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LIVING LABS FOR INNOVATION AND DEVELOPMENT OF INFORMATION AND COMMUNICATION TECHNOLOGY: A LITERATURE REVIEW

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ABSTRACT

Living Labs are environments for involving users in innovation and development, and are regarded as a way of meeting the innovation challenges faced by information and communication technology (ICT) service providers. Living Labs have thus generated a great deal of interest in the field of ICT in the course of the last few years. However, the current body of Living Lab research literature indicates a lack of common understanding of how Living Labs can be used for ICT innovation and development. Moreover, there appears to be little agreement regarding needed future research. In order to establish a basis for future work on Living Labs, a review of the Living Lab literature related to ICT innovation and development has been carried out. Literature searches were made in four academic archives, as well as the ISI Web of Knowledge, Google and Google Scholar. Thirty-two relevant academic papers were retrieved. An overview of the literature was established and the literature was analyzed with regard to (1) common and diverging perspectives on Living Labs, (2) the state-of-the-art of Living Lab processes and methods, and (3) theoretical foundations of Living Labs. On the basis of the analyses, a common Living Lab definition is suggested. Two emerging Living Lab trends, as well as a pressing need for future research on Living Lab processes and methods, are introduced and discussed.

Keywords: Living Labs, literature review, information and communication technology (ICT), innovation and development

1 INTRODUCTION

A challenge for information and communication technology (ICT) providers is to involve users in the innovation process, from the early phases of context research and idea generation through the later phases of development and implementation. Important issues include access to adequate knowledge regarding the user context, early validations in the market, trials in contexts familiar to users, valid user feedback on state-of-the-art ICT solutions and utilization of users as a co-creating resource.

In the field of ICT, Living Labs are a relatively new type of environment for innovation and development, in which new ICT solutions are tried out in contexts familiar to users, and data on users' responses are collected. It is believed that Living Labs could provide a way to meet the innovation challenges of ICT providers (Eriksson et al., 2006; Niitamo et al. 2006).There is thus a growing interest in Living Labs in a number of areas of ICT. Research involving the use of Living Labs has been described for e.g. mobile ICT (de Leon et al., 2006; Lievens, 2006), ubiquitous computing (Abowd, 1999; Intille, 2005), collaborative work (Katzy, 2005), and cognitive systems engineering (McNeese, 1996, 2004; MacEachren, 2006). Several industrial ICT Living Lab initiatives are represented in two international organizations: The European Network of Living Labs (2008a) and Living Labs Europe (2008). The European Network of Living Labs comprises more than 50 Living Labs.

Living Labs are also used in other fields than ICT. In this paper, however, the term Living Lab is used to refer only to Living Labs in the field of ICT.

1.1 Example Living Lab categories

The term Living Lab has been used in ICT research since the nineties. Lasher (1991) employed the term to describe the use of co-operative partnerships and live field trials as early as 1991. Since then, a wide range of environments for ICT innovation and development have been referred to as Living Labs. Three examples of Living Lab categories are discussed below in order to provide some insight in the range of Living Labs described in the literature.

Living Labs to experience and experiment with ubiquitous computing

Living Labs for the studies of ubiquitous computing (ubicomp) were established at a number of research organizations from the late nineties onwards. Researchers at Georgia Institute of Technology (GeorgiaTech) describe Living Labs to investigate the impact of ubicomp on education (Abowd, 1999) and home environments (Kidd et al., 1999). Other researchers who set up Living Labs to study ubicomp solutions include Beigl (2002) at the University of Karlsruhe, Schmidt et al. (2002) at Lancaster University, and Intille et al. (2005; 2006) at the Massachusetts Institute of Technology (MIT).

Living Labs as open innovation platforms

A number of European Living Labs are presented as open innovation platforms, meaning that the Living Lab serves as a real-world environment for collaboration among stakeholders in the value chain of ICT production (Eriksson, 2006). CoreLabs, a coordinating unit associated with the European Network of Living Labs, describes Living Labs as *"'functional regions' where stakeholders have formed a Public-Private-Partnership (PPP) of firms, public agencies, universities, institutes and people, all collaborating for creation, prototyping, validating and testing of new services, products and systems in real-life contexts"* (CoreLabs, 2008). Regions serving as open innovation platforms include e.g. The Helsinki Living Lab – Arabianranta (Helsinki Virtual Village, 2008) an urban area near Helsinki, and the IBBT|i-City (The European Network of Living Labs, 2008b) with 4000 test users in the Belgian cities of Hasselt and Leuven.

Living Labs exposing testbed applications to the users

The term "testbed" is understood as a delimited environment to test software and services outside production environments. Abu-Hakima (1998) used the term Living Lab to describe ICT testbeds where applications were exposed to users. Similarly, Zhong's (2006) eStadium serves both as testbed and Living Lab, enabling new wireless services to be tried out on users in a controlled network environment. Several Living Labs belonging to Living Labs Europe (2008) and The European Network of Living Labs (2008a) seem to be employed as facilities to expose users to testbed applications; e.g. the Digital Madeira Test Bed and Living Lab (Oliveira et al., 2006) and Mobile City Bremen (2008).

1.2 Previous work

A comprehensive review of the literature on Living Labs in the field of ICT has yet to be carried out. Earlier investigations or discussions conducted on the basis of experiences with more than one Living Lab include Ballon et al. (2005), Niitamo et al. (2006) and Eriksson et al. (2006).

Ballon et al. (2006) present a review of 18 benchmark cases of technology test and experimentation platforms, from Finland, the UK and the Netherlands. Each benchmark case is classified as one of six test and experimentation platforms: prototype platforms, testbeds, field trials, living labs, market pilots and societal pilots. All six platforms are defined and described according to the dimensions of technological maturity (ranging from low to high) and focus (ranging from testing to design).

Niitamo et al. presented a set of ten regional initiatives *"on the path towards Living Labs"* (Niitamo et al., 2006, p. 6). The ten regional initiatives are located in six European countries and Massachusetts, USA, and examples of good Living Lab practice are presented. Niitamo et al. also map Living Labs in relation to what they perceive as related approaches (e.g. ethnographical observation and traditional lab experimentation).

Eriksson et al. discuss *"Living Labs as a multi-contextual R&D methodology"* (Eriksson et al., 2006, p. 1). The discussion is based on the authors' knowledge of several European *""Living Labs-like" innovation environments"* (Eriksson et al., 2006, p. 6), of which five are explicitly mentioned.

1.3 The contribution of this paper

There seems to be no firm agreement as to what Living Labs are. In consequence the current Living Lab discussion is impaired by a lack of a common understanding of the role of Living Labs in ICT innovation and development, with regard both to their purpose and deployment. A review of the Living Lab state-of-the-art is therefore overdue; both in order to obtain a more thorough understanding of existing Living Labs, and to permit an efficacious discussion of their potential for innovation and development.

This paper reviews existing Living Lab literature. The review aims to (1) map out the purposes for which Living Labs have been established in the ICT field, and (2) investigate how Living Labs are deployed with regard to processes and methods, and (3) investigate the theoretical foundations of Living Labs. This will provide the Living Lab research community with a basis for discussions of Living Lab trends and future Living Lab research.

Issues concerning the scope and terminology of this paper, as well as research questions are presented in Chapter 2. Method is presented in Chapter 3. The results of the literature search and subsequent analyses are presented in Chapters 4. A general discussion is given in Chapter 5.

2 SCOPE, TERMINOLOGY AND RESEARCH QUESTIONS

2.1 Scope

This study was carried out in order to obtain an overview of the literature describing environments or approaches to ICT innovation and development explicitly referred to as Living Labs.

The rationale for adopting this approach was two-fold. (1) The term Living Lab was assumed to refer to a wide variety of user-oriented environments for ICT innovation and development, thus allowing interesting comparisons to be made. (2) In order to perform a balanced study of the field it was regarded as desirable not to start out with an arbitrary set of Living Lab characteristics based on one tradition, but rather to adopt an exploratory approach to the literature. As a basis for this exploration, the term Living Lab was regarded as an adequate scoping criterion.

