SOCIO-TECHNICAL DESIGN FOR RESILIENCE: A CASE STUDY OF DESIGNING COLLABORATIVE SERVICES FOR COMMUNITY RESILIENCE

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Abstract

This paper presents selected findings from a doctoral study on how design could be used to construct a resilient community. It describes a framework for diagnosing the resilience of people's social networks and developing strategies for a resilient community based on the network theory. It goes on to outline the methodology and findings of a case study exploring the application of this framework in designing services around a farmers' market in Milan. Based on the analysis of the producers' collaborative networks, the paper explores the perceived feasibility of this framework as a preliminary stage to develop collaborative services. It concludes by commenting on the wider implications of the framework for the field of design for sustainability.

Keywords: Sustainability, socio-technical system, social networks, resilience, social innovation

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1 INTRODUCTION

Socio-technical systems are an approach that views complex human organisations 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 in which they carry out sets of tasks related to specific goals (Trist, 1981). They also refer to the organisations that are characterised as such and include a wide variety of anthropogenic, or man-made, systems. In this paper, socio-technical system is adopted to understand and design for resilient local communities. Social and technical systems are interrelated, and their optimised integration leads to higher productivity and wellbeing of an organisation. Resilience, the capability of a system to retain its identity after a disturbance (Holling, 1973), is known to be influenced by a set of attributes (Gonzales and Parrot, 2012). For instance, a community that values the culture of diversity, conviviality, and experimentation tends to persist in time and is therefore resilient (Manzini, 2014). An example is the Sungmisan Village in Seoul, South Korea. Originating as a group of parents interested in 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 experimented (Rim, 2013). Such communities that co-design and co-produce solutions to fulfil the needs of their own have been coined as collaborative communities and their solutions collaborative services (Jegou and Manzini, 2010). In a collaborative community, solutions and social networks are interdependent: As users generate *technical 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 solutions because a larger pool of people is likely to result in more ideas to collaborate on. As a socio-technical system, a collaborative community is an integration of solutions and social networks which are interlinked and mutually supportive (Baek and Manzini, 2012). The underlying premise of this research is that by adopting socio-technical systems into design process, designers can intervene in optimising the integration of social and technical dimensions with an aim to enhance community resilience. If a collaborative service is designed in such a way that a technical solution and a social network are in a virtuous circle of enhancing resilience, the design activity is likely to contribute to community resilience.

This paper introduces an approach to design for a resilient community and its application. While existing literature discusses the notions and characteristics of resilience in social and ecological systems (Holling, 1973; Comfort, 1999; Mileti, 1999; Gonzales and Parrot, 2012), showcases resilient communities (Meroni ed., 2007; Jegou and Manzini, 2008), and its relevance to design for sustainability (Manzini, 2014), there is a lack of knowledge on how to practice design for resilient communities. We were thus motivated to explore the following questions: (1) How do we diagnose problems related to community resilience, (2) How are the diagnosis results integrated into the design of technical system so that the virtuous circle of social and technical systems is achieved? To address this question, a framework to design collaborative services based on socio-technical systems design was developed under which a community is considered as an integrated system of social and technical, its resilience diagnosed based on a set of parameters, and enhanced through design interventions. An empirical research was conducted to validate its feasibility.

2 METHODOLOGY

The framework is a process composed of (1) planning, (2) data collection and analysis, (3) problem diagnosis, and (4) objective and strategy building. Planning involves setting a target user group and defining the scope of its social and technical systems. The identified systems are then diagnosed with tools such as social network analysis (SNA) and degree of collaboration (DoC) to analyse social networks of the target users. Coming from network theory, the former is widely used in sociology to understand the social relations, and the latter is used to identify the content and quality of social networks (Baek and Manzini, 2012). The following data are 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 are interpreted by analysing the attributes that affect resilience such as diversity, redundancy, connectivity, and modularity (Gonzales and Parrot, 2012). The diagnosis result is fed into formulating the direction of transformation towards a resilient community and strategies to develop socio-technical solutions (Figure 1). The design outcome is

services which address the problems of both technical and social systems with respect to enhancing community resilience.

