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Systemic design for territorial enhancement: An overview on design tools supporting socio-technical system innovation

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ABSTRACT

The sustainable transition of the regional and urban systems in which we live represents a crucial challenge for our societies and requires a new integrated vision of the social, environmental, cultural, political and economic dimensions. Territorial systems can be considered as socio-technical systems, made up of a complex network of infrastructure and facilities and also of human interactions and activities. So far, the sustainable innovation of socio-technical systems has often been concerned with the introduction of sustainable technological solutions, but today it is clear how specific solutions must be framed from a systems perspective. The paper aims at providing a comprehensive analysis of the design tools able to support this systemic transition, starting from the analysis of the macro-strategies developed by the transition studies, in particular the Multi-level Perspective model. Through a cross-analysis with the main design fields related to the systemic design domain, four types of tools are highlighted, which aim at (i) establishing learning processes;(ii) building multi-stakeholder networks; (iii) sharing foresight visions; (iv) enhancing green niche innovations. The comparison of the different tools enables pointing out the contribution of systemic design to territorial enhancement, stressing the contact points and potential synergies between different design approaches.

Keywords: Systemic Design, Systems Thinking; design tools, sustainability transitions; socio-technical innovation; territorial development.

INTRODUCTION

Sustainable development is historically defined as the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987, p 43). Despite the anthropocentric focus of this definition, emphasizing the social and human priorities of development, in the past decades the operational approach to sustainability has mainly turned to the environment, as the ecosystem dimension provides the primary assets and resources needed for socio-economic development (Gaziulusoy, 2010). Over the years, this approach has shifted from the perception of sustainability as a static objective to the

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definition of dynamic targets that better address the interdependencies between social and ecological systems (Ceschin & Gaziulusoy, 2016). The binomial society-environment is also at the basis of the United Nations' 2030 Agenda for Sustainable Development which calls for concerted efforts towards building an inclusive, sustainable and resilient future for people and planet (UN General Assembly, 2015). The 17 Sustainable Development Goals (SDGs) set by the Agenda address global challenges in different fields, ranging from climate change to global poverty, but all aim at harmonizing three core elements: economic growth, social inclusion and environmental protection.

Despite the epochal importance of the 2030 Agenda and its undeniable focus on people in connection with the environment, in practice, it is rather difficult to strike a balance between the social, environmental and economic dimensions. The Triple Bottom Line (Elkington, 1997) has been the first theory aimed at harmonising the 3Ps (People, Planet, Profit), but it has practically prioritised economics, because of its capitalist roots challenging to eradicate. Therefore, new approaches have been emerged, based on a broader concept of the social dimension which considers economics as one of the social domains grounded in the natural one (James, Magee, Scerri, & Steger, 2015). This is especially important for territorial development, as the sustainability of a city or region implies a broader and more articulated social dimension. Theories such as the "circles of sustainability" (James, 2017) foster a comprehensive view of the social domain, by analysing the local context in relation to its cultural dimension (addressing the intersections of identity and difference), political dimension (promoting engaged and negotiated civic involvement) and economic dimension (in response to the social needs of all citizens).

It is evident that the sustainable development of a territorial system demands new instruments that radically differ from what has been adopted so far. The sustainable innovation of socio-technical systems has often been concerned with the introduction of (more) sustainable technological solutions, but today it is clear how specific solutions must be framed from a systems perspective (Farla et al., 2012). Indeed, a multi-level approach is needed to address the complexity of the sustainable transition of socio-technical systems, which goes far beyond product and service innovation. Smith, Voß and Grin (2010) pointed out that:

> The innovation systems problem framing is (predominantly) concerned with the promotion and introduction of greener goods and services into markets. The systems innovation literature frames its problem as concern for the realisation of 'societal functions' through the configuration and alignment of heterogeneous socio-technical

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> elements and processes, and how these restructure over long periods of time. Markets are an important part of this broader picture, but so too are other institutions. (p. 439)

From that perspective, design disciplines play a crucial role, as they have developed the ability to design both the elements (products and services) and the processes (systems). As Boehnert (2018) underlines, designers have always dealt with social and economic problems, but over recent decades "pioneers have opened the scope of design, often involving a shift from designing artefacts and products to co-designing and facilitating new processes, services, systems and ways of living" (p.15). In this respect, Ceschin and Gaziulusoy (2019) relate this paradigm shift to the design practices addressing spatio-social innovation (aimed at generating radical innovation in technological and production models to foster system-level sustainability) and socio-technical system innovation (aimed at triggering and supporting socio-technical changes).

Urban contexts and, more generally, territorial contexts, represent complex socio-technical systems towards which design has shown great attention. Cities and regions are geographical realities in which social, cultural, ecological, productive and technological dynamics take place, determining their complex nature. Sustainable urban transformation is a crucial challenge of our century, which requires design and transdisciplinary strategies to "effectively initiate and support rapid structural and cultural change within existing urban environments and communities, to reconfigure urban form and life in anticipation of the projected impacts of climate change and peak oil" (Ryan, 2013, p. 190). To that end, design-based research can make use of its ability to anticipate something new and define its potentials before it is implemented (Ryan, Gaziulusoy, McCormick, & Trudgeon, 2016). Moreover, design practice has developed cross-disciplinary tools to investigate socially dynamic systems as well as the actions of the social agents making up those systems (Ruttonsha, 2018).

