A socio-technical approach to design for community resilience: A framework for analysis and design goal forming

Joon Sang Baek, School of Design and Human Engineering, UNIST, Eonyang-eup, Ulju-gun, Ulsan, 689798, South Korea
Anna Meroni, Department of Industrial Design, Politecnico di Milano, 20158 Milano, Italy
Ezio Manzini, DESIS International Network, Politecnico di Milano, 20158 Milano, Italy

In the recent years, resilience has gained attention due to increasingly complex and frequent natural and man-made disasters. Resilience, originally known as the capacity of a system to retain its identity after a disturbance in ecology (Holling, 1973), is the ability of man-made and natural systems to cope with external shocks. These systems can be individuals, communities, society, nature, or a mix of them. Resilience is therefore a traversal topic across multiple disciplines such as ecology, psychology, public policy, and complex systems studies. This study focuses on the resilience of communities, which has been mainly addressed in social-ecological systems studies and public policy. We have thus adopted the definition of resilience widely accepted in these fields: the capacity of a sys-tem to absorb disturbance, undergo change, and retain the same essential functions, structure, identity, and feedbacks (Resilience Alliance, 2010). Resil-ience is an essential characteristic of a sustainable society since sustainability, in its definition of improving the quality of human life without compromising the needs of future generations, implies the capacity of a system to persist in time (Costanza & Patten, 1995).

Corresponding author:
Joon Sang Baek
joonsbaek@gmail. com

Resilience is related to the relationships within a system and their structure (Holling, 1973), and to design for it requires a systems approach. Positing that people are a component of communities, community resilience depends on, but is not limited to, their social relationships and relational structure. An approach to design for resilience is then to support people to construct so-cial relations in the direction favourable to resilience through technical interventions. These interventions could include development of services that, using resources in communities, create new social and operational values for them (Manzini, 2009). We thus propose a socio-technical system (STS) approach to design for resilience. Under this approach, communities are considered as a socio-technical system, and the resilience of their social system is enhanced through the design of the technical system. In STS studies, a human organisation is seen as an integration of two heterogeneous but mutually causative and supportive systems: a social system in which the members spontaneously create and enrich relationships through activities, and a technical system where they carry out sets of tasks related to specific goals (Trist, 1981).[1] These sys-tems are interdependent, and their optimised integration leads to higher pro-ductivity and wellbeing of an organisation. As a socio-technical system, a community comprises people and their relationships, and communal activities that transform various resources into desired values. For designers to be able to approach resilience with interventions in the technical system, a framework is necessary that explicates the interaction between the two systems, approaches resilience as an operational concept, i.e., a concrete and measurable system potential, and supports the design of the technical system based on understanding of the social one.

Although community resilience is a relatively new subject in design research, studies directly or indirectly contributing to social and ecological resilience have been conducted, particularly in the area of design for sustainability. Topics include the cultures of resilience (Manzini, 2014), design for relations and relational qualities (Cipolla & Manzini, 2009; Snelders, Garde-Perik, & Secomandi, 2014), design and social-ecological diversity (Cantu, 2012; Meroni, 2008), user empowerment (Ehn, 2008; Kimbell, 2011), and mutual benefits among stakeholders of product-service systems (Burger, Ganz, Pezzotta, Rapaccini, & Saccani, 2011; van Halen, Vezzoli, & Wimmer, 2005). In general, however, resilience is rarely addressed in design literature, and if it is, it is used as a metaphoric[2] or abstract term to be desired rather than an operational one that can be measured and assessed. Efforts to expand design knowledge on resilience and improve its rigour are thus needed. Moti-vated by these limitations, we ask the following question: How do we diagnose problems related to resilience of the social system in a community? To address this question, we developed a framework to analyse and initiate design interventions for community resilience, and conducted empirical research for validation.

The framework was built upon three research streams. The first stream is collaborative service design, which demonstrates the interaction between social and technical systems of a community. The second stream is resilience assessment, i.e., examining system resilience with measurable indicators, and it provides tools to diagnose design problems and evaluate design outcomes. The third stream is socio-technical systems design, i.e., an approach to design that considers both social and technical factors in the design of organisational systems (Baxter & Sommerville, 2011), which became the skeleton of the framework. The framework consists of (1) defining the system scope, (2) analysis of an existing system, (3) problem diagnosis, and (4) objective setting and strategy building. While the framework was developed in the context of understanding the resilience of so-called collaborative communities, it is applicable to any socio-technical system whose social dimension is described as a network of nodes and edges.

This paper is structured in the following order: We introduce the notion of collaborative communities and their services. Positing that social and technical systems within these communities are mutually supportive, we argue that community resilience can be addressed through the design of an appropriate technical system. The question of how is addressed in the following section where we describe the framework: its background, design process, and application. The framework was applied to a nascent community of producers around a farmers' market in Milan. The market is a representative of the peri-urban agricultural regions facing socio-economic changes in the process of urbanisation and industrialisation. Next, the extant social system is investigated using social network analysis, and the data are interpreted in terms of resilience, leading to design problems and directions for design interventions. We then discuss the meaning of assessing and designing for resilience despite some methodical limitations, the implications of the framework to the design of collaborative services, and its application in the wider context.

1 Collaborative communities and collaborative services

In design for social innovation, a collaborative community is defined as a group of people who are actively and voluntarily engaged in the collaborative production of solutions to a wide range of their own social problems, and in doing so, create a positive impact on society as a whole. These solutions are called collaborative services (Meroni & Sangiorgi, 2011). An exemplar is the Sungmisan Village in Seoul, South Korea. Originating as a group of parents collaborating on communal childcare, it has evolved into a community where various solutions to the members' needs such as an organic restaurant, alternative school, community theatre, co-housing, and car-sharing are being tried (Rim, 2013).

A collaborative service is distinguished from other services in that it requires relational qualities between users such as trust, intimacy, and friendship as a prerequisite, and further enriches such qualities as an outcome (Cipolla, 2008). This definition postulates the interdependency between solutions and social networks. As users generate *solutions* through collaboration, *social networks* are naturally formed and fostered. Social networks, in turn, create a more favourable environment for the users to initiate new collaborations because a larger pool of people is likely to result in more ideas and changes. In short, solutions and social networks are interlinked and mutually supportive, and their interactions can be described as a virtuous circle.

The virtuous circle of collaborative community is illustrated in the Sungmisan Village (Figure 1). Not long after the nursery school was started, they opened a primary school so that their children could receive an education tailored to meet the parents' educational philosophy and students' individual differences. As their kids grew older, their collaborative projects grew both in scale and diversity. The school has grown to an institute of 40 teachers and 170 students. Additional initiatives have been conceived, such as co-housing, car sharing, a food co-op, a community restaurant, a credit union, arts and crafts workshops, a radio station, and a theatre. For the last two decades, the community has grown to a size of over 1000 members and 50 cooperatives (Gilnunee, 2012). The community witnessed the power of social networks in starting a new project: "When we had 50 people, there were only a few things that we had a common interest in. When we became 500 people, there were more things we could do together" (Gilnunee, personal communication, November 24, 2011). What needs to be underscored is that "a few things that the community members did together" attracted an inflow of new members, and the virtuous circle thus began. This finding is consistent with the aforementioned interdependence between social and technical systems if we define the technical system as the process where (human, material, information, financial) resources are transformed into useful solutions, and the social system as stakeholders involved in the production and consumption of these solutions. A resilient collaborative community is then a system with a continuous positive feedback loop between social and technical dimensions.

To conclude, from a design perspective, fostering resilience of a socio-technical system through design interventions is the ultimate goal. If the qualities of a social system are a desired outcome to be designed for and assessed, design for collaborative services would benefit from an approach that enhances these qualities through technical interventions based on the understanding of the social system, considering it as an assessable baseline and attainable goal of design interventions.

2 Methodology

2.1 Framework design

The literature on socio-technical system design processes was reviewed to develop a socio-technical framework for the design of collaborative services.

