoothly and bind it to the established institutions, the Hiedanranta project director asked the municipal waste utility to participate in the experiment. Subsequently, the roles and responsibilities of the established institutions and the experiment network were negotiated. Despite the strategic level interest in the Hiedanranta ULL and experimenting, the waste utility adapted only a distant role. In practice, the DT planner took the overall responsibility of planning and implementation of the experiment. This sort of temporal mismatches between official organisations regarding their long-term responsibility for development and temporary experiment organisations

focusing on narrow tasks is a general problem and may hamper the formation of transformative capacity in experiments (Munck af Rosenschöld & Wolf, 2017).

In the studied case, the temporal mismatch was not only occurring between the experiment and institutions, but also within the DT experiment when moving from ideating into practice. After the ideating phase, the role of the broad idea forum and researchers diminished, and the role of the implementation phase actors increased. The new actors chose simple DTs instead of e.g. 'high-tech' vacuum toilets. As Dewulf et al. (2007) point out, the creation of fruitful communication between different actors in multidisciplinary collaboration is a challenging task requiring time and effort. Furthermore, Juujärvi & Lund (2016) argue that under time pressure teams tend to make premature decisions, and solving complex problems in ULL requires sufficient time and management dedicated to early innovation process. The fruitful communication among the divergent DT experiment network, the time allocated and project management were obviously inadequate. Consequently, the chosen robust DT technology was determined rather by price, simplicity and product availability via existing business relations instead of its ability to support new sanitation and high living-standars in the future Hiedanranta district.

Implementation of the DT experiment

The lack of common understanding regarding the experiment aims and the related premature technology choice did not hamper the implementation. The most actors of the implementation were not aware of the ideating phase discussions, but they focused on the challenging task of putting the DTs into practice.

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The DT experiment was implemented in May–June 2016 as part of renovating an old industrial hall in the Hiedanranta ULL into the Kuivaamo cultural centre. The DT planner had knowledge and determination to implement DTs in a strict timetable, and the Hiedanranta project director had the power and will to mobilise the experiment in the ULL. Other key actors in the implementation phase were the superintendent of construction, HPAC contractor and building supervisor. Cooperation at the DT construction site was considered fluent, which increased the trust between different actors and created a positive and encouraging atmosphere among the constructors. A shared history of the implementing actors facilitated cooperation, as indicated in the following quote: *'If there are 1000 people, the number of toilets [needed], especially dry toilets, none of us probably have any experience with that. … Of course, I have learnt to trust the DT planner over the years. I know that she has been involved in many of these projects and studied the subject. Therefore, I can trust the consultant, and I don't need to know everything myself'* (Building supervisor, City). Implementation of the large scale DT experiment was a remarkable achievement and shows that situated learning proceeded through informal learning-by-doing and led to a subsequent gain of transformative knowledge (Heiskanen et al., 2017) among the constructors.

ULL development

Because the studied DT experiment was one of the first experiments in the Hiedanranta ULL in 2016, it was shaped by a young ULL with the following characteristics compiled from the research data. First, the rough brownfield environment of the ULL made robust DTs acceptable. Second, the ULL attracted actors to develop the city in a new way: *'This innovative approach; involving residents and organising activities straight away in the area. … It was immediately inspiring because there is no set model, but rather actors just start collaborating and see what develops. This got us enthusiastic and we wanted to participate'* (Manager, Waste utility). Thus, using the terminology of von Wirth et al. (2019), the Hiedanranta ULL was successful in transformative place-making as a strategy to enhance

diffusion. Third, the poor resources of the ULL and DT experiment—a small Hiedanranta development project initiating the ULL, unclear roles and resources in experimenting and loose project management—caused inadequacies in documentation and communication regarding the lessons learned, which would have been essential for learning (Antikainen et al., 2017) and impact beyond the experiment (Matschoss & Heiskanen, 2017).