The present study's limited scope will inevitably exclude from the initial literature search work that some readers may regard as relevant. Examples include work related to UX (user experience) laboratories and Experience and Application Research Centres as well as work

serving as theoretical foundations for some Living Labs - such as that of von Hippel (1988) on users as innovators and Scharmer (2007) on innovation as a co-creation process involving multiple stakeholders.

2.2 Terminology

Some of the key terms used in this paper need clarification, in particular the terms ICT, innovation, and development.

ICT is understood as an umbrella term for technologies in the fields of informatics and telecoms. The field of ICT covers both end-user solutions, middleware, and network solutions. New ICT solutions that may result from Living Lab work include both end-user solutions and solutions that are only of indirect relevance to the user.

Innovation and development are two terms that refer to partially overlapping concepts. The Oslo Manual (OECD/Eurostat, 2005) provides an authoritative definition of innovation: *"An innovation is the implementation of a new or significantly improved product (good or service) […]"* [1] (Ibid., p. 46). Similarly, development is typically aimed at product implementation, but the product resulting from development may or may not be new. Innovation may be distinguished from development by being more tuned to generating new solutions. Standard development processes, such as Boehm's software process, described by Sommerville (1996), may lack adequate mechanisms to generate new ideas and designs as the basis for innovation. However, this may not be true for all development processes; authors such as Kantrovich (2004) and Singh et al. (2003) claim that the development process of User-Centred Design (see e.g. ISO/IEC, 1999) is *"essentially a process for innovation"* (Kantrovich, 2004, p.27). In this paper, innovation and development will be used as a pair of terms to reflect the importance of both innovation and development in Living Labs.

2.3 Research questions

Following from the overall purpose of the literature review, four research questions were formulated:

1. What common purposes characterize Living Labs?
2. What are the main divergences regarding the purposes of Living Labs?
3. What is the state-of-the-art of Living Lab processes and methods?
4. What are the theoretical foundations of Living Labs?

The first question was raised in order to identify a common platform on which discussions on the future development of Living Labs may be conducted. The second should enable us to reach a better understanding of the complexity of the field of Living Labs, and possibly the identification of emerging trends and aspects useful for mapping out the field of Living Labs in future research. The third was raised in order to investigate the possible need for future

[1] Only the part of the definition that concerns product (good or service) innovation is cited.

research on Living Lab processes and methods; the fourth in order to provide a broader understanding divergences and commonalities of Living Labs.

3 METHOD

The research approach comprised a literature search and subsequent analyses.

3.1 Literature search

The literature search was performed in the following academic archives: IEEE, Springer, Science-direct, and ACM. The following search terms were used: 'living lab', 'living labs', 'living laboratory', and 'living laboratories'. The same searches were repeated in all bases associated with the ISI Web of Knowledge.

In addition to the searches in academic archives, searches combining the four search terms above with search terms delimiting the search to the field of ICT were carried out with the broad-scope search engine Google and Google Scholar, a search engine for scholarly documents. The searches were performed in April/May, 2007.

3.2 Literature analyses

Two analyses were carried out. The first attempted to identify common and diverging purposes for existing Living Labs, the second to identify the state-of-the art for Living Lab processes and methods, and the third to identify common theoretical foundations of Living Labs.

Analysis 1: Purposes characterizing Living Labs

Analysis 1 consisted of a two stage process. (1) A list of characterizing purposes for Living Labs was identified, and then (2) the characterizing purposes were used to analyze the reviewed literature. In order to identify a list of characterizing purposes, the following sensitizing concepts (Blumer, 1953) served as starting points:

- *Purposes/goals.* What seems to be the authors' perspective regarding the ultimate aim of establishing or using a Living Lab?
- *Approaches.* In which ways have the Living Labs been implemented? Can implicit Living Lab purposes or goals be uncovered through the Living Lab implementations?
- *End-user involvement.* How are the Living Labs implemented in order to seek information from users or enable end-user interaction with the ICT solutions under study?

When a list of characterizing purposes was identified, each reviewed paper was scored according to whether or not each characterizing purpose was found to be of relevance. The following relevance scores were used: 1 - Clearly irrelevant of inaccurate; 2 - Assumed to be irrelevant or inaccurate; 3 - Assumed to be relevant; 4 - Clearly relevant.

Characterizing purposes that were allocated relevance scores of 3 or 4 for more than 2/3 of the reviewed papers were interpreted as common purposes of Living Labs. Characterizing purposes that received relevance scores of 3 or 4 for between 1/3 and 2/3 of the papers were interpreted as divergences regarding the purpose of Living Labs.

Analysis 2: Living Lab processes and methods

The literature was analyzed with regard to information on applied Living Lab processes and methods.

For each of the reviewed papers, a summary was made of the provided process descriptions. The process descriptions were then classified according to level of detail: No process description; High level description or reference to process description in the literature; Case-specific process description or description of particular process phase; General process description. Finally, all process descriptions were classified according to stages of innovation and development.

A summary of method presentations (or mentioning of methods) was also drawn up for each paper. Methods were understood as standardized procedures for data collection, evaluation or experimentation; typically included as elements in innovation and development processes. Methods for technical testing not meant to produce data on context of use, interaction between technology and users, or end-user feedback were not included. This limitation on the analysis was introduced in order to focus particularly on the methods supporting involvement of users in Living Lab innovation and development.

Analysis 3: Theoretical foundations of Living Labs

An analysis of the theoretical foundations reported in the papers was conducted. Theoretical foundations were typically identified in sections presenting related work or sections defining or discussing Living Labs. For each paper, a summary was made regarding the theorists or schools of thought explicitly mentioned. Theorists or schools of thought reported in more than two of the reviewed papers are presented and discussed.

4 RESULTS

4.1 Literature search results

The literature search of the four academic archives returned 15 relevant papers, while the search in the ISI Web of Knowledge returned one relevant IEEE paper that for some reason was not identified in the archive search. Five of the 16 archive papers were found in the IEEE archive, five in the Springer archive, and six in the ACM archive. No relevant papers were found in the ScienceDirect archive. Papers were judged to be relevant if they dealt with Living Labs used for ICT innovation and development.

The searches conducted at Google and Google Scholar produced another 12 relevant papers that were included in the review. Ten of these were workshop or conference papers, four were journal papers (MIS Quarterly, Computer-Aided Design and Applications, IBM Systems Journal, and Cognition Technology and Work), one was a working paper and one was a Licentiate Thesis.

The literature search thus returned a total of 29 relevant academic papers on Living Labs. In addition, three more papers were identified during the literature analysis - one white paper, one workshop position paper and one book chapter. The full set of reviewed papers thus included 32 papers. An overview of the Living Lab papers reviewed is provided in Annex 1. Annex 1 also includes summaries related to Living Lab processes and methods, to be treated in Chapter 4.6

4.2 Identified characterizing purposes of Living Labs

Nine characterizing purposes of Living Labs were identified as being of relevance during the reading of the literature[2]. The identified purposes were found to be related to three high-level issues, and were grouped accordingly. The purposes are presented in Table 1.

Four of the characterizing purposes were found to be common purposes (relevant for more than 2/3 of the reviewed papers). The remaining five were found to represent diverging perspectives (relevant for between 1/3 and 2/3 of the papers).

High-level issues	Identified characterizing purposes	Common purpose?
Living Lab contributions to the innovation and development process	*1. Context research* (To investigate the context of use)	No
	2. Discovery (To provide insight into unexpected ICT uses and new service opportunities)	Yes
	3. Co-creation (To involve users as co-creators)	No
	4. Evaluation (To evaluate or validate new ICT solutions with users)	Yes
	5. Technical testing (To conduct technical testing in a (semi)realistic context of use)	No
The Living Lab context	*6. Familiar context* (To experience and experiment with ICT solutions in contexts familiar to users)	Yes
	7. Real-world context (To experience and experiment with ICT solutions in real-world contexts)	No
Characteristics of Living Lab studies	*8. Medium- or long-term* (To conduct medium- or long-term studies involving users)	Yes
	9. Large scale (To try out ICT solutions with large numbers of users)	No

Table 1: Characterizing purposes of Living Labs, grouped according to high-level issues

[2] A tenth characterizing purpose "Investigate community aspects of ICT use" was initially identified, but excluded during the analysis due to the low number of papers for which this was clearly relevant.