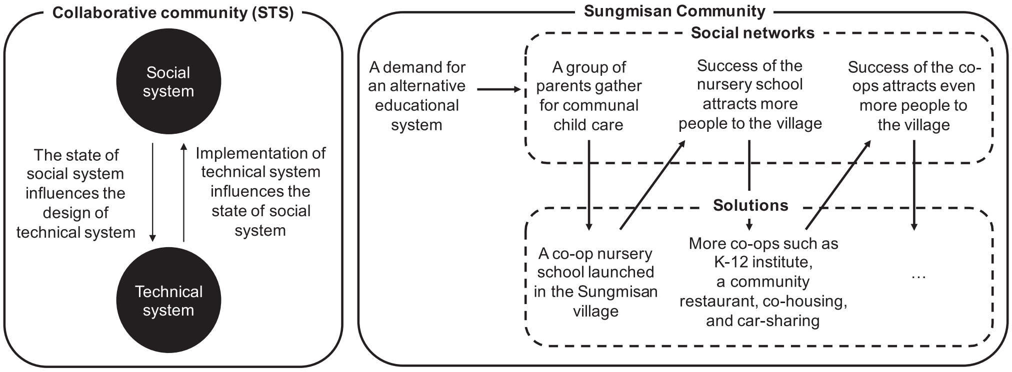

Figure 1 A virtuous circle between solutions and social networks in the Sungmisan Village

As one of the early works on STS design, Emery (1967) introduced a 9-step process aimed at improving work performance in manufacturing industries. It is distinguished from other models in that analyses of technical and social systems occur in sequence rather than in parallel. Mumford (2000)'s ETHICS (Effective Technical and Human Design of Computer-based System) model is a process to design information systems in dynamic business environment. Sussman (2000)'s CLIOS (complex, large-scale, integrated, open systems) process incorporates quantitative modelling and qualitative frameworks, and has a wide range of applications in complex systems engineering. Baxter and Sommerville (2011) proposed an STS engineering process in the context of software design. They also presented a synthesis of literature reviews on STS design under the systems engineering lifecycle. Finally, Whitworth and de Moor (2009) describe the STS design process as analyse, develop, implement, and evaluate. Despite the variance in methodology and application domain, these models share a common structure consistent with the broad stages in the design process: diagnosis (or analysis), design, implementation, and evaluation. While these models are useful references for how to approach the design of STS, they have limitations to be directly applied to design research. Some require highly domain-specific knowledge as a prerequisite, and others have limited application domains. For this reason, we devised a framework for the purpose of designing for resilience.

Resilience being the desired outcome of design, the framework incorporates resilience assessment into STS design. Resilience assessment provides a systematic approach to understand the problems of an existing system and validate the effectiveness of design outcomes. It overcomes the difficulty in establishing evaluation criteria for the social elements of the system in STS design practices (Baxter & Sommerville, 2011). There are a multitude of analytic models to assess resilience across domains, and they vary in type of distur-bance, scope of resilience, and system scale and boundary. Search for a relevant model was thus needed. In social-ecological systems studies, subjects under investigation are typically human communities and surrounding ecosystems. Although some cases are strongly orientated to ecology, others are applicable to social systems (Gonzales & Parrott, 2012; Resilience Alliance, 2010; UNU-IAS, Biodiversity International, IGES, & UNDP, 2014). In public policy, there exist guidelines and frameworks to assess community resilience to man-made and natural disturbances. While some focus on short-term disasters (or pulses) such as Hurricane Katrina and New Orleans (Arbon, Cusack, Gebbie, Steenkamp, & Anikeeva, 2013; Pfefferbaum, Neas, Pfefferbaum, Norris, & Horn, 2013), others encompass long-term changes (or presses) such as an economic downturn (Bujones, Jaskiewicz, Linakis, & McGirr, 2013; Frankenberger, Mueller, Spangler, & Alexander, 2013; Longstaff, Armstrong, Perrin, Parker, & Hidek, 2010; Schwind, 2012). We selected Gon-zales and Parrott's resilience assessment model because it is applicable to a so-cial system, flexible enough to accommodate various types of disturbance, and provides a specific protocol as well as a set of measurable indicators.

The proposed framework for the design of collaborative services follows the process of (1) defining the system scope, (2) analysis of an existing system,(3) problem diagnosis, and (4) objective setting and strategy building.

2.2 Framework application

For validation, the framework was applied to the context of developing collab-orative services around a farmers' market in Milan. Defining the system scope involved selecting the target system to investigate, and defining the boundaries of its social and technical dimensions. The system scope was identified by asking 'Who do we design for?' In terms of resilience, it is related to 'resilience of what?' (Carpenter, Walker, Anderies, & Abel, 2001) These questions were addressed by identifying the target users and stakeholders whose resilience is at stake, and their existing collaborative activities. In addition, problems of the existing system were defined by inquiring 'Why does the system need to change?' so that the rationale for a systemic change is clarified and the distur-bance(s) that threatens the target system's functioning is identified. In resil-ience, it is related to 'resilience to what?' (Carpenter et al., 2001).

Once the target system and problems were identified, the target system was analysed to understand its characteristics related to the resilience of its social dimension. The producers' collaborative network was investigated in terms of its content and structure using surveys. The survey forms were distributed to the producers through Slow Food, the organiser of the market, using email and the postal service. The participants were local farmers and artisans who came to the market regularly and lived within a 40 km radius. Their products included vegetables, fruits, meats, crops, dairy products, bread and pastries, fish, wines and beers, olive oils, honey, chocolates, plants, and other processed products. A total of 42 producers responded with one invalid response, and the response rate was 39%.

Two surveys were conducted. The first survey inquired (1) the basic profile; (2) structure, quality, and content of social networks; and (3) a demand for new services. The profile included the producer's name, address, age, gender, income level, education level, offered products and services, number of visits to the market, and use of information communication technologies in daily life. Related to the social networks, we asked for details of their collaborative activities, including: the size, involved actors, duration, frequency of interaction, type of collaboration, and finally technologies supporting collaboration (Baek, 2011). The second survey was conducted in response to the first survey data to identify the resources, competences, and tools that are needed or can be shared among the producers. These data were used in developing service stra-tegies and concepts. The questionnaire is summarised in Table 1.

The collected data were interpreted using social network analysis (SNA) and degree of collaboration (DoC). Coming from network theory, the former is widely used in sociology to understand social relations, and the latter is used to identify the content and quality of social networks (Baek & Manzini, 2012). The following data were collected as a result: demographic information of users; structure of users' social relations in the form of nodes and ties; the content of relations, i.e., the type of collaborative activities upon which these relations are formed; and the strength or intensity of relations. The data were interpreted by analysing the attributes that affect resilience such as connectivity, modularity, diversity, and redundancy (Gonzales & Parrott, 2012). UCINET 6 and Pajek were used for analysis. They are some of the social network analysis software packages widely used in academia that provide nu-merical and visual descriptions of network features.

In the problem diagnosis, the resilience analysis framework from the previous step was used as a reference to specify the problem areas. The result was fed into goal forming, i.e., the direction of transformation towards a resilient

Table 1 A scheme of the survey

The first survey	**Basic information** Age, gender, location of farm, postal code, products and services offered, total number of times participating in the market, frequency/purpose of internet use, sense of community towards the market **Extant collaborative services** Engagement in collaboration with other producers, type and content of collaborative activities, name of collaborators, duration/size/frequency/medium of interactions **New collaborative services** Interest to participate in new collaborative services, resources to share with other producers for the new services
The second survey	**Resources and needs** Physical tools and infrastructure available or needed for sharing, competences available or needed for sharing, other resources available or needed for sharing

community, and strategies to develop solutions and the environment where they can be supported, i.e., collaborative services and platforms for empowerment, respectively. This step included the discussion of potential impacts of the solutions on the system resilience. The services thus developed took into account the interaction between technical and social systems to achieve the virtuous circle.