Not only did the young ULL shape the DT experiment, but also the other way around; the DT experiment shaped the ULL's development. First, the DT experiment and the dedicated actors around it have initiated similar projects such as HIERAKKA—Hiedanranta as a nutrient cycle and public awareness development area; Leväsieppari—Growing algae biomass in source-separated urine and studying the possibilities of nutrient recovery; and NutriCity—Hiedanranta as a frontrunner in urban nutrient recycling (City of Tampere, 2020). Because of this accumulating knowledge, the Hiedanranta ULL became an important platform in Finland for piloting new sanitation. Nutrient recycling was brought up in early Hiedanranta documents (Lehtoranta et al., 2016; Solved Cleantech Network, 2016) written simultaneously with the DT experiment and later in the Hiedanranta development program plan (City of Tampere, 2018). Second, the inspiring and agile experiment culture of the Hiedanranta ULL was created during these early experiments. The Hiedanranta project director contributed to the inspiring ULL culture as a change agent and mediator by actively promoting open, innovative and visionary collaboration. Also, the shared history of the DT experiment network and fluid implementation of the DTs strengthened the ULL. Third, as illustrated in the following quote, the DT experiment clarified the need for a more established ULL process that can support cognitive learning (Heiskanen et al., 2017) and enhance the dialectic relationship (Wolfram, 2018) between experiments and formal institutions.

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"I think this is a textbook example of a project where the directors are so enthusiastic to come up with ideas that all the basic issues are overlooked: Who is responsible and for what? What's the timetable? What proper plans do we have, and, to my knowledge there are no minutes from the first meetings. … Enthusiastic talk at the onset, "Yes, yes, let's do this," but then documentation and allocation of responsibilities is forgotten. " (PR, Waste utility)

Since the DT experiment (2016), the ULL has gained better resources because a ULL project manager was hired in 2018 and the Hiedanranta development company was established in 2019. Subsequently, the Hiedanranta ULL became more organised and bound to established city institutions, which has also caused conflicts between agile experiments and rigid institutions. At the time of writing this study in 2020, the practices of the Hiedanranta ULL are still being defined, and they are about to change when the planning of the Hiedanranta district proceeds, houses are built and people move in.

4.2 Collision by formal land-use planning of the Hiedanranta district

Along with ULL experimenting, the formal land-use planning of the Hiedanranta new city district proceeded. The international idea competition was held in 2016, and the master plan was prepared 2017-2020. The timescale of the formal land-use planning and its synchronisation with ULL experimenting became critical factors for development of circular city district.

Transforming discourse

The DT experiment developed along with early and unofficial guiding documents: the Hiedanranta vision (Lehtovuori et al., 2016) and the CE concept (Solved Cleantech Network, 2016, not published).

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Together, they succeeded in promoting academic discussion of local nutrient recycling and new sanitation design as crucial elements of circular city development (Agudelo-Vera et al., 2011; Frantzeskaki & Loorbach, 2010; Hodson et al., 2012; Wielemaker et al., 2018) in the Hiedanranta ULL. In the vision for Hiedanranta, new sanitation and related nutrient recycling are highlighted: '*The new generation water and energy systems and local nutrient cycle (urban agriculture and related ecosystems) are among the elements of the resource-smart Hiedanranta*' (Lehtovuori et al., 2016). Whereas the CE concept highlights the role of the ULL in the development of new sanitation, '*Hiedanranta works as a platform for development of water management solutions that are needed to harvest nutrients and energy locally in the Hiedanranta area'* (Solved Cleantech Network, 2016, not published).

A radical turn in the city's sustainability discourse is also demonstrated in the official guiding documents. The Hiedanranta structure plan (City of Tampere, 2017) promotes a circular city by introducing a Plus City concept that *'include ecological, social and economic aspects all contributing to the holistic circular economy of Hiedanranta. The waste flows of Hiedanranta are connected to sustainable manufacturing and innovation… Raw materials, biological waste, and combustible waste are sorted and integrated into the district's reuse system*'. Influenced by the frontrunning ULL, the Hiedanranta development program plan (City of Tampere, 2018) gives more precise and exceptionally ambitious guidance; the aim is a district that produces more energy, nutrients and food than it consumes: '*In all planning and construction, resource efficient implementation of technical and biological loops is considered (materials, resources, waste recycling and reuse, circular economy in construction and nutrient recycling)'.* Using the typology by Calisto Friant et al. (2020), circular city discourse in the guiding documents of Hiedanranta is a combination of optimistic 'technocentric CE' and 'reformist circular society' discources. The focus is on technical innovations

such as new generation of water and energy systems. Also more holistic view including ecological and social aspects such as participatory governance and sharing economy is presented.