Relevance scores for all nine characterizing purposes across the 32 reviewed papers are presented in Annex 2. Details of the results related to the common purposes for Living Labs are presented in the following subsections.

Living Lab contributions to the innovation and development process

Five of the identified characterizing purposes were related to a Living Lab's contribution to the innovation and development process. Two of these purposes were found to be common to practically all the papers; three of them reflect diverging perspectives. The order of presentation for these five characterizing purposes roughly reflects their order in the innovation and development process.

Diverging perspective: Context research (To investigate the context of use)

An important early contribution to an innovation and development process is to research the context of use, including the users and their environment. However, little more than half of the reviewed papers describe Living Labs aimed to facilitate context research as such. Among these, in particular the Living Labs associated with the use of ethnographic methods seem to be oriented towards context research; e.g. the IBBT|i-City Living Lab (The European Network of Living Labs, 2008b), Hoving's (2003) Living Lab work at Moervijk, Netherlands, and McNeese's (2004) Living Lab framework for cognitive systems engineering.

The lack of Living Labs aimed at providing context research, displayed in about half the reviewed papers, may have different causes. In some cases, Living Labs mainly seem to be regarded as environments in which to present solutions to users. Thus, the early phases of innovation or development, such as context analysis, identification of requirements and early design are not seen as being within the scope of Living Labs (e.g. Zhong et al., 2006). In other cases, a highly technology-driven research agenda may be the cause of the lack of activities aimed at providing general insight into end-users' context of use (e.g. Abowd, 2000; Beigl et al.; 2002).

Common purpose: Discovery (To provide insight into unexpected ICT uses and new service opportunities)

Twenty-nine of the papers presented Living Labs judged to be environments used for the purpose of gaining such insight. Abowd (2000) describes one of the Living Labs at GeorgiaTech as an environment where the researchers are *"uncovering new issues and opportunities"* (Ibid., p. 216). Ballon et al. (2005) characterizes Living Labs as environments in which to gain insight through *"confronting (potential) users with (prototypes or demonstrators) of early technology early on in the innovation process"* (Ibid., p. 16). Intille (2005) argues for the usefulness of sensor-based behavioural data from the MIT PlaceLab as background in the development of ubicomp solutions.

A Living Lab typically is understood as an environment where ICT developers and service providers can find out how new solutions are taken up among their users, be

sensitized with regard to new and unexpected uses, and find inspiration for future innovation. At the same time, it should be noted that several authors do not seem to include mechanisms for needs analysis and idea generation in their Living Labs (e.g. Intille et al., 2005; Beigl et al., 2002). For these authors, insight into unexpected uses and new service opportunities may be obtained informally rather than through defined processes or methods.

Diverging perspective: Co-creation (To involve users as co-creators)

The European Network of Living Labs states that *"one thing is common for all of us; the human-centric involvement and its potential for development of new ICT-based services and products. It is all done by bringing different stakeholders together in a co-creative way"* (The European Network of Living Labs, 2008a). However, co-creation may not be as prevalent a feature of the Living Lab literature as the above quote may suggest. Less than half of the papers presented Living Labs were found to have co-creation as a characterizing purpose.

In spite of the modest proportion of Living Lab papers that advocate user co-creation as a purpose of the Living Lab, co-creation seems to be very important for those that do acknowledge it. Ballon et al. (2005) define Living Labs as *"experimentation environments in which technology is given shape in real-life contexts and in which (end) users are considered 'co-producers'"* (Ibid., p. 15). Eriksson et al. (2006) stress the importance of *"Society, Market [and] enabling Technology in Co-design Processes"* (Ibid., p. 6). Mirijamdotter et al. (2006) argue that Living Labs involve *"user-centric co-creation and innovation"* (Ibid., p. 1).

Co-creation seems to be implemented in slightly different ways in current Living Labs. Ballon et al. (2005) refer to co-creation as depending on user feedback based on users' experiences of technology in real-world contexts. Hoving (2003) describes the co-creative process as being conducted through a series of action-research interventions, where end-users are provided with technology and the effects of the interventions are monitored by researchers.

Mirijamdotter et al. (2006) and Niitamo et al. (2006) point out that in current Living Lab practices users are seen more as *"sources of (predefined) technology use"*, rather than *"sources of innovation"* (Ibid., p. 3), which suggests that, at least in some Living Labs, co-creation is an ambition rather than a realized approach.

Common purpose: Evaluation (To evaluate or validate new ICT solutions with users)

All the papers reviewed present Living Labs aimed to evaluate or validate new ICT solutions with users. However, great variations exist.

At one extreme, Ballon et al. (2005), Pearson and Lievens (2005) and Hoving (2003) seem to restrict Living Lab evaluation to user feedback on early designs and prototypes only, and exclude later phase validation activities with users. The most comprehensive discussion of this perspective is given by Ballon et al., who argue for viewing Living Labs as one of several different test and experimentation platforms. In the terminology of Ballon et al., Living

Labs are environments in which to confront users with medium-maturity ICT solutions for purposes of design rather than testing.

At the other extreme, de Leon et al. (2006), Niitamo et al. (2006) and Eriksson et al. (2006) present Living Labs as open innovation platforms allowing new services and products to be *"created and validated in collaborative […] real-world environments within individual regions"* (de Leon et al., 2006, p. 1). The Living Labs described by de Leon et al., Niitamo et al. and Eriksson et al. seem to provide evaluation and validation at a later stage of the innovation and development process than the Living Labs described by Ballon et al., Lievens et al. and Hoving.

Between these two extremes, several authors present Living Labs that allow for experiencing and experimenting with new ICT solutions (Abowd, 1999; 2000; Intille et al., 2005; 2006; Kidd et al,., 2005; Zhong et al., 2006; Zhong and Coyle, 2006) in order to receive user-feedback on designs, prototypes and running versions. The user feedback is typically returned to the development process, serving the purpose of formative evaluation.

Diverging perspective: Technical testing (To conduct technical testing in a (semi)realistic context of use)

One of the earliest appearances of the term 'Living Lab' in the field of ICT research is Abu-Hakima et al.'s (1998) use of it to describe a testbed for personal information networking applications, where applications were made available to users. Thirteen of the papers reviewed described Living Labs that enabled technical testing. Zhong (Zhong et al., 2006; Zhong and Coyle, 2006) and Oliveira et al. (2006) present their Living Lab as an extension of a test-bed setup. De Leon et al. (2006) describe Living Labs as an approach or methodology that can be implemented in a testbed environment.

Merges of Living Labs and testbeds may indeed prove beneficial with regard to both allowing technical testing in (semi)realistic environments and obtaining user feedback on running services. However, it could be argued that such mergers of Living Labs and testbeds may easily be oriented more towards the validation of already running services rather than towards user involvement in the whole design process (including early idea generation and user needs analysis). In line with this concern, Ballon et al. (2005) argue that we should regard Living Labs and testbeds as separate platforms for test and experimentation, rather than overlapping environments.

On the other hand, other authors present Living Labs that both utilize users as sources of innovation and allow for technical testing. In Table 1 we see that in as many as five of the papers reviewed, both co-creation and technical testing were found to be relevant characterizing purposes (de Leon et al., 2006; Eriksson et al., 2006; Mirijamdotter, 2006; Niitamo et al., 2006; Ståhlbröst, 2006).

The Living Lab context

The context of the Living Lab is the arena for user interaction with the ICT solutions under development. All but three of the reviewed papers report on the contexts of the Living Labs being familiar to the users. However, as seen below, familiar contexts are not necessary the same as real-world contexts.