3 *Context of study*

The farmers' market is one of the pilot services implemented in a project called 'Feeding Milan'. The project aims to develop a sustainable food network connecting local producers and consumers in Milan and its surrounding rural areas, and to support local producers by providing them with economically viable and environmentally sustainable service models. In the background is the dissipation of a vast agricultural area surrounding Milan due to urban expansion and, as a consequence, the danger of losing local communities and culture. The area surrounding Milan is called the Agricultural South Park (Parco Agricolo Sud Milano in Italian). It is a territory of 470 km^2 surrounding the southern part of the city of Milan in the region of Lombardy and its main utility is agricultural. The market was launched in December, 2009 with an aim to promote the culture, history, identity, and health of the local community according to the philosophy of the organiser and a project partner, the Slow Food Organisation or simply Slow Food (the Earth Markets, 2013). To organise it, Slow Food investigated potential partners through direct visits and selected 110 farms that met its criteria from the South Park and within a 40 km radius. Due to the geographic proximity, some farms have known or collaborated with one another for as long as decades.

The project team plans to develop the market into an event that is socially, economically, and environmentally sustainable and firmly embedded in the local community. Its basic function is to supply locally produced foods and vegetables to consumers, provide a stable and profitable sales channel to producers, bring producers and consumers closer, and educate consumers on sustainable food consumption. The market is a relevant case for several reasons. It has both the social function of forming a community of producers and consumers and the technical function of selling and buying locally produced foods and vegetables. Consequently, it has specific needs in social and technical systems that can be addressed as design problems. For instance, the project team wants to facilitate the development of communities through various collaborative initiatives, and simultaneously create a pleasant experience of participating in the market for both producers and customers, through user-centred design. It also wants to achieve greater autonomy through the empow-erment of users. Finally, it is yet a nascent community with the potential to grow, and any transformation resulting from design intervention could be more visible than in a mature one.

4 Results

4.1 Data analysis

65% of the respondents were already collaborating with other producers in the market. The most frequent type of collaborative service was the 'exchange of competences, time, and products' (e.g. time banking) (54%), followed by 'creation and management of a direct network with consumers' (e.g. solidarity purchasing groups) (29%); 'mutual support to solve common problems' (e.g. mutual consultation on organic farming) (21%); 'socialising' (e.g. a neighbourhood party) (18%); 'sharing products, places, and knowledge' (e.g. carpooling) (14%); and 'others' (18%). Others included collaboration among producers of the same items (e.g. plant producers sharing pollens for pollination, rice producers helping each other in husking, collaboration between beer producers), collaboration among producers of supplementary parts of a product (e.g. a jam producer and a baker to produce a tart), and collaboration confined by region (e.g. a consortium of the producers of the Parco del Ticino).

The duration of a collaborative group varied by service type. The majority of existing groups have lasted from 1 to 9 years, followed by 'more than 20 years', 'less than 1 year', and 'from 10 to 19 years'. This result indicates that their network is composed of both nascent and established relationships. The collaborative group size differed by service type. 'Socialising' groups were the biggest with the majority having more than 50 members. 'Sharing products, places, and knowledge' and 'exchanging competences, time, and products' groups were more evenly distributed in size than others. In terms of the frequency of interaction, 60% of the respondents met at least once a month. Groups for 'socialising' had the most frequent interactions among all types, followed by 'creating direct networks with consumers' and 'exchanging competences, time and products'.

Regarding the demand for new collaborative services in the market, the producers asked for a channel to announce what produce they will bring in the next cycle (70%), urban farming tutorials for consumers (50%), and a shared fridge van (30%). Related to the resources needed or available among the producers, the needed resources were: distribution channels and logistics for the services they offer in the city (55%), counselling on technical and fiscal issues of business (29%), financing to transform a conventional farm to an organic one (4%), solutions to agronomic and technical problems (3%), and collaborative restaurants (3%). The resources available for sharing with other producers included: farm store (26%), meeting space (17%), transportation to the market including a fridge van (17%), a store in the city (11%), tractor (9%), warehouse (6%), thermo-controlled winery (3%), and workshop

(3%). The competences that they could share with others included stock breeding (33%), alternative cultivation techniques (29%), horticulture techniques (17%), and human resources such as sales staff (21%).

The producers' collaborative network in the farmers' market was identified by analysing the description of personal profiles in the survey. Figure 2 illustrates the network based on code names. The nodes indicate the producers involved in any type of collaboration, their ties are their relationships, and arrows the direction of relationships. For instance, A → B means that A claims to collaborate with B but not vice versa. A ↔ B means that both A and B claim mutual collaboration.

The producers' network is fragmented, resulting in isolated groups and individuals. 18 producers were identified as connected, and 23 isolates, i.e., not connected to any other node. To identify the nature of the collaborative groups, information about the producers, such as their postal code and their products and services, was matched with their name (Figure 3−5). Figure 3 is a network diagram with each node indicating product type. Five producers did not identify their produce and were thus marked as a question mark. The majority of the nodes have homogeneous or complementary products with the neighbouring nodes, reflecting the survey result that the exchange of competence, time, and products frequently occurs among producers of homogeneous product types. Another type of collaborative service shown in the figure is mutual support, which mainly occurs between producers of the components