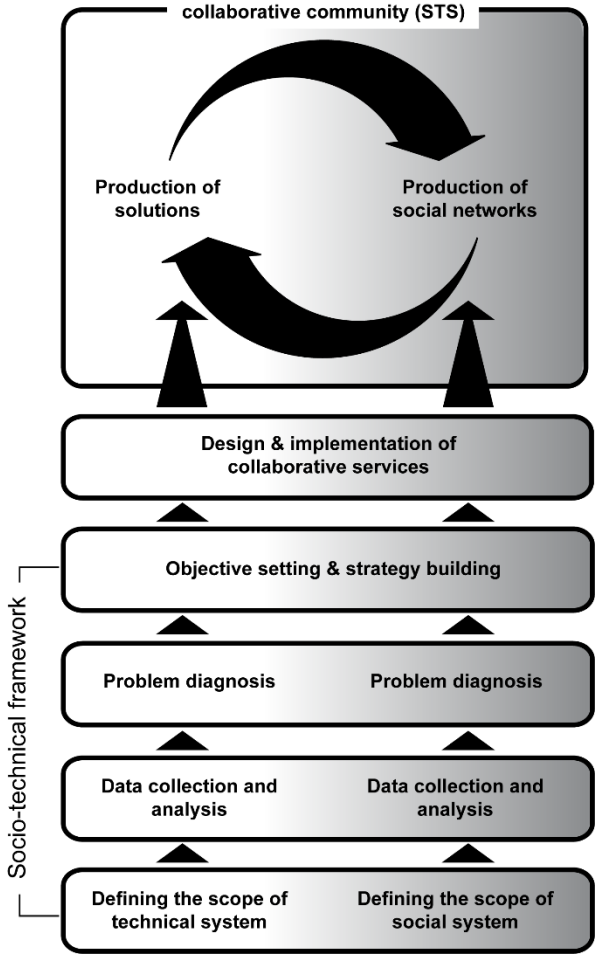

Figure 1 Socio-technical framework for collaborative services

2.1 Data collection and analysis

For validation, the framework was applied to the context of developing collaborative services for a farmers' market in Milan. Two surveys were conducted with target users - producers in a farmers' market - via email and postal service. The first survey was designed in three sections: (1) the basic profile; (2) structure, quality, and content of social networks; and (3) a demand for new services. The profile included the 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 inquired about the details of their collaborative activities, including: the size, involved actors, duration, frequency of interaction, type of collaboration, and finally technologies supporting collaboration (Baek and Manzini, 2012). The second survey was conducted in response to the first survey data to inquire about the resources, competences, and tools that are needed from or can be shared with other producers. These data were used in developing service strategies and concepts. A total of 42 producers responded with one invalid response (Table 1).

Table 1 Producers surveyed and their produces

Producer	Postal code	Products
P-01	20050	Plants, flowers, herbs
P-02	26853	Dairy products

P-03	20052	Dairy products
P-04	20148	Beer
P-05	22070	Dairy products, processed products (e.g. Sausages)
P-06	20048	Bread
P-07	20070	Vegetable, fruit, agricultural products, meat, processed products
P-08	20060	Agricultural products, dairy products, meat, rice, milk
P-09	25087	Extra virgin olive oil, eggplant cream, basil sauce, pepper sauce
P-10	24040	Dairy products
P-11	20083	Agricultural products
P-12	20017	Chocolate
P-13	95100	Fish
P-14	96011	Vegetable, fruit, processed products
P-15	20080	Agricultural products, dairy products
P-16	20078	Wine, honey
P-17	20080	Vegetable, fruit, agricultural products
P-18	21010	Dairy products, processed products
P-19	-	Wine
P-20	21055	Honey and hive products
P-21	20060	Vegetable, fruit, agricultural products, meat, processed products, bread, juices, pastries
P-22	23804	Information not available
P-23	15050	Fruit, agricultural products, processed products, juices, pastries
P-24	25080	Agricultural products, extra virgin olive oil, wine
P-25	20083	Vegetable, agricultural products, dairy products, juices, pastries
P-26	22070	Bread
P-27	20098	Meat
P-28	20144	Dairy products
P-29	-	Vegetable, fruit
P-30	20038	Cakes, cookies, chocolates
P-31	23848	Manufactured products, ham
P-32	20048	Information not available
P-33	27050	Vegetable, agricultural products
P-34	20080	Agricultural products, honey
P-35	20088	Agricultural products, meat, processed products
P-36	-	Agricultural products, dairy products, meat
P-37	21010	Dairy products, processed products
P-38	26812	Dairy products
P-39	-	Fruit, processed products
P-40	22030	Vegetable, fruit, processed products
P-41	20078	Wine

The analysis of producers' collaborative network is elaborated in the previous research (Baek and Manzini, 2012), and the findings are briefly summarised in this paper. The producers' network was fragmented into isolated groups, bounded by geographic location and product item, and exhibited low connectivity. 65% of the respondents were already engaged in collaboration with other producers in the market, and their relationships have lasted from less than one year to more than 20 years. The remaining 35% were not engaged in any collaboration and remained as isolates. The network was fragmented into six groups based on geographic location, i.e., most farms were less than 50 km away from their collaborators. Their products were homogeneous or complementary to those of the collaborators. Complementary products refer to the ingredients of another product (e.g. dairy products and bread for panini). The extent to which the producers were connected to the others was low, i.e., the number of relationships in the network was limited, resulting in low network connectivity.