Common purpose: Familiar contexts (To experience and experiment with ICT solutions in contexts familiar to users)

For 29 of the papers reviewed, a characterizing purpose of Living Labs was to experience and experiment with new ICT solutions in contexts familiar to the users. E.g. the MIT Place Lab is described as a *"real home where the routine activities and interactions of everyday home life can be observed"* (Intille, 2005, p. 1941). The Living Lab for virtual enterprises described by Katzy (2005) has a physical layout, with group meeting rooms and individual working zones to support regular business collaboration. The GeorgiaTech Aware Home is constructed in such a way as to allow experimentation in an authentic home setting (Kidd et al., 1999).

Allowing ICT to be tried by users within familiar contexts may make Living Labs a useful supplement to traditional experimentation environments such as usability laboratories and field studies. Collecting user feedback in the confined spaces of the usability laboratory may threaten ecological validity. Field studies, on the other hand, are costly and resources-intensive. Some of the Living Lab presentations, e.g. Katzy et al. (2005) and Lievens and Pierson et al. (2005), seem to represent a good balance between the potentially low ecological validity of the labs and high resource requirements of traditional field studies.

Diverging perspective: Real-world contexts (To experience and experiment with ICT solutions in the real-world)

Familiar contexts of use may either be real-world contexts or simulations; the latter understood as contexts of use that are constructed and used particularly for the purpose of the research described. At least six of the reviewed papers present Living Labs that are only simulations of user contexts, such as the MIT PlaceLab (Intille et al., 2005; 2006) and the virtual enterprise lab of Katzy et al. (2005). Thus, less than two-thirds of the reviewed papers present Living Labs assumed to facilitate experiencing and experimenting with ICT solutions in real-world contexts.

The real-world Living Labs presented in the reviewed literature represent a wide range of contexts; from relatively small-scale and geographically delimited, such as the electronic classrooms at GeorgiaTech, to large-scale Living Labs covering whole geographical regions, such as the Digital Madeira Test Bed and Living Lab (Oliveira, 2006).

Characteristics of Living Lab studies

Two of the identified characterizing purposes address characteristics of Living Lab studies. One of these (Medium or long term) is common tom most Living Labs, whereas the other (Large scale) reflect a diverging perspective.

Common purpose: Medium- or long-term (To conduct medium- or long-term studies involving users)

Twenty-four of the papers presented Living Labs facilitating medium- or long-term studies of the uptake and use of new ICT solutions; 'medium- or long-term' is understood as data collection across one week or more. Such studies may provide knowledge of relevance for future ICT development not easily gathered through other means, and may be important as a means of giving priority to user-oriented activities. As Abowd et al. (1999) state: *"[In the Living Laboratory] we really needed to listen and react to the requests of our users."* (Ibid., p. 515).

Knowledge obtained through medium- and long-term studies may provide insight in evolving patterns of ICT use and may possibly be used for predictions regarding future patterns of ICT use in society at large. The attentiveness to the patterns of ICT use that evolve as new solutions are being integrated in the everyday life of users is most clearly displayed in recent Living Lab literature, such as Ballon et al. (2005) and Niitamo et al. (2006). However, it also seems to be reflected in the early Living Labs for unobtrusive ICT services (Abowd, 2000; Beigl, 2002). The ambition to investigate evolving patterns of use is also in line with the ambitions set out in Living Labs Europe (2008) and the European Network of Living Labs (2008a).

Diverging perspective: Large scale (To try out ICT solutions with large numbers of users)

Trying out new ICT solutions with large numbers of users is almost exclusively a characterizing purpose of the Living Labs presented in the most recent literature; 'large numbers of users' being understood as several hundred or more. With one exception (Hoving, 2003), the 14 papers that describe Living Labs with large numbers of users are from 2005 or later. Also, the large scale Living Labs described in the reviewed papers are all also realized in real-world contexts.

In the whole body of the literature, Living Labs including only small numbers of users are just as frequently described as large-scale Living Labs. Examples of small-scale Living Labs are those oriented towards ubiquitous ICT (e.g. Abowd et al., 2000; Beigl et al., 2002; Intille et al., 2005) and cognitive systems engineering (e.g. McNeese et al., 1996; 2004).

The Living Labs represented in the two European networks of Living Labs usually seem to involve large numbers of users, often covering whole geographical regions. Large-scale Living Labs typically seem often to be regarded as a solution to regional innovation issues, and associated with co-creational processes (Eriksson et al. 2006; Ståhlbröst, 2006; de Leon et al., 2006; Mirijamdotter et al., 2006; Niitamo et al., 2006).

4.3 Living Lab processes and methods

As we have seen above, Living Labs do indeed have different characterizing purposes. It is therefore hardly surprising that the literature also includes diverging perspectives with regard to Living Lab processes and methods.

Living Lab innovation and development processes

All the papers reviewed were inspected with regard to descriptions of Living Lab processes. Thirteen were found to contain only high-level descriptions, six included case-specific process descriptions, three provided general descriptions of particular process phases, and only three included general process descriptions in some detail[3]. The remaining six papers were not found to incorporate any degree of process description.

Stages of innovation and development represented in Living Lab processes

All process descriptions were analysed with regard to which stage of the innovation and development they were judged to belong to. The classification of process stages was conducted with the categories developed on basis of Analysis 1. The overall results are presented in Table 2. Details are presented below. Details regarding the classification of each individual paper are provided in Annex 1.

Stages of innovation and development	Count
Context research	13
Discovery	14
Co-creation	7
Evaluation	18
Technical testing	5

Table 2: Process descriptions classified according to stages of innovation and development

Eleven of the provided process descriptions covered one of the five stages only, whereas just as many covered three or more stages.

General process descriptions

The three papers that include detailed general process descriptions cover different areas of ICT. Pierson and Lievens (2005) dealt with broadband innovation, McNeese (2004) complex systems and cognitive systems engineering, and Mirijamdotter et al. (2006) collaborative working environments.

Pierson and Lievens' (2005) description of a Living Lab research cycle, targeting the stages of context research, discovery, and evaluation, is structured as a four-phase process.

[3] Lievens et al. (2006) also provides a general process description with some detail, but this is interpreted as a reference to a process description of the existing literature since it closely follows the referred process description of Pierson and Lievens (2005).

The process includes Contextualization (explorations regarding relevant technologies and respondents), Concretisation (baseline measurements and respondent profiling), Implementation (provision of new technology to end-users), and Feedback (ex post hoc measurements and inferences of technology recommendations). The process of Pierson and Lievens seems to have been developed particularly to support ethnographic studies of technology uptake and use.

McNeese's (2004) Living Lab process description, targeting the stages of context research, discovery, and evaluation, also consist of four elements: Ethnographic Study (ethnographic analysis of system and work context based on observation), Knowledge elicitation (tool-based identification of relevant cognitive factors such as goals, schemas, situation awareness, strategies and beliefs), Scaled worlds (high-fidelity simulations of real-world contexts), and Reconfigurable prototypes (evolving prototypes implemented in a scaled world).

In spite of being developed for different areas of ICT, the processes of McNeese and of Pierson and Lievens display a number of similarities. The context of use is thoroughly researched, new technologies are implemented in contexts familiar to the participants, and feedback from the participants is used for improvements of the technological solutions. An important novelty of these two process descriptions, from the perspective of traditional development processes (e.g. as described by Sommerville 1996), is their reliance on ethnographic research and contextually situated development of new technology.

The third general process description found in the literature is an innovation process called Appreciating Needs by Mirijamdotter et al. (2006), targeting the stages of discovery, co-creation, and evaluation. The process is divided in three phases: Discovery and Dream (eliciting and prioritizing needs), Design and Develop (prototype development), and Destiny and Disseminate (prototype test and evaluation). This process description resembles existing user-centred design processes (e.g. ISO/IEC, 1999; Maguire et al., 1998); however, no mechanisms for context research seem to be included.

The process of Pierson and Lievens and McNeese have been referenced by one of the other reviewed papers each (Lievens, et al., 2006; MacEachren et al., 2006). The process of Mirijamdotter has been referenced by none of the papers under review.

Living Lab methods

Living Lab methods may be used as elements in Living Lab innovation and development processes. The following summary includes methods that are mentioned in more than two of the reviewed papers.