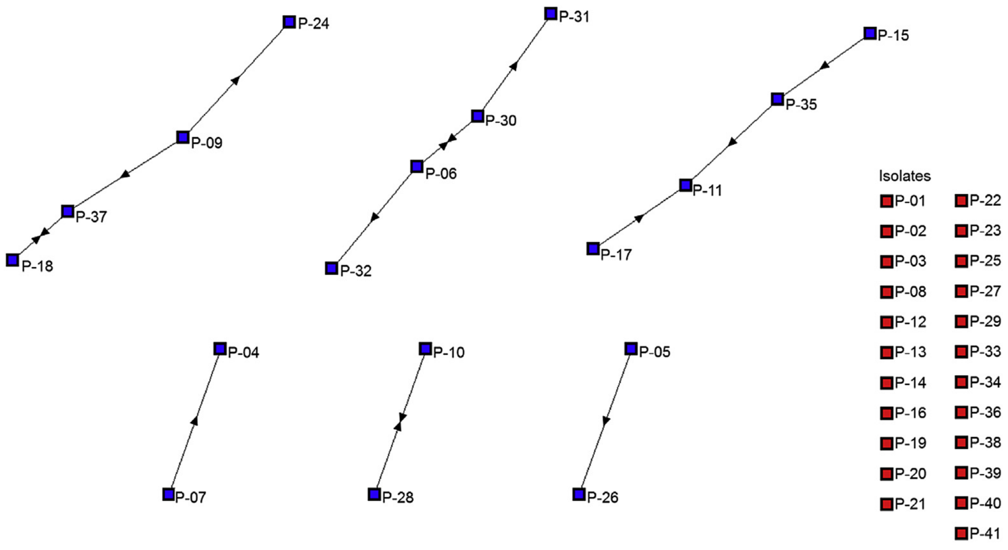

Figure 2 Producers' social network based on the name code

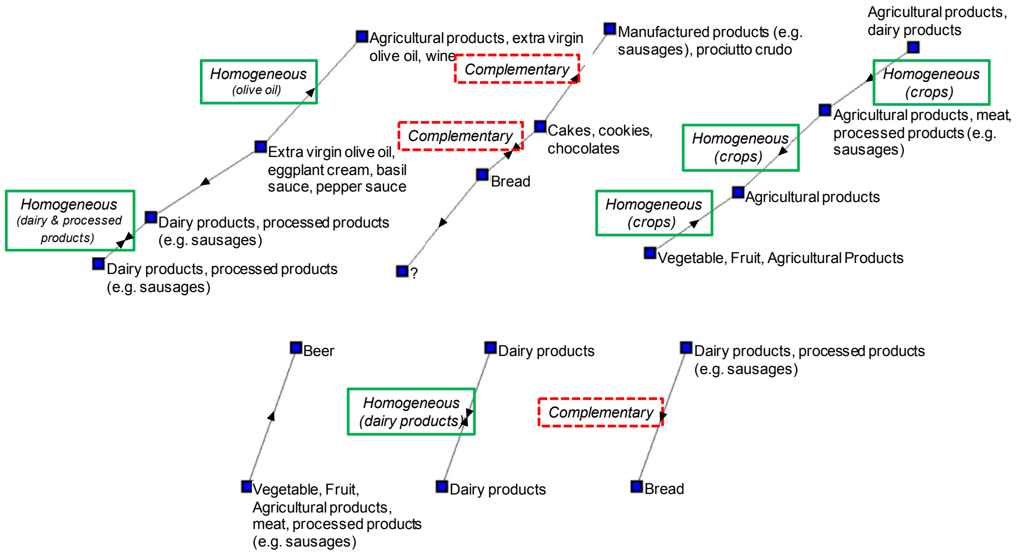

Figure 3 Producers' social network based on product type (same type of product in orange dotted box, supplementary products in green solid box). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of a product. For instance, a dairy farmer (P-5) supplies high-quality dairy products to a baker (P-26). Likewise, a patisserie (P-30) collaborates with a baker (P-6) and a manufactured foods producer (P-31) to make pies and cakes.

Likewise, the postal codes of the producers were mapped onto the nodes to identify a correlation between the geographic proximity and the collaboration (Figure 4). The result shows that collaborative groups are often confined by geographic location. Most producers collaborate within a boundary of 30 km. The exceptions were a tie between P-10 and P-28 who were 50 km apart, and a tie between P-9 and P-37 who were 210 km apart. P-10 and P-28 produce dairy products. P-37 produces milk, cheese, beef, and salami while P-9 pro-duces olive oil and sauces. The result indicates that the producers' social network is fragmented and geographically bounded.

The network can be visualised based on service type (Figure 5). There was much homogeneity in terms of service type, not only within the groups but also within the sample, indicating that the respondents have homogeneous business models based on multifunctional farming. In other words, they create value through the economy of scope, i.e., production of multiple products and services with common and recurrent use of resources, which increases the efficiency of production despite a limited production volume. Some of the more popular service types are direct sales (100%), courses/workshops (50%), didactic farm (38%), and farm visits (31%).

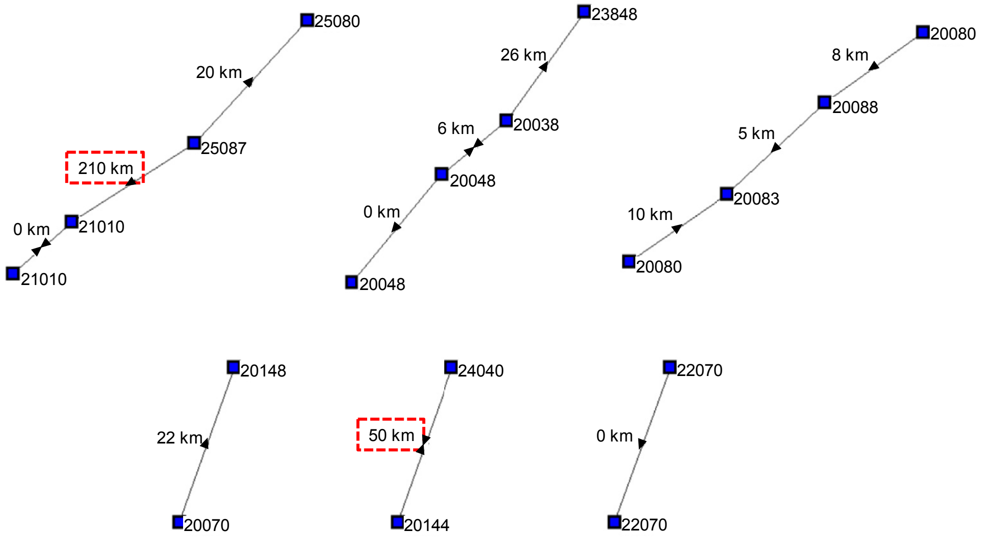

Figure 4 Producers' social network based on their postal code

4.2 Diagnosis

4.2.1 Initial conditions for collaborative services

The majority of producers are currently engaged in some types of collaboration, and social relations necessary to initiate collaborative services in

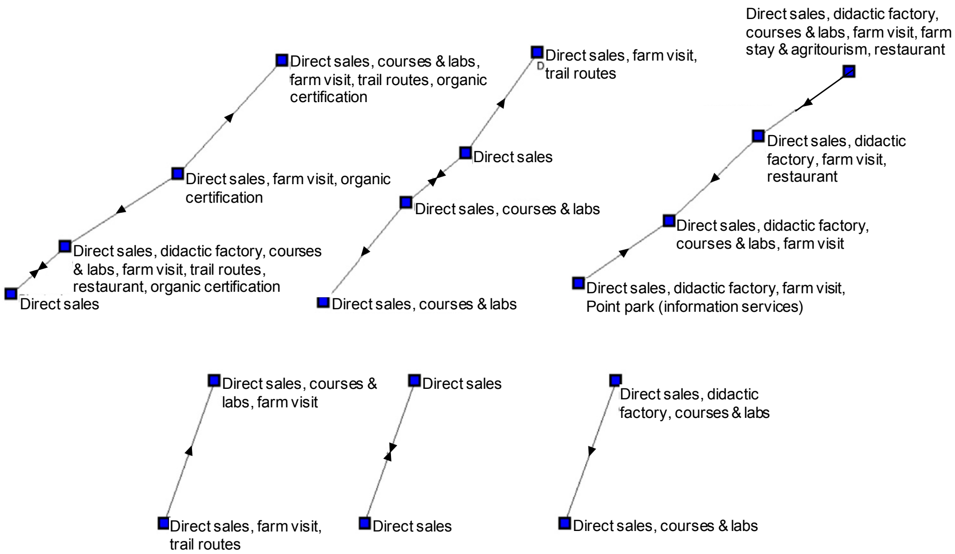

Figure 5 Producers' social network based on service type

connection with the market already exist. These relations are a mixture of strong and weak[3] as they are formed via various types of activities of different frequencies and durations (Granovetter, 1973). The producers share the interest of developing new business models around a local and sustainable food network and the threat of losing their community and habitat, which acts as a catalyst to stimulate their sense of community (McMillan & Chavis, 1986). Among various types of collaborative service (Baek, Manzini, & Rizzo, 2010), resource sharing and exchange (e.g. tool, space, knowledge sharing) and direct sales (e.g. farm stores, GAS[4]) are most frequently observed where a majority of the producers are engaged. Lastly, as the second survey result shows, they are open to new forms of collaboration which utilise resources available to them to fulfil their socio-economic needs. In short, existing collab-orative networks and shared demands among the producers provide a neces-sary condition for initiating collaborative services in the market.

4.2.2 Needs and resources

The demand and availability of resources in the producers' network partly overlap, suggesting that some demands could be fulfilled with the resources in the network. For instance, a demand for distribution channels in the city could be met by collaborating with a producer who owns a store in the city. A demand for solutions to agronomic and technical problems can be partly addressed with the equipment, facilities, spaces, and knowledge owned by other producers. Or, if someone wants to open a collaborative restaurant, he or she might want to talk with those in the network who have access to a space, human resources, experience, or needed ingredients.

4.2.3 Connectivity and modularity

A balance of connectivity and modularity in a network are known to contribute to resilience (Webb & Bodin in Gonzales & Parrott, 2012).[5] Connectivity in network theory is defined as the extent to which nodes are connected to each other (Gonzales & Parrott, 2012). Connectivity is related to the resilience and efficiency of a system, as a disturbance that removes edges between nodes could be quickly overcome by the use of alternative routes (Holling, 1973; Gonzales & Parrott, 2012). For instance, the loss of a wheat producer in the bread production network can be overcome if an alternative tie to a producer of the same function can be quickly established. Connectivity also indicates the richness of relationships: the more connective a network is, the denser it is. The density of the producers' was 0.009[6], indicating that the relationships are few, the capacity of information and resource flows are limited, and it is vulnerable to disturbances.