Whether related to the system framing or to the engagement of the actors that are part of it, design tools are essential to support the sustainable transition of territorial systems. However, a comprehensive analysis of the design tools able to support this transition is lacking. Indeed, the present paper addresses the connection between sustainable transition strategies and systemic design approaches, to define a framework for systemic design practices addressing territorial enhancement, based on established works in the transition and design sciences.

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1. METHODOLOGY

The present paper adopts a deductive research methodology (Figure 1) that starts from a general vision of the relationship between transition management theories and systemic design disciplines.

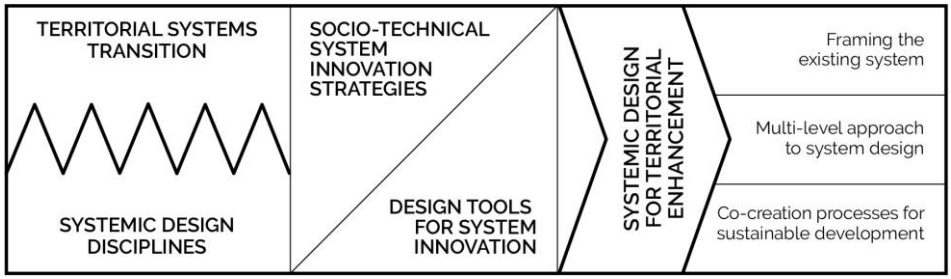

Figure 1 Graphical visualisation of the research methodology

This general vision lays the foundations for a more in-depth exploration of the interrelationship between the two scientific domains through a cross-comparison between the socio-technical system innovation strategies and the design tools for system innovation. Socio-technical system innovation strategies are adapted from the work of Geels, Monaghan, Eames, and Steward (2008), which provides a comprehensive and validated synthesis of four established strategies for the sustainable transition of complex systems.

The article explores the contribution of design disciplines to these strategies, identifying the methodological tools that can actively support their implementation. Finally, the paper defines three main methodological approaches that are common to the described tools and identify the contribution of systemic design to territorial enhancement: (i) framing the existing system, (ii) designing multi-level systems, (iii) implementing co-creation processes for sustainable development.

2. THE CONCEPT OF SYSTEMIC DESIGN AND ITS RELATION TO SUSTAINABLE INNOVATION IN TERRITORIAL DEVELOPMENT

Design disciplines have developed the ability to focus on sustainability as a system of resilient relationships instead of a characteristic of individual components in systems (De los Rios & Charnley, 2017). This skill is of particular interest for territorial enhancement. As Ruttonsha (2018) pointed out referring to the socio-ecological transition of human settlements, the connection between sustainability and inhabited environment shows deep analogies as regards intellectual and practical challenges, because “both are concerned with how human populations have organized within the biosphere, over time, in an effort to

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survive and thrive" (p.175). However, the role of design for the sustainability of territory has no immediate comprehension; as a matter of fact, design discipline had originally crossed into natural and social disciplines, while remaining distinct from any of these fields in its focus and methods (Buchanan, 1992; Nelson & Stolterman, 2012). Moreover, design outcomes have been conventionally associated with the world of the artificial, since they are neither explicitly social nor natural (Simon, 1996).

In the past three decades, design research took a more systematic approach in addressing complex problems related to sustainability, even if still tending to frame problems within narrow spatio-temporal contexts, thus lacking a comprehensive approach (Irwin, 2018). More recently, different design disciplines have been pursuing a more holistic approach, advancing an evolution in methodology and practice aimed at "developing a culture and a posture capable of connecting what design experts do to long horizons of time and visions of a sustainable future" (Manzini, 2015, p.59).

In particular, the literature shows six research approaches that combine a design vision with interest in the analysis, exploration and development of complex systems in response to wicked problems: Product-Service System (PSS) Design, Systems-Oriented Design, Systemic Design, Advanced Design, Design for Sustainability Transitions, and Transition Design. Jones and Kijima (2018) define them as co-evolving fields of 'design-led systemics', grouping them under the umbrella of Systemic Design, to clearly distinguish from Systems Design disciplines related to engineering and hard sciences.

Although there are evident ontological differences in their vision as well as in the modes and scope of action, the above-mentioned design fields have in common the ability to provide "practical tools to approach complex scenarios with a holistic perspective, while supporting active cooperation among involved stakeholders" (Giraldo Nohra, Pereno & Barbero, 2020, p. 3). Hence, without examining the peculiarities of each design approach that have been extensively explored by Ceschin and Gaziulusoy (2019), this paper aims to investigate different methodological tools supporting a sustainable transition of territorial systems.