Analysis of system logs or automatically collected behavioural data

The most widely presented method used in the Living Labs described in the literature was the collection and analysis of system logs or behavioural data, described in nine of the reviewed papers. Interestingly, this methodological approach is used both by researchers oriented

towards field studies and technical testing of prototype solutions in real-world environments (e.g. Abowd, 1999; Zhong et al., 2006), and by researchers heavily oriented towards user-context analysis based on ethnographic research methods (Pierson and Lievens, 2005; Lievens et al. 2006).

Ethnographic research

The use of ethnographic research methods - typically referring to a research approach that encompasses a variety of data-collection methods – were reported in seven of the reviewed papers. Authors who reported using ethnographic methods belonged to either the tradition of cognitive systems engineering (MacEachren et al., 2006; McNeese, 2004) or ICT innovation, in line with Pierson and Lievens (2005) (Hoving, 2003; Lievens et al., 2006; Pierson et al., 2007). It is noteworthy that all papers that described ethnographic research methods also presented or referred to fairly detailed process descriptions.

Questionnaires

Questionnaires are reported to have been used in six of the reviewed papers. One characteristic of questionnaires are that they enable data to be gathered from a large number of respondents at low cost (Robson, 1993).This may make them suitable for Living Labs that involve large numbers of participants. The reported surveys were either constructed for quantitative measurement (e.g. Lievens et al., 2006) or permitted data collection for both qualitative and quantitative purposes (Abowd et al., 1999).

Focus groups

Focus groups were described in five of the papers reviewed. The strength of focus groups is that they can provide qualitative in-depth information on a topic relevant to the participants (Halkier, 2002). Focus groups, as described by the authors in the literature reviewed here, seem to be used as a complementary method to gain in-depth knowledge. Lievens et al. (2006), for example, employed both focus groups and questionnaires.

Observation

Observation was reported as a method in five of the papers. It may be noted that observation, due to its resource-intensive nature, may be most suitable for studies of small and easily demarcated contexts - such as the control-room settings of cognitive systems engineering (McNeese, 1996; 2004) and e-commerce simulations (Bendavid et al., 2006).The reason why more authors do not report the use of observations may well be that the broad and complex contexts represented in many of the Living Labs are not easily captured in observation studies.

4.4 Theoretical foundations of Living Labs

Twenty-one of the 31 papers provided presentations of the theoretical foundations of their Living Labs. In some papers the theoretical foundations were presented just as a reference in a section on previous work, in others the theoretical foundations were discussed extensively. Theoretical foundations presented in more than two papers are summarized in Table 3.

Theoretical foundations	Count
Co-creation and users as innovators	7
Science and technology studies (STS)	5
Human-computer interaction/Human factors	4
TEP framework of Ballon et al.	5

Table 3: Theoretical foundations presented in more than two of the reviewed papers[4]

The most frequently reported theoretical foundation is work related to co-creation and users as innovators. Von Hippel, presenting users as innovators, is referred to by three of the reviewed papers (Eriksson et al., 2006; Katzy et al., 2005; Kusiak, 2007). Others refer to Sharmer's work on co-creation (Niitamo et al., 2006) and the papers by Eriksson et al. and Niitamo et al. on co-creation in Living Labs (e.g. Oliveira et al., 2006; Kusiak, 2007).

A second theoretical foundation for Living Lab literature is that of Science and technology studies (STS), focusing on the relationship between social/cultural values and innovation. Pinch and Bijker (Pierson and Lievens, 2005; Lievens et al., 2006) and Suchman (McNeese, 2004) are among the theorists referred to.

The fields of Human-computer interaction (HCI) and Human factors are also presented as theoretical foundations for Living Labs (e.g. Ballon et al., 2005; McNeese, 2004; Ståhlbröst; 2006). An important assumption common to these highly overlapping fields is the importance of context research, user requirements specification, and user involvement in the development process in order to provide ICT systems that satisfy user and organization needs.

The test and experimentation platform (TEP) framework of Ballon et al. also seem to have provided some impact on the Living Lab literature (e.g. Ståhlbröst, 2006; Niitamo et al, 2006, Eriksson et al., 2006); in particular as a basis on which to understand Living Labs in relation to other test and experimentation platforms.

[4] It may also be noted that work on ubicomp Living Labs, in particularly that at Georgia Tech and MIT, seem to have served as an important source of inspiration; mostly within the field of ubicomp research, but also for authors from other fields (e.g. Niitamo et al., 2006). These papers are not included in the overview of theoretical foundations, as they seem to present little in the way of theoretical perspectives.

5 DISCUSSION

A literature review has been performed in order to generate new knowledge about the nature of Living Labs and how they can be implemented with regard to innovation and development processes and methods. The review provides an overview of 32 papers that appear to make up the current body of literature on Living Labs.

The following discussion is structured in terms of three main headings. First, common and diverging perspectives on Living Lab characterizing purposes are discussed. This first part of the discussion will also address the theoretical foundations of Living Labs, as well as suggest aspects of Living Labs useful for classification. The second part of the discussion will address the Living Lab processes and methods. Finally, a brief discussion of the limitations of this study will be given.

5.1 What are Living Labs?

The literature review has generated an overview of the wide-ranging field of Living Labs. Differentiating between common and diverging perspectives on characterizing purposes for Living Labs makes it clear that even though there are several differences between Living Labs it is justifiable to establish a general Living Lab definition based on an analysis of existing practices.

Common Living Lab purposes: long-term innovation efforts in the user context

All the Living Labs described in the literature appear to be environments in which new ICT solutions are evaluated or validated with users. Nearly all these Living Labs also offered insights into unexpected ICT uses and new service opportunities. These two characterizing purposes indicate that practically all Living Labs described in the literature target two key contributions to the innovation and development process: discovery and evaluation.

These dual purposes of Living Labs seem to reflect an underlying assumption regarding innovation; viz. that innovation is not achieved through short and fragmented project initiatives but through long-term innovation efforts involving cycles of gaining new insight and gathering experience of implemented solutions.

Most Living Labs enable experimentation with new ICT solutions in contexts familiar to users, even though several Living Labs only utilize context simulations, rather than real-world contexts. Also most Living Lab studies seem to include medium- or long-term user involvement, rather than just short term involvement such as participation in single focus groups or workshops.

To summarize the common core of Living Labs, a minimum definition is suggested:

> *Living Labs are environments for innovation and development where users are exposed to new ICT solutions in (semi)realistic contexts, as part of medium- or long-term studies targeting evaluation of new ICT solutions and discovery of innovation opportunities.*

Diverging perspectives on Living Labs: emerging trends and pragmatic considerations

Diverging perspectives on Living Labs clearly exist in the current literature. Five of the nine identified characterizing purposes were found to be relevant for only between 1/3 and 2/3 of the reviewed papers, reflecting five issues on which diverging perspectives exist.

Divergences regarding three of the characterizing purposes seem to reflect emerging trends. Two of these (context research and co-creation) will be discussed together. The third (technical testing) will be discussed separately. The two remaining characterizing purposes (real-world context and large scale) are interpreted as caused by pragmatic considerations rather than differences in opinion.

Emerging trend: Context research and co-creation - Living Labs founded in theories on users and society

Slightly more than half of the papers seem to relate Living Labs to studies that provide context research. Slightly less than half of them also include arguments in favour of involving users as co-creators. These two groups of papers are largely overlapping, and seem to reflect a growing tendency for Living Lab authors to argue for co-creation and insight in context of use as important keys to innovation (e.g. Mirijamdotter, 2006; Pierson and Lievens, 2005; Hoving, 2003). This trend, however, by no means encompasses the whole spectrum of Living Lab literature; these issues are not even discussed in a fair proportion of the literature.

The analysis of the theoretical foundations of Living Labs implies that the trend towards context research and co-creation is founded in a small set of theorists and schools of thought. It seems as if theorists on users as innovators and co-creation – in particular von Hippel and Scharmer – constitute the most widespread foundation for Living Labs. In addition the fields of Science and technology studies (STS) and Human-computer interaction/Human factors seem to be an important motivation for the trend towards increased attention towards context research. The field of STS may also be seen as an important motivator related to the Living Lab purpose of contextually situated experimentation with new technology.