Modularity measures the degree of network partitioning, i.e., to what extent a network is composed of smaller subsystems. Structural modularity helps reduce the spread of a disturbance in a system. Like other characteristics, it can be measured quantitatively using different network modularity metrics

(Scott, 2000; Newman, 2004). Using Girvan-Newman clustering, the modularity of the producers' network was 0.635[7]. The producers' network structure is segmented into six isolated groups whose sizes range from two to four members. Looking into the groups, the members are connected via a mixture of strong and weak ties, and collaboration is associated with product type and geographic location. With no inter-group connectivity and a highly modularised structure, the network has the weakness of inefficient communication between groups, and is therefore not resilient. The isolation of groups hinders the diffusion of innovations, thereby limiting their scope and impact. Intermediary nodes known as bridges that connect segmented groups can improve the resilience by reinforcing information and resource flows while controlling the spread of a disturbance.

4.2.4 *Diversity and redundancy*

The existing literature reports that diversity and redundancy of resources that perform a particular function in a system contribute to resilience (Longstaff et al., 2010; Ehrlich & Walker, 1998; Norberg & Cumming, 2008; Webb & Bodin, 2008 in Gonzales & Parrott, 2012). Diversity can be measured in different ways (Magurran, 1988 in Ibid.). We used the Simpson's index to measure the diversity of the product and service types in the network. It is described as $D = 1 - \sum_{i=1}^{S} Pi^2$, where D is the Simpson's diversity index, S is the total number of categories of components in the system, and Pi is the proportion of components belonging to the i^{th} category. The diversity of the product and service types were 0.91 and 0.80, respectively, with total 20 product types and 9 service types. The diversity in the producers' network not only promotes biodiversity in the region but also becomes a potential for the farms to generate higher economic values by initiating various local food services such as the farmers' market. Until now, collaboration has occurred mainly among the producers of homogenous items (e.g. crops) or complementary items (e.g. bread and dairy products). The limited types of collaboration, despite the geographic proximity and diversity in products and services of the producers in the South Park, leave ample opportunities to initiate new collaborative services related to local food, which will contribute to both economic and environmental sustainability.

Redundancy contributes to resilience by providing a back-up or buffering when an individual unit fails (Longstaff et al., 2010). For instance, redundancy of dairy farmers in the bread supply chain means there is a backup to replace the loss of a dairy farmer. Redundancy is expressed as the inverse function of diversity (Gonzales & Parrott, 2012). The producers' network exhibits redundancy in certain types of products and services. For instance, dairy products, crops, vegetables, and processed foods are produced by multiple producers and thus have relatively high redundancy while beer, bread, and wine are produced by few and have low redundancy. Redundancy is observed across most service types due to the multifunctional business models of the producers. It varies among producer groups in the network: groups of homogeneous items (e.g. crops) have high redundancy and low diversity while those of complementary items have the opposite (e.g. bread and dairy products), indicating that fragmentation of the network acts as a barrier to achieve a balance of diversity and redundancy.

4.3 Objective setting and strategy building

Based on the diagnosis, objectives were set to enhance the resilience of the producers' network by increasing the overall network size, increasing the network density and intergroup connectivity, maintaining modularity by supporting and creating functional clusters, and achieving a balance of diversity and redundancy. The desired outcome would be a community of producers and consumers who are densely connected, actively functioning in clusters, and interacting with individuals and communities surrounding the market. This change would reinforce the resilience of their social system to the ongoing urbanisation and industrialisation of the territory (Figure 6).

The producers' network needed to be reinforced in both size and quality by introducing services that create new nodes and ties. Scaling up the network by adding new nodes contributes to achieving the critical mass for the virtuous circle as illustrated in the Sungmisan Village case, and reinforces the network resilience by increasing diversity and redundancy. The new nodes can come from the producers who are not currently involved in a collaborative network, or consumers interested in the sustainable consumption of foods. Forming

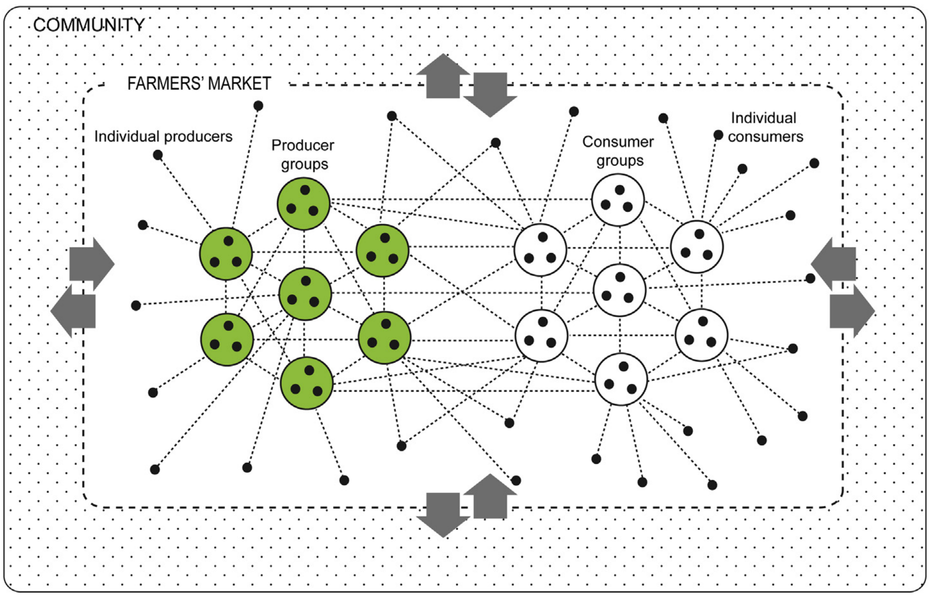

Figure 6 The desired network shape of the market through design intervention

new ties increases the overall network density, and so-called “bridges”, which are the weak ties that connect groups that would otherwise be disconnected, improve inter-group connectivity (Granovetter, 1973), thereby improving resilience. These bridges will facilitate communication and diffusion of innovative ideas in the network, and contribute to transforming the extant collaboration pattern defined by geographical boundaries and product types. Strategies to attract isolated producers and reach out to consumer networks have thus been designed, such as an online platform for matching resources and the needs of producers (self-help platform); a regular social event for the producers to eat together and share information, competences, and re-sources (neighbourhood dinner club); and collaboration with large organisa-tions such as schools or apartment complexes that are potential consumers of locally produced foods (extended GAS).

The producers’ network exhibits diversity in terms of the product and service types. This is because the multifunctional farm has been accepted as an economically viable and environmentally sustainable agricultural model by the producers. To foster and spread multifunctional farms in the South Park, strategies to encourage their competitiveness by taking advantage of such diversity are needed. For instance, in addition to the farmers’ market, ser-vice models that promote diversity are currently being undertaken, such as a food box delivery service and a local distribution network of restaurants and shops (Nutrire Milano, 2011). The network is also modularised into func-tional clusters based on product type, i.e., clusters formed by producers of homogeneous and/or complementary items of a final product: a baker and a dairy producer form a cluster to produce bread; a baker, a processed food producer, and a patisserie form a cluster to produce cake; and crop producers form a cluster of their own. New products and services can be conceived to fos-ter the extant clusters and create new ones. Related ideas are being developed by the project team such as local supply chains of cereal, meat, and fruit (Nutrire Milano, 2011).