For this purpose, it is necessary to understand how the disciplines related to anticipation and transition studies have dealt with the issue. Indeed, the sustainable transition of large territorial systems is a wicked problem that demand for new environmental policy approaches to foster systemic changes. Fundamental theories of socio-technical systems transition have been addressing the issue of sustainable development since the 1990s. Today, one of the most established analytical and theoretical models is the multi-level

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perspective (MLP) on system innovations, aimed at explaining the transition dynamics from one socio-technical system to another (Kemp, 1994; Kemp, Schot & Hoogma, 1998) and fostering new governing strategies (Loorbach & Rotmans, 2010). The works of Geels, in particular, contributed to developing system innovation strategies able to cope with the complexity of co-evolutionary, multi-dimensional, multi-stakeholder, long-term transition processes towards sustainability (Geels, 2005a, 2005b). The MLP and the related theories on sustainable innovation and transition of complex systems had a significant impact on design disciplines, strengthening awareness of the need for a broader and more strategic vision of sustainable design. The potential and actual contribution of systemic design to the sustainable development of complex socio-technical systems is evident, as proven by the extensive literature review carried out by Ceschin and Gaziulusoy (2019).

The present paper starts from the MLP model, focusing on the four system innovation strategies developed by Geels, Monaghan, Eames and Steward (2008):

1. Establishing learning processes;
2. Building multi-stakeholder networks;
3. Sharing foresight visions;
4. Enhancing green niche innovations.

The strategies are cross-referenced with the design tools developed by the systemic design disciplines (Figure 2) to better position the contribution of each tool toward system innovation.

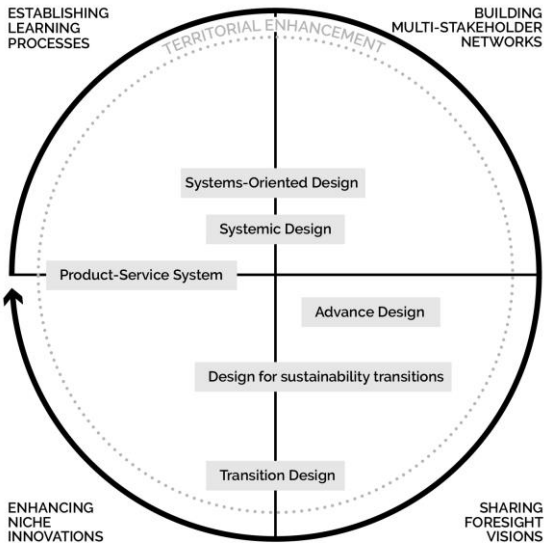

Figure 2 Diagram of systemic design disciplines related to socio-technical system innovation strategies

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It is important to highlight that all six systemic design disciplines include, in their methodological framework, a focus on learning processes, stakeholder involvement, envisioning strategies and niche innovations development. Therefore, the representation is not intended to divide the design disciplines into separate categories, but to underline the different (and complementary) role of the various tools developed by each design field, as described in detail in the following section.

3. SYSTEMIC DESIGN TOOLS FOR SOCIO-TECHNICAL SYSTEM INNOVATION

The sustainable transition of large territorial systems requires effective research methods and tools to manage its systemic complexity. As discussed above, design disciplines have developed a systemic approach providing major connections with the transition sciences, encompassing system analysis, multi-level design, and co-creation processes.

Although the role of design is evident in addressing multiple-level, long-term systems, the literature does not broadly specify what practical tools design offers to support system transition. Even more difficult is to define how to enhance the sustainable transition of a region, city or community. Territorial systems can be considered as socio-technical systems, made up of a complex network of infrastructure and facilities and also of human interactions and activities (Hillier, 2012). But the sustainable transition of a city or region also implies radical changes in its socio-technical sub-systems such as manufacturing, transport, healthcare, or energy.

For this reason, it is essential to start from the macro-strategies that policy design and transition management disciplines have developed to support policy-makers in triggering system changes. Specifically, we have chosen to rely on the MLP model (Geels, Monaghan, Eames & Steward, 2008), which identifies four main strategies for socio-technical system innovation:

- *Establishing learning processes.* The transition of socio-technical systems is based on learning. Not only learning about new technologies but also new behaviours and social models. The policy tools focusing on this strategy are different, ranging from established measures, such as research and development subsidies and experimentation programmes, to new training and competence building programmes, to the definition of pilot projects.
- *Building multi-stakeholder networks*. The radical innovation of a system necessarily requires the involvement of the actors that are part of it, through the creation of ‘transformative coalitions’ (Geels et al., 2019). A quadruple helix model should be

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pursued, involving not only research organisations and companies but also civil society, local communities, end-users and leading institutions. In addition to the established stakeholders, it is important to involve frontrunners and outsiders who could play a key role in the sustainable transition. The policy tools that support this strategy address the creation of multi-scale platforms, as well as the adoption of network management methods and participatory strategies to facilitate multi-stakeholder interactions.

- *Sharing foresight visions*. Each stakeholder is guided and motivated by personal visions, but it is essential to foster the development of shared, articulate, inspiring and promising visions that can guide the transition in the short-, medium- and long-term period. The tools proposed for this strategy concern foresight exercises and future methodologies aimed at translating long-term visions to short-term actions.
- *Enhancing green niche innovations*. Niches are key instruments for enhancing system transition since they represent protected spaces where innovations can be tested without direct exposure to the mainstream market (Geels et al., 2019). The successful scale-up of niche innovations can drive the transition to a new sustainable regime. Policy- and decision-makers can support the creation and diffusion of niche innovations through public subsidies, regulations, infrastructure investments, and innovation-oriented procurement policies.