This sharpening focus on context research and co-creation appear to be a substantial contribution to the state-of-the-art of Living Labs. It implies greater attention to the early stages of innovation and development processes in Living Labs, and it also serves to establish a unique Living Lab identity that clearly separates Living Labs from related environments for technology innovation, such as field studies or pilot testing. This trend also appears to be a reasonable extension to any Living Lab. Given that Living Labs are environments wherein users are involved in innovation and development, a certain amount of contextual knowledge is necessary in order to study user involvement. Without sufficient contextual knowledge, it may not even be possible to establish whether or not the Living Lab activities reflect real users in real-world-environments.

However, it should be noted that context research and co-creation activities may be highly resource-intensive, and also require special competence; two possibly prohibitive

factors for the continued Living Lab uptake of such activities. For example, several of the papers written in support of studies of context of use also report the use of relatively resource-intensive ethnographic methods. Important challenges related to future Living Lab initiatives will include developing tools and methods for context research and co-creation with lower demands as regards resources.

Emerging trend: Living Labs as extensions to testbeds

Just as there appears to be a distinction between Living Labs with regard to context research, and co-creation there also seems to be a distinction between Living Labs with regard to facilities for technical testing in (semi)realistic environments. However, there is no simple relationship between these two distinctions. Some authors advocate context research and co-creation without focusing on technical testing (e.g. Hoving et al., 2003; Pierson and Lievens, 2005); others focus only on technical testing (e.g. Zhong et al., 2006; Abu-Hakima et al., 1998), while a fair number seem to support both technical testing in (semi)realistic environments and users as co-creative resources in the innovation process (e.g. Niitamo et al., 2006; Mirijamdotter, 2006; de Leon et al., 2006).

The reason why technical testing is a characterizing purpose for a number of Living Labs seems to be that these labs typically spring from technical testbeds, and serve as facilities for making testbed applications available to users. Technical testing may reasonably be regarded as a valuable activity in the later phases of an innovation process. Even so, technical testing is not included in the majority of Living Lab descriptions. As noted above, Ballon et al. (2005) even argue for an explicit demarcation between Living Labs and testbeds as two distinct platforms for testing and experimentation.

It may be that the diverging perspectives with regard to whether or not technical testing is within the scope of a Living Lab are grounded in a disagreement with regard to whether or not it is possible to conduct both idea generation and technical testing within the same environment, without too much bias towards one or the other. Authors such as Niitamo et al. (2005) and de Leon et al. (2006) argue that both these aspects of innovation should be catered to through Living Labs. However, neither of them presents strong descriptions of how this should be implemented.

Divergences grounded in pragmatic consideration

Diverging perspectives were identified regarding whether Living Lab involves experimentation in real-world contexts or simulations only. Since certain areas of application (e.g. consumer market broadband or mobile applications) relatively easily allow real-world implementation, whereas others (e.g. complex systems and ubiquitous computing) seem to favour the use of simulated contexts, this diverging perspective is quite possibly the result of pragmatic considerations.

The diverging perspectives of whether a Living Lab involves a large number of participants also mainly seem to reflect pragmatic considerations (e.g. “How many users do

we need to involve to fulfil the purpose of the lab"). The observation that all large scale Living Labs described in the reviewed literature are also real-world Living Labs seem to support the interpretation that this issue reflect pragmatic considerations. It may, however, be noted that one set of authors, Eriksson et al. (2006), do argue that a larger pool of participants in principle gives a richer background for innovation (which may be at odds with the basic assumptions of small-scale Living Labs), something that could be interpreted as a difference in opinion rather than a pragmatic consideration. Even so, this argument of Eriksson et al. does not seem to be reflected in the other papers reviewed here. Neither do Eriksson et al. seem to present a convincing approach regarding how to access and process new ideas from large pools of participants.

It should be noted, however, that even though these divergences are likely to be the result of pragmatic considerations, it may be well worth doing further research on (1) whether or not simulated contexts provide sufficient ecological validity to serve as substitute real-world contexts and (2) what considerations are needed to decide the number of participants required in a given Living Lab.

Classifying Living Labs

The definition of Living Labs as above is valid for practically all Living Labs. In addition, the discussion of diverging perspectives within the Living Lab literature has served to identify two aspects that may be used to discriminate between the Living Labs that comply with the general definition:

- *Contextualized co-creation:* Living Labs supporting context research and co-creation with users
- *Testbed association:* Living Labs serving as a testbed extension, where testbed applications are accessed in contexts familiar to the users.

To exemplify the classifications that may be done on basis of these two aspects, they have been used to classify a few of the Living Lab descriptions of the reviewed literature. The classification is provided in Table 4.

		Testbed association	
		No	Yes
Contextualized co-creation	No	Abowd (1999) Intille et al. (2005) Katzy et al. (2005)	Abu Hakima et al. (1998) Zhong et al. (2006) Oliveira et al. (2006)
	Yes	Hoving (2003) Ballon et al. (2005) Kusiak (2007)	De Leon et al. (2006) Niitamo et al. (2006) Mirijamdotter et al. (2006)

Table 4: Classification of example Living Lab papers

Highly important issues for future research are associated with these aspects; in particular (1) the continued development of theories, processes and methods for contextualized co-creation in Living Labs, (2) the development of a Living Lab structure that support contextualized co-creation in testbed-oriented Living Labs, and (3) studies to critically investigating the usefulness or impact of contextualized co-creation in the innovation process.

5.2 Living Lab processes and methods

According to the Oslo Manual (OECD/Eurostat, 2005), innovation refers to the implementation of new products. Given this interpretation of innovation, Living Labs established in order to facilitate end-user involvement for innovation and development purposes clearly depend on adequate processes and methods. Even so, the reviewed literature is characterized by a remarkable lack of in-depth descriptions and discussions of Living Lab processes and of innovative methods for end-user involvement.

Living Lab processes

Only three of the papers reviewed provide fairly detailed general descriptions of Living Lab innovation and development processes. These three general descriptions are in turn referred to by only two of the other papers.

Provided that the current wave of Living Lab establishments we currently see across Europe and elsewhere in the world is well-founded in long-term attempts to improve ICT innovation, such a lack of Living Lab process descriptions and discussions is surprising. It seems reasonable to expect a certain level of maturity with regard to Living Lab innovation and development processes, and the low number of general process descriptions and associated references should cause concern.

Another important cause for concern is that none of the papers were found to provide critical discussions or investigations of existing Living Lab processes. It may be that such processes exist and are described in other documents that are available in a literature search; however, the existing literature provides no indication of this.

A possible cause for optimism regarding the future of Living Lab process description is that more than half the provided process descriptions address the context research and discovery stages of innovation and development. This is in compliance with the emerging and highly relevant trend of Living Labs for context research and co-creation, and may make a good starting point for future research in this area. It should be noted, however, that less than a third of the proposed process address co-creation. This may mean that even though co-creation seem to be a growing trend, existing Living Lab processes do not seem to incorporate co-creation in an adequate manner. The Living Lab processes development does not seem to keep up with a growing ambition to involve users in co-creation processes.

Research is urgently needed to address innovation and development processes for Living Labs, with regard to both the development of processes and critical studies of the same.

The process descriptions of Pierson and Lievens (2005) or of McNeese (2004) could provide a good starting point for such research, even though neither of these presents critical discussions regarding the quality of the proposed processes.

Living Lab methods

The state of Living Lab method descriptions seem to be almost as bleak as the state of Living Lab process descriptions. Of the five methods mentioned in more than two papers, three were the long-standing methods of questionnaires, focus groups, and observation. These methods may be well suited for some Living Lab studies, but does not represent important methodological advances.