5 *Discussion*

Assessing resilience is analogous to measuring the distance between a system state and a critical threshold, where the term system state refers to a set of variables that influence resilience, and threshold a border between two different system states (Resilience Alliance, 2010). It entails two formidable challenges: defining the system state and locating the critical thresholds. Defining the system state is challenging because there are a myriad of variables associated with community resilience. Researches have thus focused on certain subsystems of the target community. They include social, ecological, economic, physical infrastructure, and governance subsystems. Within each subsystem are indicators that are measured quantitatively or qualitatively. For instance, the resilience of a social subsystem is measured in terms of connectivity, modularity, diversity, redundancy, institutional memory, and innovative learning of community members. That of an economic subsystem is measured by conditions of the labour market, the composition of the community's businesses, its fiscal position, and other factors (Longstaff et al., 2010). Whilst narrowing down to a specific subsystem makes the assessment feasible, it also presents a fundamental limitation to accuracy.

Locating the critical thresholds is to predict at which condition a system will shift to a different state. It involves defining key variables that trigger a shift to a different system, identifying their interactions, and determining the certainty of the thresholds (Resilience Alliance, 2010). Locating the thresholds in subsystems of a community (except the ecological one) is not at all easy, and in fact is rarely reported due to the sheer complexity of the system and the short history of the field. After all, community resilience cannot be tested like that of an ecological system.

> "[Communities], the systems we are trying to measure for their resilience are big and complex with many variables. … [T]he resilience of these systems is only measured by a real crisis. … [I]t may be like measuring the safety of a car. … But it is not possible to crash test communities" (an email from Longstaff, March 15th, 2015).

In this regard, community resilience represents the potential to respond to a change (Levine et al., 2011 in Frankenberger et al., 2013).

If resilience assessment is difficult to measure accurately, and only an estimation of the potential, what value does it have to communities vulnerable to real disturbances? First of all, the assessment is meaningful in the sense that it identifies potential problems in a system state and presents them in quantitative or qualitative data. It thus informs a community where and how to allocate its resources to improve resilient capacities. Secondly, as the existing literature argues, the meaning of resilience assessment is more in understanding how a system changes in terms of its vulnerability to disturbance and its capacity to respond than in pinpointing the location of a threshold. By repeating the assessment regularly as system dynamics change, one's understanding of the community will grow. By the same logic, the meaning of design for resilience can be found in strengthening capacities and resources that contribute to resilience with appropriate design interventions so that the level of uncertainty around the occurrence of disturbances is reduced, and in the long run, the impact of individual events minimised.

Resilience is a system capacity. When it is considered essential to the persistence of a system, it becomes a system need. (Resilience is not necessarily a positive characteristic, however. It may not be desired or needed by members of a system such as a tyranny.) The socio-technical framework in this study is then an approach to understanding system needs and their implications to collaborative services. In a complex system, the needs of a system component and those of a system as a whole may not align. An intervention to fulfil the component's need does not necessarily act in favour of the entire system and may even cause unintended side effects. This discrepancy between individual and system needs and between the approaches to fulfil them has led to acknowledging the limitation of traditional microscopic approaches to sustainable design and the need for a holistic one (Blizzard & Klotz, 2012). An exemplary microscopic approach is user-centred design, which is widely accepted as an approach to design products, services, and processes based on end users' needs. For this reason, we have selected it as a contrast to the socio-technical approach to the design of collaborative services. User-centred design focuses on a detailed understanding of individual users, and is effective in developing service infrastructures and interfaces that are usable, useful, and desirable to end users. On the contrary, the socio-technical approach is holis-tic, focusing on how individuals contribute to the dynamics of the social sys-tem as a whole. Therefore, it is difficult to detect the problems in the domain of one approach with the other. In the farmer's market, it is difficult to analyse the system state with regard to resilience with user research. For instance, the low connectivity among the producers or the lack of local bridges connect-ing isolated groups is not likely to be perceived 'as a problem' by the producers because it is the manifestation of their wilful social choices, unless there are other external factors that constrain them. Low redundancy in some producers' groups is not likely to be seen as problematic until the removal of a member causes dysfunction of the group because it is efficient and reduces competition.

Likewise, individual producers' needs are outside the radar of the socio-technical approach, which is illustrated in the episode of an online platform for collaborative services in the Feeding Milan project. During the project, strategies to enhance network connectivity through an online platform were developed to fulfil system needs. One of them was to help the producers find potential collaborators and connect them by providing an online catalogue of each producer including his or her needs and resources. The beta version of the platform featured a search engine and a mashup map empowered by the database of user profiles. In reality, however, the platform was not utilised much by the users, and was soon replaced with a simpler version, no more than an introduction of the project. What caused the failure remains to be clarified, but one major reason is speculated as the lack of understanding users. The platform was developed without rigorous user research or validation of design. Although preliminary research confirmed that most producers utilise the internet in business, their use behaviour, especially their interest in and capa-bility of using it for specific tasks related to collaborative services (e.g. forming social networks), was not studied in depth. To reduce the cost, the website was built on an existing template which was not validated with usability testing. The case of the farmers' market demonstrates that both systems and user-centred designs are necessary to the production of collaborative services, and they supplement each other. In today's design, where the user-centred approach is predominant, the socio-technical framework can shed light on the blind spots, i.e., system needs, with the provision of relevant theories and tools to understand and influence the system state.

The socio-technical framework aims at transforming the social system state through the design of a technical system, which in turn requires an understand-ing of the social system. In other words, the social system is both an input (or baseline) and output (or goal) of design interventions. This proposition is distinguished from the view of traditional service design that the social system as part of a service system is a resource necessary to deliver the desired service processes and interfaces (Edvardsson & Olsson, 1996; Secomandi & Snelders, 2011). The social system is thus a means to achieve the production of quality services and value creation, but not the goal of design activities per se. We argue that due to the distinctive role of social systems in collaborative services, evaluation of design activities will benefit from an analysis of the system state, and the socio-technical framework can also be used to evaluate technical interventions. The framework then becomes a part of an iterative cycle in which in-teractions between social and technical systems occur along the process of collaborative service design (Figure 7). Analysis and design phases constitute the process of understanding the social system and reflecting its qualities or state on the design of the technical system (feedback from social to technical system). Implementation of the technical system influences the state of the social system, resulting in a change of resilience while evaluation validates the effectiveness of design interventions and sets a new baseline for future inter-ventions (feedback from the technical to the social system). Design and implementation of collaborative services are driven by communities taking

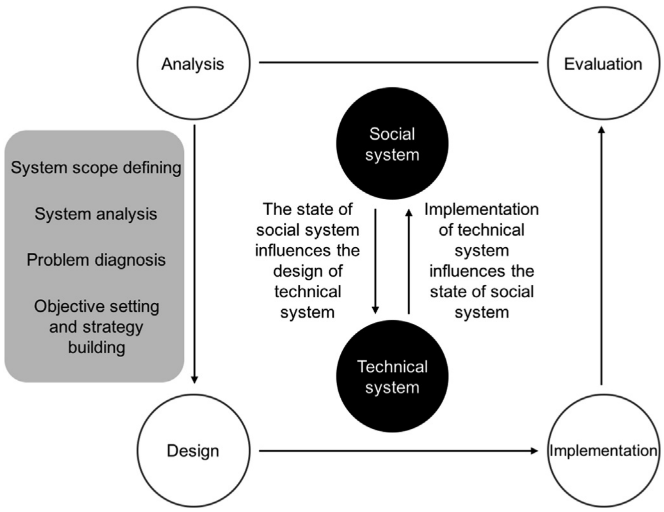

Figure 7 An iterative process of collaborative service design

advantage of the extant knowledge in design for service, and lie beyond the scope of this research.