Distinct logics of planning and experimental governance

Despite the ambitious aims in the paper, putting transformation into practice in the detailed plans and material elements of the new city district has proven to be hard. Project-driven attempts to make the DT experiment and other new sanitation projects impactful include active and informal knowledge transfer between the experiment networks and formal land-use planning in publications, social media, meetings, workshops, seminars and site visits (Table 3, Section 3.2). Urban planners have been interested in the outcomes, but administrative barriers prevent transition. One concrete step in infrastructure development is a plan for the water, waste water and storm water networks for future Hiedanranta district (unpublished). The planning was done by private infrastructure consults guided by city planners. The result was a conventional plan without elements of new sanitation, even though the Hiedanranta project director adviced the consults to be innovative and utilise ULL outcomes.

Inability to utilise experiment results demonstrates a weak role of the ULL as a mediator between experiments and formal planning. When dealing with increasingly complex issues such as a circular city and nutrient recycling, conventional planning knowledge is not sufficient. Accordingly, von Wirth et al. (2019) present education and training as one strategy for ULLs to create long-term transformative capacity. Based on the Hiedanranta experiences, rethinking of short- and long-term economic, social and environmental risks in the cross-section of the ULL and formal land-use planning is also needed. On the one hand, changing the currently functioning infrastructure system has great risks for individual planners, and on the other hand, continuation of the current linear

sanitation systems compromises the sustainability of urban development. Furthermore, the common understanding of the experiment outcomes and their critical review is lacking—what is worth scaling? According to Frantzeskaki et al. (2018), ULL experiments can be expected to show what needs to change, how it can be changed and actors' roles in change. Setting this kind of realistic long-term goals could enhance synchronisation between the ULL experiment and formal land-use planning.

Partial match between planning and ULL experimenting

The ULL has generated a promising cross-sectoral initiative—the Hiedanranta super blocks. These versatile blocks with shared high-quality functions and facilities were first introduced when the Dwellers in Agile Cities (DAC) project co-developed the results of the international idea competition with residents (Alatalo et al., 2017). Since 2017, the super block has become useful concept for various ULL experiments to link and study the possibilities of scaling-up to the first houses or blocks of the new city district. Among the other topics of a circular city (Figure 1, Section 3.1), the possibilities of new sanitation in the first blocks have been studied. The Hiedanranta ULL has grown up to 40 experiments during four years, which has been sufficient volume and time for the super block initiative to mature and become impactful in the context of formal land-use planning. This is a remarkable achievement because previous studies have shown that a lack of time and other resources for scaling may lead to diminishing of the experiment in the early stages of diffusion (von Wirth et al., 2019).

Putting new sanitation into practice as part of the super blocks is forwarded to the next phase and actors of detailed planning and house building. The openness to new solutions is written into Hiedanranta development program plan (City of Tampere 2018) and the current idea in sanitation

infrastructure case is that besides the conventional waste water network in the Hiedanranta district, houses or super blocks can develop source separating collection systems to enable further systemic change, if the new sanitation solutions mature in the future. This approach is supported by Drangert et al. (2018), who argue that 'In the case of EU, many new buildings will be built in the next generation, and large stretches of worn-out sewer lines need replacement. If an extra pipe for excreta is laid at the same time, a high-quality nutrient waste will be available at low cost in the future'.