Innovative methodological approaches are limited to system log analyses and the use of ethnographic research methods for the purposes of ICT innovation. The relevance of ethnographic research to Living Lab innovation and development is promising, because this seems to be one of the areas in which the Living Lab approach may be differentiated from more traditional approaches to ICT innovation and development. It is interesting to note that there seem to be a connection between ethnographic research on the one hand and the widespread use of system logs and automatically collected behavioural data on the other, and the usefulness of automatically collected behavioural data for ethnographic is foreseen by the researchers behind the MIT PlaceLab. Intille et al. (2005) states that the behavioural data collected through the PlaceLab may be a valuable resource for ethnographers, as a *"library of everyday activity"* (Ibid., p. 1944).

Given the growing importance of contextualized co-creation in Living Labs, it is highly surprising that none of the identified methods seem to be particularly suited to support co-creation. Surveys and focus groups may be useful methods in order to gather user feedback, but are not particularly suited to elicit the full innovative potential of users participating in Living Labs.

It is also noteworthy that no critical studies on the quality of Living Lab methods have been presented, not even for the relatively novel methodological approaches.

Future research on Living Lab methods is clearly needed, and should be given the same high priority as future research on Living Lab processes. Important problem areas include novel methods for co-creation, methods particularly suited to the characteristics of Living Labs, and critical studies of Living Lab methods.

5.3 Limitations of the present study

The literature review discussed here is limited by factors related to its scope and method. The scope was restricted to a review of literature describing environments of approaches termed 'Living Lab'/'Living laboratory'. This scope was well founded, given that no definition covering the field of Living Labs was available. However, with the new understanding of Living Labs reached in this study, future surveys could extend the scope to include literature describing

environments or approaches for innovation that fall under the suggested Living Lab definition but that do not employ the term Living Lab. The current review has been instrumental in grasping the concept of Living Labs, but more research is needed in order to obtain an overview of the complete treatment of Living Lab-like environments and approaches in the literature.

The methodological approach of the present study was limited to a literature review. This limitation implies that only Living Labs described in the reviewed literature have been taken into account. It is also conceivable that some relevant aspects of the Living Labs described in the literature have not been sufficiently described in the papers reviewed or sufficiently understood by the reviewer. This limitation of the research method might have been alleviated by including supplementary data collection methods; e.g. surveys targeting the authors of the existing literature or Living Lab owners. Future research, including supplementary data collection activities, such as surveys of existing labs, will be highly relevant as a means of improving our understanding of Living Labs.

5.4 Concluding remarks

This review of the Living Lab literature offers the ICT researcher and developer community a new understanding of existing Living Labs and Living Lab trends, and provides some insights into relevant future research.

The author is optimistic as regards the future of Living Labs for innovation and development in the field of ICT. In particular, the Living Lab trend towards a sharper focus on early-phase innovation activities such as context-of-use research and co-creation seems promising as a way of improving user involvement in ICT innovation processes and thereby realising the innovative potential of the users. The trend towards extending ICT testbeds with Living Lab facilities is also interesting, although the suitability of such extensions for early-phase innovation needs to be validated.

The most pressing challenge for future Living Lab research seem to be related to the current lack of studies of Living Lab processes and methods. It is to be hoped that this review may serve as an inspiration for Living Lab researchers to give this research challenge the high priority it demands.

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APPENDIX 1: OVERVIEW OF THE REVIEWED LIVING LAB PAPERS

Note that stages of innovation and development associated with the processes descriptions are reported as follows:

R (context research); D (discovery); C (co-creation); E (evaluation); T (technical testing).

Paper reference	Overview	Living Lab concept	Technology (and application) areas	Innovation and development process	Methods
Abowd (1999)	Short presentation of four Living Lab initiatives at Georgia Tech.	Long term trial of running end-user services in real-world contexts.	Ubiquitous computing (Education).	Case-specific description (E): Field trial in the context of university education	NIL
Abowd et al. (2000)	Case study of ubocomp solutions implemented in university classrooms.	Experimentation/trials with running end-user services in real-world contexts.	Ubiquitous computing (E.g. education and home applications).	NIL	Questionnaire survey, system log data analysis.
Abu-Hakima et al. (1998)	Presentation of setup and utilization of multi-agent testbed with end-user services.	Testbed setup for end-user services. No details given regarding user involvement.	Agent technology (Personal information networking applications).	NIL	NIL
Ballon et al. (2005)	Presentation of a typology of test and experimentation platforms, based on a review of 18 existing platforms.	Environment for shaping of technology in real life contexts, where users are considered co-producers.	Broadband technology and services (Private sector services, education).	High level description (R, D, C, E): Context analysis and user feedback in early development	NIL
Beigl et al. (2002)	Presentation of location based products/services validated in a semi-realistic context.	Laboratory context implementation of end-user services and products.	Ubiquitous computing (Location aware services).	NIL	NIL
Bendavid et al. (2006)	Presentation of a case study to prove an e-commerce supply chain concept.	Laboratory simulations of technology enabled e-commerce scenarios are referred to as "Living Lab".	RFID - Radio-frequency identification (e-Commerce).	Case-specific description (E, T): "Proof of concept"	Observation and "self-trial" learning in laboratory simulation.
Curwell (2006)	Project presentation: Intelligent cities focusing on innovative e-Government services.	A "living lab testbed condition" is mentioned as the project's research methodology.	Integrated open systems platform (e-Government).	High level description (T): Prototypes tried out in "living lab testbeds"	NIL

Paper reference	Overview	Living Lab concept	Technology (and application) areas	Innovation and development process	Methods
de Leon et al. (2006)	Presentation of a proposed structure/ implementation for a Living Labs network.	Methodology for collaborative creation and validation of innovations in testbeds associated with real-world environments.	Mobile and wireless networks and services.	High level description (R, D, C, E, T): User feedback and co-creation in testbed-oriented Living Labs)	NIL
Eriksson et al. (2006)	Position paper presenting Living Labs as framework for stakeholder and user involvement in innovation processes.	Methodology for collaborative creation and validation of innovations in regional real-world environments.	ICT in general.	High level description (R, D, C, E) : Living Lab innovation through co-creation processes)	NIL
Hoving (2003)	Presentation of a research project utilizing a Living Lab to shape technology in society.	"Environment in which technology is shaped by specific social contexts and needs and where users are seen as co-producers."	ICT in general.	Case-specific description (R, D, C, E): Contextualized technology experiences as feedback in iterative development.	"Social lab methodology" (Participants are followed through ICT-related action research interventions).
Intille et al. (2005)	Presentation of the MIT PlaceLab, discussed in relation to other tools and methods for end-user involvement.	Semi-realistic environment for long-term sensor-based behaviour data collection, and service experimentation.	Ubiquitous computing (Home applications).	High level description (R): Behavioural datasets used for context knowledge and future development.	Automatic gathering of behaviour data.
Intille et al. (2006)	Presentation of the MIT PlaceLab, with an example set of sensor-based behaviour data.	Same as Intille et al. (2005).	Same as Intille et al. (2005).	Same as Intille et al. (2005).	Same as Intille et al. (2005).
Katzy et al. (2005)	Presentation of a Living Lab collaboration support in virtual enterprises.	Semi-realistic environment allowing innovation, exploration and validation of end-user services.	Collaborative work support (Virtual enterprises).	High level description (D): Living Lab setup and research guided by scenario development process.	NIL
Kidd et al. (1999)	Presentation of the Georgia Tech Aware Home as a research environment.	Semi-realistic environment enabling long-term studies of ubicomp end-user services.	Ubiquitous computing.	NIL	NIL