2.2 Diagnosis

2.2.1 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 connection with the market already exist. These relations are a mixture of strong and weak- 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 and Chavis, 1986). Among various types of collaborative service (Baek, Manzini and Rizzo, 2010), resource sharing and exchange (e.g. tool, space, knowledge sharing) and direct sales (e.g. farm stores, GAS-) were 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 collaborative networks and shared demands among the producers are expected to provide sufficient conditions for initiating collaborative services in the market.

2.2.2 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.

2.2.3 Connectivity

Connectivity in network theory is defined as the extent to which nodes are connected to each other (Gonzales and Parrot, 2012). A high connectivity contributes 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; Ibid.). For instance, a 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 producers' network has a very low density[1], implying that it is vulnerable to disturbances, the capacity of information and resource flows are limited, and relationships are few.

[1] Connectivity of a network can be assessed by calculating the density metric, which is the proportion of existing links within all the possible links of the network and ranges between 0 and 1. The density value of the producers' network was 0.009.

2.2.4 Diversity

A high functional diversity is known to contribute to the resilience of a system (Ehrlich and Walker, 1998; Norberg and Cumming, 2008; Webb and Bodin, 2008 in Gonzales and Parrot, 2012). The functional diversity of the given network can be expressed as the diversity of products and services offered by the producers. Products include vegetables, dairy products, meat, processed foods, plants, wines and beers; and service models include direct sales of produce, didactic activities, restaurants, certification, and information services. Such diversity not only promotes biodiversity in the region but also becomes a great potential for the farms to generate higher economic values allowing them to initiate various local food services such as the farmers' market. In reality, however, collaboration has been limited so far mainly between producers of homogenous items (e.g. crops) or complementary items (e.g. bread and dairy products). Limited types of collaboration despite geographic proximity and diversity in products and services of the producers in the South Park leave ample opportunities for them to initiate new collaborative services related to local food, which will contribute to both economic and environmental sustainability.

2.2.5 Redundancy

Redundancy can be expressed as the inverse function of diversity. 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 has relatively high redundancy while beer, bread, and wine are produced by few and has low redundancy. Redundancy is observed across most service types due to the multi-functional business models of the producers. Redundancy 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.

2.2.6 Modularity

Modularity measures the degree of network partitioning, i.e., to what extent a network is composed of smaller subsystems. Like other characteristics, it can be measured quantitatively (Scott, 2000; Newman, 2006). A resilient system is known to have a balance between a high modularity and an effective sub-group connectivity (Webb and Bodin in Gonzales and Parrot, 2012). The producers' network structure is segmented into six groups which are not connected to one another and whose size 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 correlated with product type and geographic location. With no inter-group connectivity and a highly modularized structure, the network has the weakness of inefficient communication between groups, and is therefore not resilient. An isolation of groups hinders the diffusion of social innovations, thereby limiting their scope and impact. To improve resilience, intermediary nodes that connect segmented groups, or bridges, and thus reinforce the flow need to be created.

2.3 Objective and strategy building

Based on the diagnosis, objectives to reinforce the producers' network were set as follows: to increase the size and connectivity; and to reinforce the diversity and modularity. A desired outcome would be a resilient community of producers and consumers who are densely connected, actively functioning in clusters, and interacting with individuals and communities surrounding the market (Figure 9).

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 reinforcing 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 new ties increases inter-group connectivity and density of the network as a whole, thereby improving the resilience. In particular, bridges that connect isolated groups will facilitate communication and diffusion of innovative ideas in the network, and contribute to transforming the existent collaboration pattern defined by geographical boundary and product type. Strategies to attract isolated producers and reach out to consumer networks have thus been designed

such as an online platform for matching resources and needs of producers (self-help platform); a regular social event for the producers to eat together and share information, competences and resources (neighbourhood dinner club); and collaboration with large organizations such as schools or apartment houses that are willing to consume locally produced foods (extended GAS).
The producers' network exhibits diversity in terms of the product type. This is because the multifunctional farm has been accepted as an economically viable and environmentally sustainable agricultural model by the producers. To foster and diffuse 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, service 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, 2014). The network is also modularized into functional 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 forms 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 foster the existent clusters and create new ones. Related ideas are being developed by the project team such as local supply chains of cereal, meat, and fruit (Ibid.).