The socio-technical framework aims at understanding resilience of the social system in communities and setting the direction for design interventions. It is applicable to the development of any socio-technical systems with such goals if the social dimension is represented as nodes and edges. These systems include society, communities of varying scales, companies, and governments. With a rapidly growing population, aggravating ecological impacts, and technological advances, our society is becoming increasingly complex and vulnerable to a variety of disturbances, both man-made and natural. Resilience has thus emerged as an essential quality of any future society (Manzini, 2014). Resilience is becoming increasingly important at the communal level, too. Socio-economic changes including urbanisation, ageing, and economic globalisation have made local communities and economies more vulnerable than ever. In a turbulent and unpredictable business environment, the concept of static growth is obsolete, and management scholars emphasise the need for resilience (Hamel & Valikangas, 2003 in Fiksel, 2006). Despite its relevance and importance, resilience is a difficult concept to apply to design practice. As Gonzales and Parrot (2012) succinctly put it:

> "[T]here are … many possible applications of resilience depending on which of the system's functions is at stake, the potential threats to this important function, and the time scale of interest. … Additionally, this concept is often difficult to translate into clear, measurable, system variables." (p. 4)

However, they also claim that if a system can be represented as a network, network analysis can provide a tool to measure certain characteristics of resilience. This approach is useful to the socio-technical framework because the social system can be described as a network of people, organisations, and physical infrastructure. In addition, by translating a seemingly abstract concept into specific variables, it can provide designers with specific goals and directions in designing for a resilient organisation as well as a set of indicators to measure resilience.

The validity of social network analysis depends on the accuracy of the data. In this study, we used surveys to collect social network data: Producers who had access to and were capable of using the Internet were asked to participate in the online survey, and those who did not were approached during the market to get the response. The survey was chosen because we targeted the whole population of the producers and thus needed an efficient method both time and cost wise. In addition, its asynchrony minimised the interruption by the data collector. The survey was distributed by Slow Food, which had the contact information of the producers, and its relationship with the producers as the supporter and organiser of the market was beneficial to the prompt data collection and nonresponse reduction. At the same time, observation of the offline survey also revealed some limitations of the method. Recalling social relations and the past records of collaboration was a laborious task as they involved reflection of a significant amount of data. Boredom and distraction were occasionally observed, which may have caused invalid data. These limitations can be miti-gated in part by the adoption of a participatory approach to collect social network data (Emmel & Clark, 2009). For instance, participatory mapping of social networks in conjunction with an interview allows a designer to examine the reasons for representing networks in particular ways. Walking in-terviews utilise the spatial information to stimulate the participants' reflection of memory by taking them on a walk through their neighbourhood. These methods depend on designers' ability to facilitate user participation (Light & Akama, 2012), and can be used with the survey to improve the quality of data.

6 Conclusions

This paper proposes an approach to designing for collaborative services to foster community resilience. We noted that a collaborative community is a socio-technical system in which social relations and technical solutions are interdependent: the state of the former influencing the design of the latter and the implementation of the latter influencing the state of the former. We also noted that the design of technical systems can enhance the resilience of a social system if the system state can be understood and concrete design problems identified. We thus propose a socio-technical framework for the design of collaborative services. This framework provides a step-by-step approach to analysing the social dimension of community resilience and conceiving design goals and strategies. It has been applied to a farmers' market in Milan to verify its feasibility. The diagnosis reveals that a collaborative network exists in a sparsely-knit and fragmented structure based on geographic proximity and product type, and lacks the balance of resource diversity and redundancy. The producers also share a need for collaborative business models around sustainable agriculture.

We draw the following conclusions from the application of the framework. The framework reveals problems related to community resilience in the form of social network characteristics. These problems can be addressed with design interventions such as service strategies for human relations or resource management. The framework employs a systems design approach and addresses system problems which are difficult to identify with traditional user-centred design methods. It is applicable to any socio-technical systems whose resilience is at stake and is describable as nodes and edges. It has methodical limitations inherent to resilience assessment in that it is based on the diagnosis of a potential at a given period of time. The meaning of design for resilience should thus be found in system capacity building rather than pin-pointing the exact location of thresholds.

This paper contributes to design knowledge in several aspects: Firstly, it approaches resilience as an operational concept, allowing designers to diagnose it with measurable indicators. The framework can be utilised to assess resilience and build capacities of a system at one time, assess the change of resilience in a single system over time, or compare resilience in multiple systems. Secondly, the systems design approach can provide a new source of inspiration for designing sustainable and resilient socio-technical systems. For instance, nature is an abundant source of inspiration for resilient systems; there are several cases of sustainable system development in biomimicry (Ayyadurai, 2011; Briscoe, Sadedin, & Wilde, 2011; Kulyk, 2009) and numerous studies related to resil-ience in ecology. The systems design approach also offers a new domain of problems that have been relatively unexplored in the design discipline, i.e., the problems related to system needs. These problems have been off the de-signers' radar partly because they exist at a systemic level, and hence are difficult for individual users to perceive and for designers to detect through user studies.

Acknowledgments

The authors thank the Nutrire Milano Project Team and the producers for their cooperation. They also thank the reviewers, Patricia Longstaff, Henri Christiaans, Lael Parrott, and others for giving valuable comments and insights in crafting this article. The project Nutrire Milano was conducted in collaboration with Slow Food Italia and the Universita degli Studi di Scienze Gastronomiche, and funded by the Fondazione Cariplo, a private foundation that supports research on social, environmental sustainability.

Notes

1. The notion of STS emerged from the understanding of interrelationship between workers and the productivity of a work environment, and that re-design of the organisational structure and activities as well as the need fulfilment of the former influences the latter. In its original usage, technical system can be defined as a conversion process of transforming inputs (e.g. raw materials) into outputs (e.g. products or services) by people or machines, and social system as people that perform a set of tasks (Badham, Clegg, & Wall, 2001). In later studies, the notion of technical and social systems have developed into technologies and artefacts for production; and elements of people encompassing interaction, relationships, activities, needs, motivations, laws, and policies, respectively.
2. The notion of resilience is rooted in physics and mathematics and is used to describe the characteristic of a material to return to equilibrium after a displacement, such as rubber that bends and bounces back (Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2007).
3. One way to categorise interpersonal ties (or relations) is based on the tie strength according to Granovetter (1973). Strong ties arguably take decades to be formed and are observed in intimate relations such as families and cliques. Weak ties, on the other hand, take a relatively shorter time to be formed and are observed among friends, colleagues, and acquaintances. Tie strength is measured in combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterise the tie. There is no singular way to measure the tie strength. In this research, it was estimated based on the frequency and duration of interaction.
4. GAS (Gruppi d'Aquisto Solidale) is a network of food purchasing groups organised by a group of consumers and producers in Italy who promote sustainable and ethical food consumption.

5. Density and modularity trade-off each other, i.e., increasing density decreases modularity, and the right balance of the two means intermediate density and intermediate modularity. However, Gonzales and Parrott do not mention how to find the right balance. The implication is that with uncertainty designers should pursue the balance of the two variables, trying to avoid an extreme value for either of them.
6. Density ranges between 0 and 1, and higher the value, higher the density.
7. The Girvan-Newman algorithm was developed to detect community structure in a network, and is used as an indicator of the network modularity. Values above 0.3 are considered to indicate significant community structure (Newman, 2004). In this study, fragmentation of the producers' network is apparent due to the small number of edges and nodes so modularisation is immediately recognised. In a more complex network, however, metrics such as the Girvan-Newman algorithm are useful to detect the modularisation.

References

Arbon, P., Cusack, L., Gebbie, K., Steenkamp, M., & Anikeeva, O. (2013). *How do we measure and build resilience against disaster in communities and households?* Adelaide, Australia: Torrens Resilience Institute.

Ayyadurai, V. A. S. (2011). Biomimetics of communication and media. In *Paper presented at the 12th international research symposium on service excellence in management*. (NY).

Badham, R. J., Clegg, C. W., & Wall, T. (2001). Sociotechnical theory. InKarwowski, W (Ed.). (2001). *International encyclopedia of ergonomics and human factors, Vol. 1* (pp. 1370−1373). London: Taylor & Francis.

Baek, J. S. (2011). *A socio-technical framework for collaborative service. Designing a digital platform for collaborative communities*. Milan: Politecnico di Milano. (Doctoral thesis).