Table 1. Cross-analysis of system innovation strategies and design tools for system innovation

Socio-technical system innovation strategies	Design tools for system innovation	Authors
Establishing learning processes	Holistic Diagnosis; Gigamapping.	Battistoni, Giraldo Nohra and Barbero (2019); Bistagnino (2011); Jones and Bowes (2016); Sevaldson (2010, 2011, 2018).
Building multi-stakeholder networks	Ontological variety in participation; Structured Dialogic Design; Mid-range Transition Pathway creation Toolset; Appropriate Stakeholder Configuration Design.	Hyysalo, Marttila, Perikangas and Auvinen (2019); Hyysalo et al. (2019); Jones (2017; 2018); Vezzoli et al. (2018);
Sharing foresight visions	Double-flow scenario method; Advanced Design model; Multi-level Design Model; Transition Design Phased Approach.	Celaschi and Celi (2015); Celi (2015); Gaziulusoy, Boyle, and McDowall (2013); Irwin (2015, 2018); Joore and Brezet (2015).
Enhancing green niche innovations	Handbook for the scaling up of PSSs; Virtual city experimentation; Systemic Matrix.	Barbero and Giraldo Nohra (2018); Ceschin (2012, 2014); Giraldo Nohra, Pereno, and Barbero (2020); Ryan (2013); Ryan, Gaziulusoy, McCormick and Trudgeon (2016).

Note: Socio-technical system innovation strategies are adapted from Geels, Monaghan, Eames & Steward (2008).

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The system innovation strategies promoted by the MLP model have been cross-analysed with systemic design models and tools (see Table 1). The purpose of the cross-analysis is to determine which methodological tools the systemic design disciplines have adopted and which synergies can be created with the innovation strategies.

3.1. Systemic design tools for establishing learning processes

Framing cities, regions and territorial communities as complex adaptive systems imply an understanding of the interrelationships between technologies, environmental systems, social and cultural practices, and local governance (Marshall, 2012). However, a decision-maker can hardly grasp the identity of territory from all points of view. The complexity of territorial systems requires a learning process to understand the local context and to make this knowledge available to the actors involved in the transition process. As seen above, policy-makers can provide economic and strategic support to projects and programmes, enabling the understanding and development of new technologies as well as new behaviours and social models.

Design tools can support these learning projects by framing the complexity of the territorial system as a whole. Indeed, the studies undertaken at urban or regional levels often lack an overall vision since they address a single technology, supply chain, or societal dimension. Systemic design disciplines aim to connect different aspects to draw an overarching picture that gives back the identity of the territory, building a comprehensive basis for developing new strategies.

All systemic design disciplines have developed specific tools for framing the existing systems, usually relying on the design's ability to visualise problems and graphically shape complexity. This is often done in a personal and implicit way by individual design researchers or practitioners. However, the literature shows two main tools that have built their own methodological identity over time (Figure 3).

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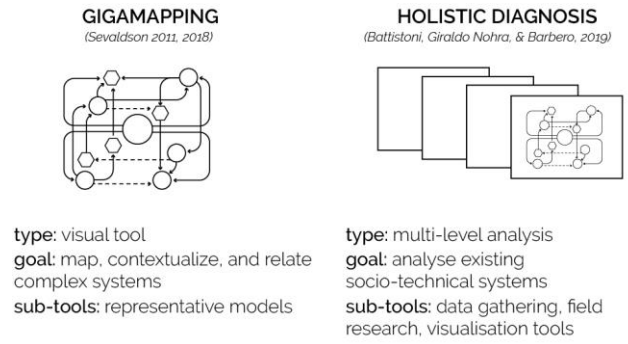

Figure 3 Visual comparison of the systemic design tools for establishing learning processes

The first tool is *Gigamapping* that Sevaldson (2018) defines as "a technique for collaborating groups to map, contextualize, and relate complex systems, revealing their environment and landscapes (of interaction), their current states, as well as preferred future states" (p.243). Also known as 'synthesis maps' (Jones & Bowes, 2016), Gigamaps aims at supporting designers in building a vision on complexity in larger-scale projects. Therefore, Gigamaps consider and visualise a considerable number of elements, ranging from stakeholders to material resources and interaction processes, but they also integrate a high number of representative modes and models (such as causal loop model, data visualisation techniques, mind mapping, scenarios, user journey, rich picture). Another key aspect of Gigamapping is its cross-disciplinary and cross-cultural value, which makes it an effective bridging tool in the co-design processes, where system visualisation facilitates discussion between different practitioners (Sevaldson, 2011).

The second tool is *Holistic Diagnosis*, which can be defined as "an analysis and visualization of all the components that define the current scenario, considering both the surrounding context and the flow of energy and matter" (Battistoni, Giraldo Nohra, & Barbero, 2019). The Holistic Diagnosis is based on two process steps: the first step concerns the mapping and visualisation of matter and energy flows within the analysed socio-technical system; the second step deals with context analysis and focuses on the demographic, cultural and social factors affecting the system. The two steps combine desk research, field research and visualisation tools to provide a quali-quantitative vision of the existing system (Bistagnino, 2011).

Holistic Diagnosis has evident synergies with Gigamapping in building collaborative visualisations and using the design's problem framing capability to support co-creation processes. While Gigamaps are visualisation tools that find application within different

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design methodologies, Holistic Diagnosis is a proper methodology that integrates different tools - including Gigamapping - to define the present system.