5 Formation of transformative capacity

Comparing matches (Figure 6) to the diffusion elements of embedding, translating and scaling (von Wirth et al. 2019), the DT experiment has been successful in creating transformative capacity. In this study, which is focusing on the development of the circular city district, locally oriented mechanisms of embedding and scaling were highlighted. Moreover, in the brownfield environment, the role of novel material elements and their integration into existing buildings and activities were emphasized. For example, along with and supported by the DT experiment, nutrient recycling aims were included in the guiding documents of Hiedanranta. Also, new technology and infrastructure (DT seats, collection, treatment, etc.) requiring new user practices were built (embedding). Furthermore, a functioning DT experiment has attracted new experiments that have made Hiedanranta one of the leading sites for urban nutrient recycling development in Finland and beyond (scaling). A prominent pathway to scaling appeared in the form of the matching the different fields of study in the Hiedanranta ULL when the idea of the super block was introduced as a next scale pilot environment. Synergies between inspiring ULL led by a visionary change agent; alternative sanitation cluster with long-term competence and networks; and the functioning DT experiment were essential in the creation of transformative capacity.

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Along the DT experiment timescales, mismatches (Figure 6) hindering the formation of transformative capacity have also taken place. First, the informal and loosely coordinated experiment organisation was not able to shape DT implementation to meet the initial visionary aims of the circular city. The need for an improved ULL process to support cognitive learning (Heiskanen et al., 2017) is evident. Second, the first detailed plans and infrastructure elements of the new Hiedanranta district are traditional from the perspective of sanitation and nutrient recycling. This is because of the path dependent infrastructure development, lack of expertise in complex CE, immature solutions experimented and abstract aims. It can be said that learning from new sanitation and nutrient recycling is deepening among the alternative sanitation cluster, but not widening towards formal land-use planning so efficiently. Situated learning (Heiskanen et al., 2017) can also enhance diffusion, but in a new city district, infrastructure transition would require stronger involvement of institutionalised actors in experiments. As project driven knowledge transfer is not impactful towards formal planning, there is a demand for more systematic role of ULL in translating knowledge from experiments and making space for learning in formal planning process.

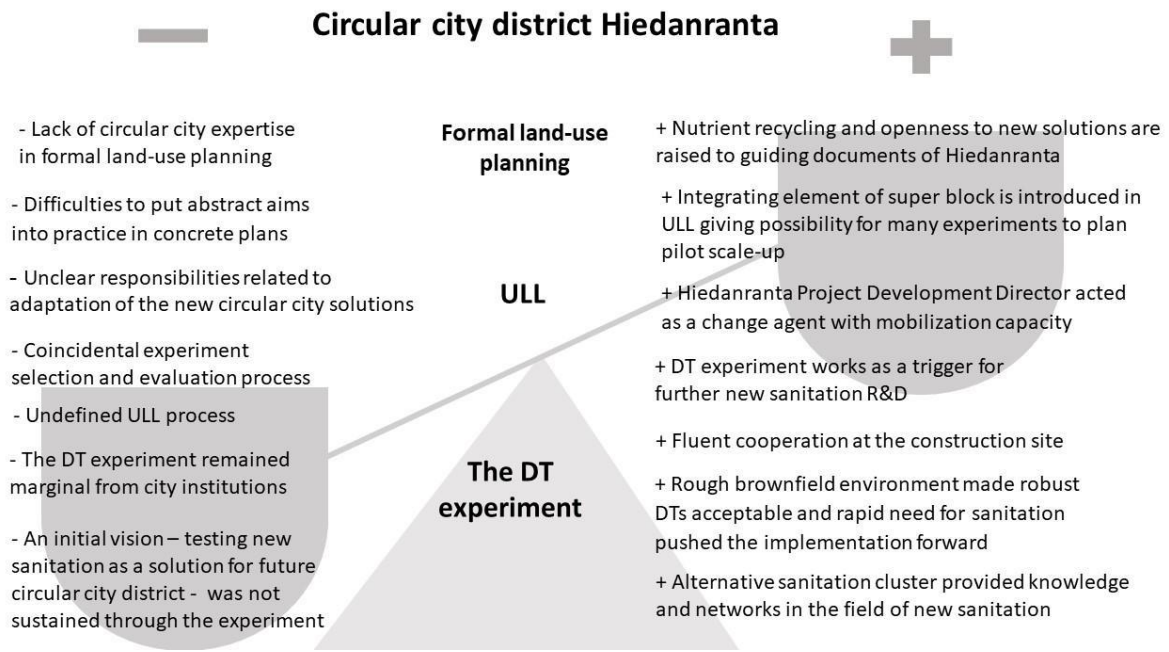

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Figure 6. Matches and mismatches between and within the timescales contributing to transformative capacity towards circular city district.