Baek, J. S., & Manzini, E. (2012). A socio-technical framework for collaborative services. In *Paper presented at the DRS conference 2012*. Bangkok, Thailand.

Baek, J. S., Manzini, E., & Rizzo, F. (2010). Sustainable collaborative services on the digital platform: definition and application. In *Paper presented at the design research society International conference 2010*. Montreal.

Baxter, G., & Sommerville, I. (2011). Socio-technical systems: from design methods to systems engineering. *Interacting with Computers, 23*(2011), 4−17.

Blizzard, J. L., & Klotz, L. E. (2012). A framework for sustainable whole systems design. *Design Studies, 33*(2012), 456−479.

Briscoe, G., Sadedin, S., & Wilde, P. D. (2011). Digital ecosystems: ecosystem-oriented architectures. *Natutral Computing, 10*, 1143−1194. http://dx.doi.org/10.1007/s11047-011-9254-0.

Bujones, A. K., Jaskiewicz, K., Linakis, L., & McGirr, M. (2013). *A framework for resilience in fragile and conflict-affected situations*. NY, USA: Columbia University.

Burger, T., Ganz, W., Pezzotta, G., Rapaccini, M., & Saccani, N. (2011). Service development for product services: a maturity model and a field research. In *Pa-per presented at the European Association for Research on Services*. Hamburg. Cantu, D. (2012). "Ideas Sharing LAB". Co-designing multifunctional services with local food communities. In *Paper presented at the Cumulus Northern World Mandate 2012*. Helsinki.

Carpenter, S., Walker, B., Anderies, M., & Abel, N. (2001). From metaphor to measurement: resilience of what to what? *Ecosystems, 2001*(4), 765−781. http://dx.doi.org/10.1007/s10021-001-0045-9.

Cipolla, C. (2008). Creative communities as "relational" innovations: a service design approach. In F. Jegou, & E. Manzini (Eds.), *Collaborative services.*

Social innovation and design for sustainability (pp. 153–156). Milano: POLIDESIGN.
Cipolla, C., & Manzini, E. (2009). Relational services. *Knowledge, Technology & Policy, 22*(1), 45–50.
Costanza, R., & Patten, B. C. (1995). Defining and predicting sustainability. *Ecological Economics, 15*, 193–196.
Edvardsson, B., & Olsson, J. (1996). Key concepts for new service development. *The Service Industries Journal, 16*(2), 140–164.
Ehn, P. (2008). Participation in design thinking. In *Paper presented at the 10th Anniversary conference on participatory design*. New York.
Ehrlich, P., & Walker, B. (1998). Rivets and redundancy. *BioScience, 48*(1998), 387.
Emery, F. (1967). The nine step model. In *Paper presented at the International meeting on socio-technical systems*. Lincoln: England.
Emmel, N., & Clark, A. (2009). *The methods used in connected lives: Investigating networks, neighbourhoods, and communities. Real life methods, the Manchester/Leeds node of the national centre for research methods*. UK.
Fiksel, J. (2006). Sustainability and resilience: toward a systems approach. *Sustainability: Science, Practice, & Policy, 2*(2), 14–21.
Frankenberger, T., Mueller, M., Spangler, T., & Alexander, S. (2013). *Community resilience: Conceptual framework and measurement*. Rockville, MD: Westat. Feed the Future.
Gilnunee. (2012). Introduction to the Sungmisan town. In *Paper presented at the Asia NGO innovation Summit 2012*. Seoul: South Korea.
Gonzales, R., & Parrott, L. (2012). Network theory in the assessment of the sustainability of social–ecological systems. *Geography Compass, 6*(2), 76–88.
Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology, 78*(6), 1360–1380.
van Halen, C., Vezzoli, C., & Wimmer, R. (2005). *Methodology for product service system innovation*. The Netherlands: Koninklijke Van Gorcum.
Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics, 4*(1973), 1–22.
I Mercati della Terra: The earth markets. Retrieved October 2nd, 2010, from http://www.mercatidellaterra.it/welcome.lasso.
Kimbell, L. (2011). Designing for service as one way of designing services. *International Journal of Design, 5*(2), 41–52.
Kulyk, R. (2009). *Smart grid: Taking our cue from nature*. Toronto: Regen Energy.
Light, A., & Akama, Y. (2012). The human touch: participatory practice and the role of facilitation in designing with communities. In *Paper presented at the participatory design conference*. Roskilde, Denmark.
Longstaff, P. H., Armstrong, N. J., Perrin, K., Parker, W. M., & Hidek, M. A. (2010). Building resilient communities: a preliminary framework for assessment. *Homeland Security Affairs, 6*(3).
Manzini, E. (2009). View point. New design knowledge. *Design Studies, 30*(2009), 4–12.
Manzini, E. (2014). Cultures of resilience: a cosmopolitan localism. Retrieved September 25th, 2014, from. http://ual.force.com/apex/EventFormPage?id=a0RD000000AhAUUMA3&book=true.
McMillan, D. W., & Chavis, D. M. (1986). Sense of community: a definition and theory. *Journal of Psychology, 14*(January), 6–23.
Meroni, A. (2008). Strategic design to take care of the territory. Networking creative communities to link people and places in a scenario of sustainable

development. In *Paper presented at the P&D Design 2008-8° Congresso Brasileiro de Pesquisa e Desenvolvimento em Design*. Brazil: São Paulo.
Meroni, A., & Sangiorgi, D. (2011). A new discipline. In A. Meroni, & D. Sangiorgi (Eds.), *Design for services*. Surrey: Gower Publishing Limited.
Mumford, E. (2000). A socio-technical approach to systems design. *Requirements Engineering, 2000*(5), 125–133.
Newman, M. E. J. (2004). Fast algorithm for detecting community structure in networks. *Physical Review E, 69*(6), 066133.
Norberg, J., & Cumming, G. S. (2008). *Complexity theory for a sustainable future*. New York, NY: Columbia University Press.
Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2007). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *Am J Community Psychol, 2008*(41), 127–150. http://dx.doi.org/10.1007/s10464-007-9156-6.
Nutrire Milano. (2011). Retrieved February 11th, 2014, from http://www.nutriremilano.it/.
Pfefferbaum, R. L., Neas, B. R., Pfefferbaum, B., Norris, F. H., & Van Horn, R. L. (2013). The Communities Advancing Resilience Toolkit (CART): development of a survey instrument to assess community resilience. *Int J Emerg Ment Health, 15*(1), 15–29.
Resilience Alliance. (2010). *Assessing resilience in social-ecological systems: Workbook for Practitioners*. Version 2.0.
Rim, S. J. (2013). *From gangnam style to sungmisan style: Creating "Village" communities in South Korea*. Retrieved July 3rd, 2014, from. http://urbantimes.co/2013/06/from-gangnam-style-to-sungmisan-style-creating-village-communities-in-south-korea/.
Schwind, K. (2012). *Community resilience toolkit 2.0*. Oakland, CA USA: Bay Localize.
Scott, J. (2000). *Social network analysis: A handbook*. Thousand Oaks, California: Sage.
Secomandi, F., & Snelders, D. (2011). The object of service design. *Design Issues, 27*(3), 20–34.
Snelders, D., Garde-Perik, E. v. d., & Secomandi, F. (2014). *Design strategies for human relations in services*. Paper presented at the ServDes 2014, Lancaster, UK.
Sussman, J. M. (2000). *Introduction to transportation systems*. Boston: Artech House.
Trist, E. (1981). *The evolution of socio-technical systems: A conceptual framework and an action research program*. Occasional Paper no. 2.
UNU-IAS, Biodiversity International, IGES, & UNDP. (2014). *Toolkit for the indicators of resilience in socio-ecological production landscapes and seascapes (SEPLS)*.
Whitworth, B., & de Moor, A. (Eds.). (2009). *Handbook of research on socio-technical design and social networking systems*. Hershey, PA.