3.2. Systemic design tools for building multi-stakeholder networks

The interactions and dynamics between the actors profoundly shape the identity of a territory, not only from a socio-cultural viewpoint but also from a technological and productive one. Therefore, structured and proactive networks of stakeholders represent a fundamental asset to foster the sustainable transition of a territorial system. Geels et al. (2019) define them as 'transformative coalitions', i.e. partnerships of multiple actors that generate innovation through knowledge flows. Because established stakeholders tend to be locked into existing systems, "radical innovations often depend on the involvement of new entrants, outsiders, entrepreneurs, users or communities" (p.49). As seen above, policy-makers can support transformative coalitions by establishing multi-scale platforms and adopting participatory methods to facilitate collaboration among stakeholders.

Over the last two decades, design disciplines have developed collaborative practices grouped under the umbrella of participatory design, that has diffused into mainstream practice as design co-creation (Jones, 2018). Co-creation refers to a normative mode of participatory engagement aimed at design conception, creative problem solving and decision-making (Sanders & Stappers, 2008). Jones (2018) also highlights how "Systemic design practices have developed co-creation approaches that integrate social systems principles to guide stakeholder design for complex systems" (p.4). In this field, four main design methods and tools are aimed to support the active engagement of multiple stakeholders in the transition processes of socio-technical systems (Figure 4).

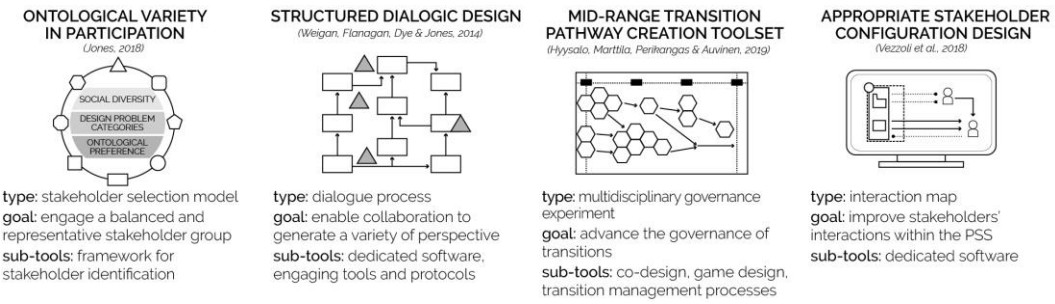

Figure 4 Visual comparison of the systemic design tools for building multi-stakeholder networks

The first method is the *ontological variety in participation*, a model based on engaging stakeholders that represent the multiple social systems to which they belong (Jones, 2018).

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Systemic Design has developed this specific model for participant selection in foresight processes and anticipatory studies (Jones, 2017), aiming at balancing the variety of disciplines, perspectives, authorities, diversity and interest among participants. The model builds on Ashby's theory (1958) of the Requisite Variety of stakeholders and Latour's ontological perspectives (2013) to develop a framework for stakeholder identification based on three modes: social diversity, design problem categories, and worldview (ontological preference). The method ensures the involvement of a balanced and representative stakeholder group, identifying in advance the possible risks and conflicts between different interests and views.

The second method is the *Structured Dialogic Design* (SDD), based on systems science and group behavioural research. The SDD model focuses on the dialogue process between stakeholders and integrates scientifically-validated techniques to enable the stakeholder group to generate the variety of perspectives needed to describe and understand complex systems (Weigan, Flanagan, Dye & Jones, 2014). The SDD engages stakeholders as co-interpreters of the creation process, enabling them to define scenarios and new requirements and to co-construct an influence map based on the most voted participant inputs. SDD adopts specific software, tools and protocols to facilitate the collection and visualisation of participant responses. This method has found application in a wide range of collaborative planning domains, included urban planning.

The third method is the *Mid-range Transition Pathway Creation Toolset* (MTPT) that integrates co-design research methods, game design tools and transition management processes (Hyysalo, Marttila, Perikangas & Auvinen, 2019). The MTPT aims at advancing the governance of transitions through multidisciplinary governance experiments between the public sector, private companies and citizens. The tool is designed to be applied in specific territorial contexts in a 10-20-year timespan. The focus on a specific socio-economic environment makes MTPT particularly interesting for territorial enhancement processes. Hyysalo et al. (2019) has implemented the toolset in the Finland context – both at city and national levels – within the 'transition arenas', that are deliberative platforms where groups of frontrunner stakeholders can co-create new policy pathways of transition. The MTPT provides physical and digital media to facilitate the co-creation process, in particular, it uses magnetic, pre-categorised elements for small-group path construction, and a digital platform for further refinement (Ceschin & Gaziulusoy, 2019).

Lastly, the *Appropriate Stakeholder Configuration Design* (Vezzoli et al., 2018) is "built up by a set of stakeholders and by a set of interactions in between them, namely material, financial

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and information flows" (p. 126). The tool is based on Jégou's stakeholder system map (Jégou, Manzini & Meroni, 2002), and its primary purpose is to design innovative interactions among locally-based stakeholders (Gao & Vezzoli, 2019). The tool has been specifically designed for the energy transition towards PSS distributed renewable energy networks and proposes a top-down vision of material flows (hardware, resources, ecosystems), knowledge/information flows, and labour performance flows. Unlike the tools mentioned above, it does not rely on a fully-fledged co-creation process, but brings the designer closer to the stakeholders' perspectives, proposing a digital visualisation of the interactions between providers and users.