The Hiedanranta ULL is characterised by an informal process, and as such, it is successful in terms of attracting actors and action but has difficulties setting the scope for experimenting or transferring results to formal land-use planning, which is typical for ULLs (Bulkeley et al., 2019). There are also signs of 'organised irresponsibility' (von Wirth et al., 2019), because the Hiedanranta ULL has not had the resources to select or evaluate experiments, and these activities have been outsourced to external experts or have been based on personal relations. To serve as a mediator between experiments and formal planning, ULL needs proper management (Juujärvi & Lund 2016). This study highlighted the need of transparent ULL processes that support learning, including goal setting and subsequent selection and evaluation of the ULL experiments. Alongside becoming more organised to synchronise with formal planning, the ULL should hold to its strength: the inspiring and creative atmosphere.

6 Conclusions

Cities have started to run ULLs as arenas for experimenting with solutions for sustainable urban development, but so far, there has been a poor understanding of how to make experimentation impactful in the context of institutionalised urban planning. In the current study, a single experiment of new urban sanitation provided a window to explore the accumulation of transformative capacity towards resource-efficient infrastructures, which are vital in the transformation from current urban functions to the implementation of a circular city. Timescales become extremely critical factors in this type of transformation.

Temporal analysis showed that the creation of transformative capacity via experimentation requires a long development trajectory extending beyond a single experiment. The co-evolution perspective

shows that urban-sustainability transitions happen incrementally (Nevens et al., 2013) as a series of micro-transitions. In this case, the DT experiment became impactful due to the existing R&D networks of the alternative-sanitation cluster and the frontrunning ULL offering sufficient time and space for multiple experiments to co-develop. Trustworthy networks enabled implementation of ever-advanced new sanitation experiments and pushed nutrient recycling into the sustainability discourse of urban planning. Alongside individual experiments, the ULL nurtured the cross-sectoral initiative of the super block, which supported reframing alternative sanitation as prominent solution of the future circular city.

Hiedanranta ULL grew to such a volume, shape and lifetime – ca. 40 informal experiments between 2016–19 – that it succeeded to create a strong base for an alternative-development path of the circular-city district. Puerari et al. (2018) point out that a city portfolio of ULLs could broaden the impact and visibility of each individual lab and enhance knowledge development and learning across different laboratories. In the Hiedanranta ULL, similar phenomena took place within a single large ULL as co-creation dynamics occurred between a wide range of experiments. The informal brownfield ULL with multiple interesting experiments and a direct connection to urban planning created a frontrunning image and convincing results that supported pushing institutional boundaries during the preliminary planning phase of the circular city district. A variety of experiments also increased the likelihood of fruitful matches such as the super block, which accumulated a transformative capacity from the co-creation of different experiments.

Proceeding with implementing of the new city district is revealing a deep gap between informal experimenting and formal urban planning. On one hand, in the preliminary planning phase and on paper, formal planning has interacted with ULL experiments in a flexible manner; e.g., enhanced nutrient recycling and super-block initiatives. On the other hand, the strong base for the circular city district created in ULL has started to become undermined as material infrastructure solutions follow

either a conventional ‘linear-city’ path or are forwarded to the next phase and actors of the district’s development. New sanitation is not (yet) completely denied in formal land-use planning, but it remains unclear who is going to orchestrate the sustainability transition in Hiedanranta and what will be the role of the ULL in the transition. In the early 2020s, the more regulated and investor-driven era in the development of Hiedanranta’s new city district will challenge the ULL to sustain its credibility in the creation of transformative capacity.

How to achieve the twofold enabling and organised role of ULLs could be a promising avenue for future ULL research. Furthermore, governance and operations models for decentralised infrastructures, which promote local-resource circles, require further research and development.

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