3 DISCUSSION

An analysis of the producers' collaborative network revealed the characteristics of the network's resilience and suggested the direction of design interventions. Resilience is closely related to sustainability which, in its definition of improving the quality of human life without compromising the needs of future generations, has an implication for the capacity of a system to persist in time (Costanza and Patten, 1995). It is thus described as an essential characteristic of a sustainable community. Manzini (2014) argues that resilience should be considered as a fundamental characteristic of our society given the crises and catastrophic events - both man-made and natural - that contemporary societies face. Resilience is also becoming increasingly important at the community level as urbanisation, ageing, and economic globalisation render local communities and their economies more vulnerable than before. Despite its relevance and importance, resilience is a difficult concept to be applied 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 suggest that if a system can be represented as a network, network analysis can provide a tool to measure certain characteristics of resilience. This approach can be useful to design for resilient communities because the social system can be described as a network of people involved in the design and implementation of collaborative service. 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 community as well as a set of indicators to measure resilience.
Social and technical systems are inherently heterogeneous, the former being highly situated and contingent in terms of change and the latter being pre-programmed and controllable (Fischer and Hermann, 2011). The framework is designed to reflect their heterogeneity by addressing them separately from planning to problem diagnosis. At the same time, these systems should be interactive enough to have an integrated outcome to achieve the design goal. In designing for a resilient community, development and integration of the two systems are critical since resilience is affected by both social (e.g. connectivity, modularity) and technical attributes (e.g. diversity, redundancy) of the system that are interactive (e.g. high connectivity results in high diversity and/or redundancy). Therefore, problems of social and technical systems need to be addressed and managed together in generating solutions. In other words, the following question needs to be inquired for every solution proposed: "how does the solution contribute to the enrichment of social relations AND fulfilment of users' technical needs in the operation of a service?" In the framework, this occurs from the stage of objective and strategy building and continues to the design and implementation of solutions.
Integration of social and technical problems is critical to the realisation of a solution for both theoretical and practical reasons. According to the socio-technical system, social and technical systems

are two dimensions of an organisation whose relationship is mutually supportive, i.e., they integrate to increase their performance reciprocally and create a synergic effect. For example, an exchange of resources among producers creates and reinforces a social network. The expansion of the network then supports the very activity by rendering it more attractive with a greater variety of resources available for exchange. A practical reason is that any solution – whether it be a product, a service, or both – has to meet a set of basic functional (or technical) requirements (e.g. an easy access to a wide variety of local produces), and in the generation of a service concept, designers and users are often motivated and driven by an aim to fulfil them. Fulfilment of requirements in the social system (e.g. connecting the producers across geographic boundaries), on the other hand, is more challenging to address, because the symptoms are implicit and hard to define, while the manifestation of resolution is intangible, contingent, and gradual. Dealing with the social problems outside the context of technical ones may thus be perceived as abstract, unreal, and disoriented. In the framework, the problems in social and technical systems were addressed together during the strategy development. For instance, the producers' network was fragmented and sparsely connected. At the same time, there was a demand to share or exchange the resources related to production, distribution, and sales among the producers. As a solution, we proposed an online platform where users can search and contact people with the resources they need. In consequence, it will also create more opportunities for the producers to interact and collaborate with each other.

4 CONCLUSION

This paper proposes an approach to design interventions to foster resilience of a community. We noted that a collaborative community is a socio-technical system in which people's social networks and technical solutions grow interdependently. We also noted that existing design interventions tend to focus on developing technical solutions while research on fostering social networks is few. We thus propose a socio-technical framework for collaborative services which aims at understanding a collaborative community as a socio-technical system and designing for a resilient community where the optimised integration between the social and technical dimensions can be achieved. The framework is a process of (1) planning, (2) data collection and analysis, (3) problem diagnosis, and (4) objective and strategy building, and has been applied to a farmers' market in Milan to verify its feasibility. The diagnosis of the producers' relationships reveals that while a collaborative network has existed prior to the market, it is highly fragmented and modularised, based on geographic proximity and product type. It is also loosely knit, and lacks the balance of redundancy and diversity. The producers also share the need of collaborative business models around sustainable agriculture.
We draw the following conclusions from the application of the framework. First, social network analysis is a useful tool to diagnose the resilience and provides specific directions for design interventions along with indicators for measuring the resilience. Second, for theoretical and practical reasons, integrating social and technical dimensions is critical to the enhancement of resilience and realisation of feasible solutions. Some methodical issues remain to be explored in future research including how to integrate the needs in social and technical systems more effectively, and how to evaluate the effectiveness of the framework. As resilience becomes increasingly an important quality of sustainable society, an effort to bridge relevant knowledge in various disciplines to design for sustainability might be a useful attempt. In this regard, this paper contributes to design knowledge by adopting the notion of resilience established in social-ecological systems studies into development of sustainable services.

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