3.3. Systemic design tools for sharing foresight visions

The sustainable transition of a territorial system requires shared objectives rooted in a long-term collective vision. Therefore, envisioning processes are needed to collectively identify problems, build alternative visions and establish the strategies required to implement them. Design disciplines contribute to the foresight process by addressing two different levels: on the one hand, they support companies or organisations in developing a strategic vision of themselves in relation to the broader vision of the socio-territorial system; on the other hand, design disciplines become a medium for envisioning large spatio-temporal contexts in which individual stakeholders identify shared strategies to balance their needs and interests. The literature highlights four main design-based models (Figure 5).

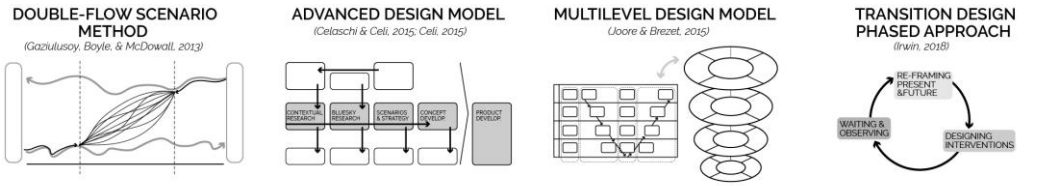

Figure 5 Visual comparison of the systemic design tools for sharing foresight visions

The *double-flow scenario method* (Gaziulusoy, Boyle, & McDowall, 2013) combines different design and anticipatory tools. It focuses on product development but also provides visions of sustainability at a societal level. It is based on workshop processes and consists of three phases:

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1. the preparation phase focuses on the analysis of the interrelationships between environment, society and economy, identifying a company's social function and possible enabling technologies;
2. the scenario development phase builds a sustainable society vision based on forward and backward scenarios, where the company fulfils its social function also thanks to innovative product and service ideas;
3. the completion phase deploys an action plan to be followed for implementing the desirable scenario.

The double-flow approach enables to identify alternative innovation paths which are "possible from a technological point of view, acceptable from a social/cultural point of view and desirable from a sustainability point of view" (p. 107). The double-flow scenario method, differently from other design-based foresight tools, embeds the sustainable transition of the micro-elements of the system (companies) within wider-scale systemic changes (such as territorial systems) (Gaziulusoy & Brezet, 2015).

Advanced Design (ADD) is "a branch of industrial design that directs and uses the tools, practices and knowledge of conventional industrial design in long-term projects" (Celaschi & Celi, 2015, p. 159). The *Advanced Design model* integrates traditional design methods, such as trend analysis and problem framing, with process methodologies elaborated from anticipation studies (Celi, 2015). The design process consists of four phases (Deserti, 2015):

1. the contextual research defines the information and tools available to set the research boundaries;
2. the bluesky research explores the possible directions and opportunities through visual tools providing cultural, material and formal references;
3. the scenarios and strategy phase focuses on the creation of 'maps of innovation' that indicate strategic directions for the following phase;
4. the concept development aims at designing innovative product concepts that anticipate possible future scenarios by exploring new possibilities that open up to the imagination (Celaschi, Formia & Franzato, 2018).

Similarly to the double-flow scenario method, the ADD model focuses on the long-term role of companies. When applied to large scale phenomena, such as Industry 4.0 (Celaschi, 2017), the ADD model bears repercussions also in the development of a territory, proposing a strategic vision of the company within a wider socio-economic system.

The *Multilevel Design Model* (MDM) by Joore and Brezet (2015) relates PSSs to societal change processes, by combining a cyclic iterative design approach that describes both the

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design process of new tangible products and PSSs, as well as the way that complex societal change processes may take place, and a hierarchical system approach that describes the design, change or transition process of each system level. According to Ceschin and Gaziulusoy (2019), the MDM addresses four typical design phases (product design, service design, system design and vision development) as well as four typical system levels (product-technology, product-service, socio-technical and societal) which provide the foundation for design and innovation processes. The cyclic iterative and hierarchical nature of MDM enables interpreting complex problems to envisioning a new desired situation, that is then translated into creative and concrete directions. Therefore, the PSS design dimension (e.g. transport service) becomes part of a wider vision of the territorial system (e.g. the way mobility will develop in mid-range).

Lastly, the *Transition Design Phased Approach* (TDPA) aims at addressing wicked problems and catalysing systems-level change; rather than a tool, Irwin (2018) defines it as an 'approach' since it entails a variety of tools and methodologies. The TDPA model is based on three main phases:

1. Re-framing the present and future. Designers support stakeholder groups to visually map the problem in the present, to identify the relations and dynamics between actors, and to envision long-term, lifestyle-based futures that solve the problem.
2. Designing Interventions. This phase situates the problem map and the future vision within a large, spatio-temporal context to develop interventions for problem resolution and systems transition.
3. Waiting and Observing. Wicked problems cannot be addressed through one-off projects; therefore multiple interventions should be interspersed with intervals of observation and reflection.