Paper reference	Overview	Living Lab concept	Technology (and application) areas	Innovation and development process	Methods
Kusiak (2007)	Presentation of a "Living Innovation Laboratory" for co-creative innovation.	Innovation process and methods to support end-user co-creation.	NIL	High level description (R, D, C, E): Innovation process to enable end-user co-creation.	Reference to >30 methods, e.g. focus groups, surveys, observation, logging.
Lasher et al. (1991)	Lessons learned from an industrial case on partnerships in ICT development.	"Living Lab" used in reference to co-operative partnerships and live field trials.	Information management systems (Mail scanning and imaging).	High level description (E): Practical advice for co-operative partnerships with few process details.	NIL
Lievens et al. (2006)	Case presentation of a co-creative design process following a Living Lab approach.	Environment for shaping of technology in real life contexts, where users are considered co-producers.	Mobile ICT (Digital newspapers).	Reference to Pierson and Lievens (R, D, E): Living Lab research cycle description.	Ethnographic research via questionnaire surveys, system log data analyses, focus groups.
MacEachren et al. (2006)	Short overview article on approaches and success cases in a particular application area.	An integrated approach to understand and work supporting theory and technology development.	Geographical information technology (Crisis management).	Reference to McNeese (R, D, C, E): Short Living Lab framework description.	Cognitive fieldwork. Simulations to elicit end-user feedback.
Markopoulos and Rauterberg (2000)	Presentation of a planned Living Lab for experimentation with ubicomp services.	Semi-realistic environment enabling long-term studies of end-user services.	Ubiquitous computing (Home applications).	NIL	NIL
Markopoulos (2001)	Same as Markopoulos and Rauterberg (2000).	Same as Markopoulos and Rauterberg (2000).	Same as Markopoulos and Rauterberg (2000).	NIL	NIL
McNeese (1996)	Presentation of a first implementation of a Living Lab	An ecological approach to understand work and support theory and technology development.	Cognitive systems engineering. (Complex systems)	NIL	Ethnographic methods, CSE knowledge elicitation, "scaled worlds" testbeds, prototyping.
McNeese (2004)	General presentation of a Living Lab development process. Case examples are provided.	Same as McNeese (1996)	Same as McNeese (1996)	General process description (R, D, E): A four-phase Living Lab development process.	Same as McNeese (1996)

Paper reference	Overview	Living Lab concept	Technology (and application) areas	Innovation and development process	Methods
Mirijamdotter et al. (2006)	General presentation of Living Labs and the European Network of Living Labs.	Approach to systemic innovation directly involving end-users.	Collaborative work support (Innovation).	General process description (R, D, E): The Appreciating Needs innovation process.	Needs eliciting and prioritizing, prototyping, evaluation with users.
Niitamo et al. (2006)	Presentation of Living Labs state-of-the-art.	Public Private Partnerships for creation, prototyping, validation and testing in real-life contexts.	ICT in general.	High level description (R, D, C, E, T): Living Lab practices described. Few process details provided.	NIL
Oliveira et al. (2006)	Presentation of the Madeira Living Lab initiative.	Approach to innovation in regional collaborative real-world environments.	Mobile ICT (Tourism, health, work, education).	High level description (D, E): Living Lab process description.	NIL
Pierson and Lievens (2005)	Presentation of a Living Lab innovation process.	Environment for shaping of technology in real life contexts, where users are considered co-producers.	Mobile ICT (e-Paper).	General process description (R, D, E): A four-phase Living Lab research cycle.	Ethnographic research via questionnaire, system log data analyses, focus groups, interviews.
Pierson et al. (2007)	Presentation of archetype user research in the context of a Living Lab.	Same as Pierson and Lievens (2005).	Mobile ICT.	Case-specific description (R, D): Two approaches to user requirements identification.	Ethnographic research via focus groups and questionnaire surveys.
Schmidt et al. (2002)	Description of a weight-sensor system and associated services in a semi-realistic environment.	Semi-realistic context where prototypes are implemented for end-user interaction.	Ubicomp; load sensing.	Case-specific description (E): Living Lab used for validation.	System log data analysis.
Ståhlbröst (2006)	Licentiate thesis: Human-centric evaluation of innovation in the context of Living Labs.	Innovation through user-centric methods in real-world environments.	ICT in general.	General description of process elements (E): User-centric evaluation.	Questionnaire survey, interviews, focus groups, observations.
Van Laerhoven et al. (2003)	Presentation of an innovative input device, validated in a Living Lab.	Semi-realistic context where prototypes are implemented for end-user interaction.	ICT input mechanisms (Audio systems).	Case-specific description (E): Living Lab used in validation study.	NIL

Paper reference	Overview	Living Lab concept	Technology (and application) areas	Innovation and development process	Methods
Zhong et al. (2006)	Presentation of a large-scale testbed, implemented as a Living Lab in the eStadium.	Real-world environment where new services are made available to end-users.	Wireless ICT (Infotainment).	General description of process elements (T): Applications in eStadium testbed and Living Lab.	System log analysis.
Zhong and Coyle (2006)	Presentation of eStadium as Living Lab for safety and infotainment applications.	Same as Zhong et al. (2006).	Wireless ICT (Safety, infotainment).	Same as Zhong et al. (2006).	Same as Zhong et al. (2006).

ANNEX 2: RELEVANCE SCORES

Relevance scores for each reviewed paper regarding the characterizing purposes of Living Labs. (1=Clearly irrelevant or inaccurate. 4=Clearly relevant.)

Paper reference	Contributions to the innovation and development process					Context		Study chara-cteristics	
	1. Research	2. Discovery	3. Co-creation	4. Evaluation	5. Technical testing	6. Familiar contexts	7. Real-world	8. Medium- or long-term	9. Large scale
Abowd (1999)	2	3	2	4	2	4	4	4	2
Abowd et al. (2000)	2	3	2	4	2	4	4	4	2
Abu-Hakima et al. (1998)	2	2	2	4	4	3	3	2	2
Ballon et al. (2005)	4	4	4	4	1	4	4	4	4
Beigl et al. (2002)	2	3	2	3	2	3	2	2	2
Bendavid et al. (2006)	2	2	2	4	4	4	1	2	2
Curwell (2006)	2	3	2	3	4	3	3	3	3
de Leon et al. (2006)	3	4	4	4	4	4	4	3	4
Eriksson et al. (2006)	4	4	4	4	3	4	4	3	4
Hoving (2003)	4	4	4	3	1	4	4	4	4
Intille et al. (2005)	4	3	2	4	2	3	1	4	1
Intille et al. (2006)	4	3	2	4	2	3	1	4	1
Katzy et al. (2005)	2	4	2	3	2	4	1	4	2
Kidd et al. (1999)	2	4	2	4	2	3	1	4	2
Kusiak (2007)	4	3	4	4	2	2	2	2	2
Lasher et al. (1991)	2	3	3	3	2	4	4	4	2
Lievens et al. (2006)	4	4	4	4	1	4	4	4	4
MacEachren et al. (2006)	3	3	3	3	2	3	1	2	1
Markopoulos (2001)	4	3	2	4	2	4	1	3	1
Markopoulos and Rauterberg (2000)	4	3	2	4	2	4	1	3	1
McNeese (1996)	4	3	3	4	2	3	1	2	2
McNeese (2004)	4	3	3	4	2	3	1	2	2
Mirijamdotter et al. (2006)	4	4	4	4	3	4	4	3	3
Niitamo et al. (2006)	4	4	4	4	3	4	4	3	4
Oliveira et al. (2006)	3	4	2	3	3	2	4	4	4
Pierson and Lievens (2005)	4	4	4	4	2	4	4	4	4
Pierson et al. (2007)	4	4	4	3	2	4	4	4	4
Schmidt et al. (2002)	2	3	2	3	3	3	1	2	2
Ståhlbröst (2006)	4	4	4	4	3	4	4	4	4
Van Laerhoven et al. (2003)	1	2	2	4	3	1	1	4	2
Zhong et al. (2006)	2	3	2	4	4	4	4	4	4
Zhong and Coyle (2006)	2	3	2	4	4	4	4	4	4
Count 1 (irrelevant or inaccurate)	1	0	0	0	3	1	12	0	5
Count 2 (assumed irrelevant/inaccurate)	12	3	17	0	16	2	2	8	13
Count 3 (assumed relevant)	3	16	4	9	7	10	2	7	2
Count 4 (relevant)	16	13	11	23	6	19	16	17	12
Percent assumed relevant/relevant	**59 %**	**91 %**	**47 %**	**100**	**41 %**	**91 %**	**56 %**	**75 %**	**44 %**