Overall, the model aims to amplify and link the grassroots efforts undertaken by local communities, designing innovative and place-based solutions guided by transition visions (Irwin, 2015).

3.4. Systemic design tools for enhancing green niche innovations

Transition studies define niches as "protected spaces outside or on the fringe of the established regime, where new entrants or relative outsiders […] can experiment without direct exposure to mainstream market pressure and institutional forces" (Geels et al., 2019, p. 28). These can be socio-technical spaces as well as market niches where radical innovations take hold on a small scale. Public subsidies and innovation-oriented procurement policies are some of the tools that decision-makers can put in place to support

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the scale-up of successful niche innovations. Design disciplines have developed tools that enhance PSS innovation or support new policies and local projects triggering systemic transition. The literature shows three main tools designed to strengthen niche innovations development and scale-up (Figure 6).

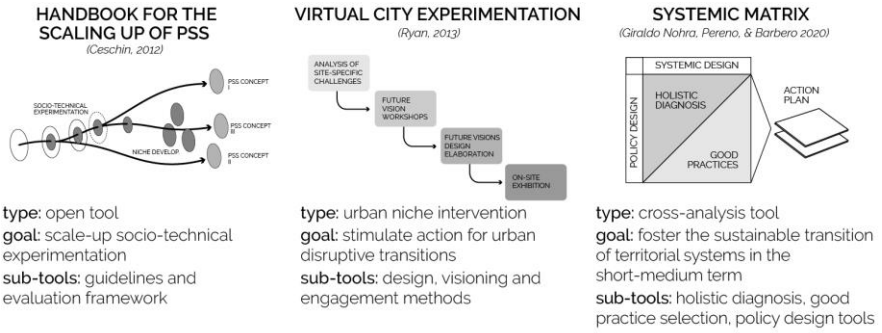

Figure 6 Visual comparison of the systemic design tools for enhancing green niche innovations

Ceschin's (2012) *handbook for the scaling up of PSS* provides an extensive set of open tools that strategic designers can adapt to fit their specific needs and projects requirements. The handbook includes tools for developing PSS innovations, envisioning transition strategies, managing the network of stakeholders, and monitoring and assessing the transition process. Although the design process is not straightforward, the main obstacle concerns the effective implementation and diffusion of PSS innovations on the market. Therefore, the handbook includes four specific tools to enhance scaling-up of what Ceschin calls 'socio-technical experiments':

1. The *socio-technical experiments ideas generation guidelines* provide a set of idea generation guidelines to support the PSS design process towards the development of experiments;
2. The *scaling-up ideas generation guidelines* provide a set of idea generation guidelines to enhance designers identifying the actions needed to bring the PSS innovation to a broader context.
3. The *experiment evaluation framework* supports the monitoring and evaluation of socio-technical experiments through alternating phases of observation, reflection and improvement;
4. The *scaling-up evaluation framework* supports the monitoring and evaluation of the scaling-up process, through the observation and adaptation of several variables (PSS

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innovation, broadening, scaling-up, communication & visibility, and actors involved).

In this case, design not only contributes to developing green niche innovations but also supports their implementation and spread on the market through practical tools that take into account the role of the PSS within the socio-technical system.

The *Virtual city experimentation* is a design approach that aims "to catalyse action in the context of rapidly emerging disruptive challenges to the fabric and life of cities" (Ryan, Gaziulusoy, McCormick, Trudgeon, 2016, p.1). The term 'virtual' refers to the conceptualisation of alternative realities that stakeholders are invited to explore, by shaping new sets of social, physical, and technological relationships. Virtual experimentation adopts design research, visioning and engagement methods to develop medium- and long-term scenarios that transform the community's sense of *permissible, desirable and possible* futures. These methods can be summarised in the VEIL process (Ryan, 2013), based on four steps:

1. The analysis of site-specific challenges is carried out together with local experts and institutions and defines city or neighbourhood features and requirements;
2. The engagement phase is based on future vision workshops involving a network of relevant local stakeholders and institutions to envision 'optimistic, desirable futures';
3. The design phase elaborates future visions and develops plausible trajectories to implement the desirable future through sustainable niche innovations;
4. The feedback is obtained through on-site exhibitions aimed at generating community discussions.

The innovative aspect of Virtual city experimentation is the realisation of living laboratories, where the effects of possible failures are mitigated, and the eventual successes can be scaled up over the whole system. Those urban niche intervention actually show the possibilities for new system architectures and infrastructures, such as distributed water, food, energy, transport, and housing (Ryan, Gaziulusoy, McCormick, Trudgeon, 2016).

Lastly, the *Systemic Matrix* is a tool developed to foster a dual level of innovation (policy and product/service) within projects oriented to the sustainable transition of territorial systems (Giraldo Nohra, Pereno & Barbero, 2020). The Matrix is composed of five main steps:

1. The definition of the critical issues emerging from the analysis of the territory at social, environmental, physical and technological levels. This is done through Holistic Diagnosis methods (see par. 3.1).

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2. The mapping of existing good practices (Pallaro & Pereno, 2018), i.e. the definition of policy and business niche innovations that effectively address the needs of local communities in relation to a specific issue (e.g. circular economy).
3. The cross-analysis of systemic issues and good practices is aimed at revealing the policy gaps threads that a new systemic vision should address in the short- and medium-term.
4. The discussion with stakeholders and local authorities is essential to get feedback and engage them in a co-creation process of the action plan.
5. The definition of the action plan, that includes actions related to policy strategies (e.g. innovative funding instruments) and actions aimed at implementing pilot projects.

The main innovation introduced by the Systemic Matrix is the creation of a design tool specifically addressed to urban and regional systems, which combines policy design and systemic design methods to support the transition of such systems starting from a short-term timespan.

4. SYSTEMIC DESIGN FOR TERRITORIAL ENHANCEMENT

The sustainable development of a territorial system passes through its transition from an existing social, economical and productive structure to a new one that deeply changes the previous relationships to meet new needs of the territory, being it a nation, a region, a city or a neighbourhood.

The design methods presented in the previous section have the common goal of helping the actors involved in the transition process to understand the current system, build a new vision and implement it into a new territorial system.

In particular, the contribution of systemic design to territorial enhancement relies on three fundamental competencies that the combination of systems- and design-thinking has generated: the understanding of the existing system and its complex dynamics; the multi-level approach to the design of local systems; the knowledge of system stakeholders and their involvement in a co-creation process.

Framing the existing system. Improving the understanding of the dynamic interaction of different actors involved in sustainable transition processes is essential to address some of the complexities of system transitions (Farla et al., 2012). Problem definition is the first crucial step of every design process (Buchanan, 1992) and it is formally applied in systemic design, through a process of analysis and visualisation of all the components that define the current scenario. Systemic design expands the concept of 'problem' considering the

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surrounding context and the flows of matter, energy and above all, the information and interactions between different users. (Battistoni, Giraldo Nohra, & Barbero, 2019). In this respect, systemic design strengthens the interest and ability of the design disciplines towards 'problem finding' (Simon, 1995), investigating the complexity of the system to discover and define emerging and hidden critical issues, bringing to light the conflicting factors as well as the potentialities of the relationship within a territorial context.

Adopting a multi-level approach to envision the system. The broadening of problem framing leads to explore and design the territorial system beyond isolated products, processes or technologies, evaluating them as embedded in the system context (Smith & Stirling 2010). At the same time, managing complex territorial systems involve the risk of losing sight of the smaller elements, i.e. everyday life products. As underlined by Jones (2014), systemic design brings human-centred design to multi-stakeholder service system design, moving from artefacts and communication, products, and services, to organisational transformation and social transformation: the last domain does not supersede the others but rather integrates them into a broader design approach. To this end, the combination of traditional design methods (such as process thinking, sketching, and visualisation practice) with new tools integrating systems thinking into design (gigamapping, divergent thinking, critical thinking, and creative making) (Jones, 2014) is essential to guarantee a long-term design vision, without neglecting the product dimension.

Establishing co-creation processes for sustainable development. Socio-technical transitions involve a broad range of stakeholders over considerable time-frames (Farla et al., 2012). The interactions between different actors of the system are very different; the values and interests of each one can generate collaboration or conflict, giving rise to a tacit or explicit hierarchy that affects the system. Often the sustainable evolution of a territorial system requires modifying, sometimes overturning, existing hierarchies. In all cases, it is necessary to understand the present situation to define which stakeholders should be involved and in what way. For that reason, both design and systems methods have traditionally employed participatory stakeholder engagement processes, whether referred to as inquiries or interventions (systems methods) or workshops and studios (design methods) (Jones, 2019). Systemic design practices have developed co-creation approaches that integrate social systems principles and stakeholder co-design processes to engage actors in the (re)definition of complex systems. Therefore, co-creation is not only a creative participatory practice (Sanders & Stappers, 2008) but rather a process method in action research, enabling facilitating stakeholder engagement in formal design processes.

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5. CONCLUSIONS

The paper has addressed the issue of sustainable territorial development by combining the policy vision of transition studies with the strategic vision of systemic design disciplines. Under the umbrella of systemic design are grouped different design approaches that all share similar modes and scopes of investigation: the ability to analyse, define and visualise the existing system and its challenges; the capacity to envisage creative and desirable future scenarios to solve existing problems; the ability to build co-creation processes in which multiple actors and sectors are involved.

The findings contribute to the debate on systemic design, highlighting the contact points between different sub-disciplines. The intention is not to flatten the heterogeneity and richness of different approaches but to establish a common ground of action. At the same time, the paper presents models taken from different design approaches which constitute an abacus of the tools that design has developed over time to support system innovation theories, from which it has been influenced and which, in turn, influences. Further exploration of these methods will be necessary to determine the specific tools that design employs, in particular in the field of visualisation tools.

Another major topic emerging from the study is the need for systemic design scale-up: as also confirmed by previous works (see Ceschin and Gaziulusoy, 2019), most design disciplines operate at a component, product or service level. The analysed design tools prove how a holistic approach to design can combine the product and the system dimension. Although the shift towards a more strategic vision of design is underway, it is undeniable the need to foster a systemic approach, which does not replace the product dimension but integrates it to overcome the insular concept of innovation.

Finally, the research has shown how the development of a region, a city or a neighbourhood starts from the bottom up, both in the creation process, through the joint work of multiple stakeholders, and in the design process, moving from the PPS and the company dimension to a socio-technical vision involving the whole territorial system.

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