EthnoVis: Developing an interactive visualization as a designerly tool and process of longitudinal data analysis and communication

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Abstract: In this paper, we report on an interactive visualization that served multiple purposes and diverse roles in a research-through-design (RtD) study. The visualization is part of the study on the sociocultural factors that shape energy exchanges between households. It showcases an ethnographic data combined with quantitative logs collected for 11 months, comprising of around 1200 energy exchanges between 27 energy-receiving households and one energy-giving household in a rural village in India. In this paper, we reflect on how designing the visualization as a *process* as well as the visualization as a *tool*, played three significant roles in the RtD study. First, as a process, it helped design researchers to select, reduce, and summarise qualitative and quantitative findings and find connections between them. Second, interactive visualization as a *tool* became a means of disseminating longitudinal data. Third, interactive visualization as a boundary object enabled interaction, cooperation, and collaboration amongst designers, researchers, engineers, and anthropologists. Overall, we suggest to the design research community to consider designing of an interactive visualization as a way to make sense of longitudinal collected in a RtD project and to utilize their design skills for such creative ways of analysis and knowledge dissemination.

Keywords: Interactive Visualisation; Ethnography; Longitudinal Data; Energy Exchange; Rural India; Research through Design

BEYOND RATIONAL ENERGY MARKET

What happens when a household is given complete control of renewable energy distribution for a village?

Welcome to this interactive data visualization of energy exchanges between households at a village in India. The visualization is one of the outcomes of an **'anthropology-through-design' research** and is based on ethnographic data collected for **11 months**, comprising of around **1200 energy exchanges** between **27 energy-receivers and 1 energy-giver**. The visualization demonstrates how people's social relations influence their choices in exchange of energy. We invite you to press PLAY to see an animation of the type of returns that emerged.

VIEW

CASTE **SOCIAL RELATIONS**

TRANSACTIONS PER MONTH

Click the play button to start the visualization and see the evolution of the energy exchanges.

FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

FILTER

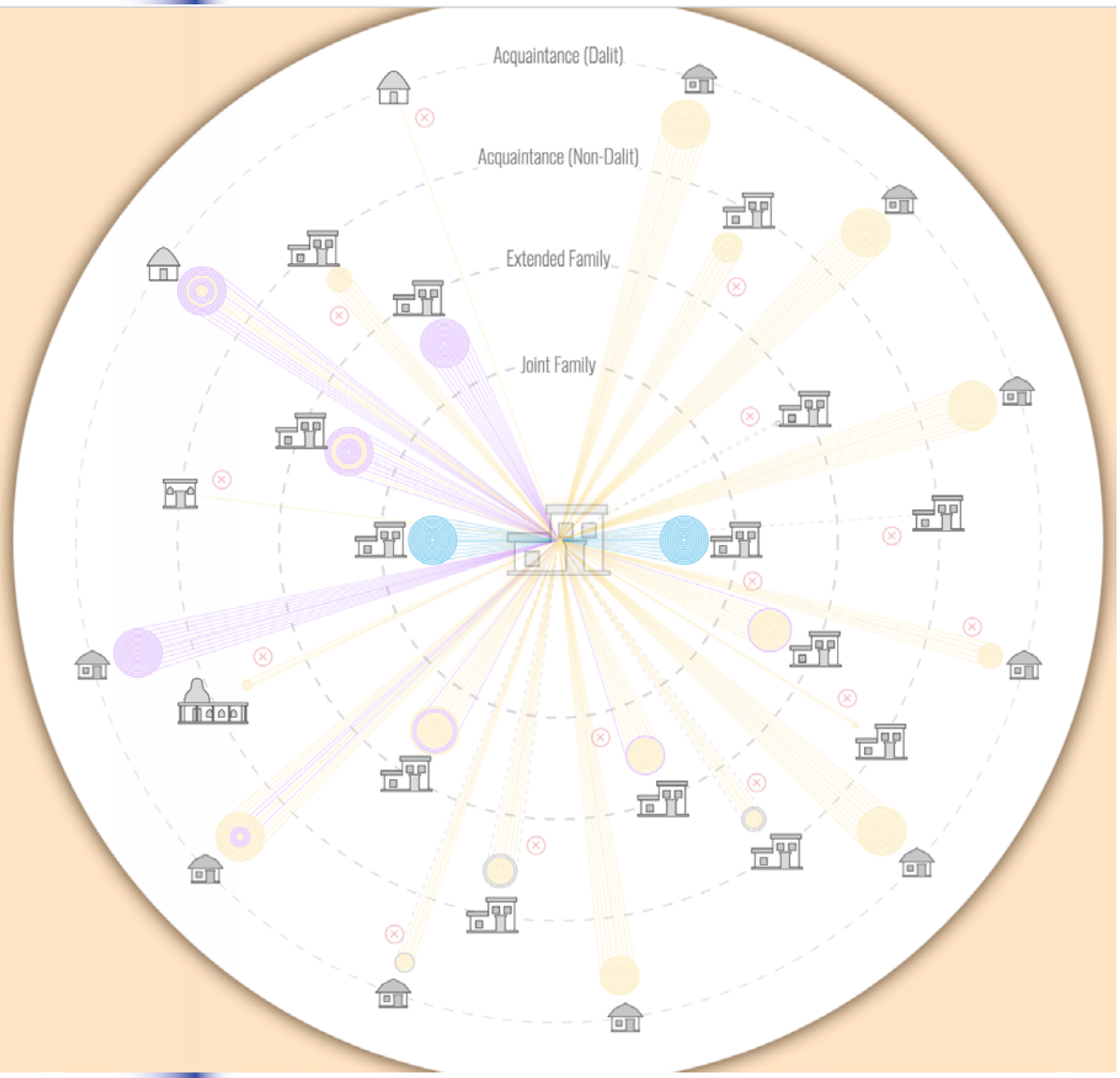
Select one of the following options to have a more detailed view

TYPE OF RETURN

Cash | In-Kind | Intangible | No Return

CASTES

Brahmin | Yadav | Teli | Ravidas | Manjhi



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Context

How can we make 'rich' longitudinal data collected and associated knowledge generated in a RtD study understandable and accessible in an engaging way?

This is the broad question this paper explores through an interactive visualization, 'Beyond Rational Energy Market,' designed and developed as part of a Research through Design (RtD) study. Often RtD study involves a collection of rich qualitative and quantitative data over a time period. We find that in the contemporary RtD literature, a discussion on relevance and process of communicating longitudinal data and its analysis in a designerly way needs more attention. This paper reports on the development of the interactive visualization that explores a designerly tool and process to analyze and communicate longitudinal data. In this paper, we first describe the RtD study, followed by a description of the process, and finally a general discussion.

Description of the RtD Study

The RtD study reported in this paper explores the social and cultural dimension of 'returns' in 'off-grid' renewable energy systems. With the increasing societal adoption of renewable energy technologies, such as solar photovoltaic panels, many 'off-grid' renewable energy systems are emerging in the global south. There are two key features of these emerging 'off-grid' renewable energy systems. First, energy is locally produced, stored, exchanged, and consumed (Singh, 2019 ; Singh et al., 2017; Singh et al. 2011a). Second, householders take an active part in local energy management (ibid.). Many of the off-grid initiatives provide access to clean energy to underprivileged population of the world in the form of an 'energy exchange' between households, where a household in a village is set as a charging station (referred as 'energy-giver') for solar products such as solar lanterns and battery packs, and other villagers (referred as 'energy-receivers') access these products by providing a monetary 'return' (also referred as 'rent,' 'payment,' tariff, and 'fee-for-service') (Adkins et al., 2010; Chaurey et al., 2012; Palit and Bandyopadhyay, 2016). See Figure 1 and Figure 2. The existing discussion on returns in such off-grid energy systems is mostly rooted in a techno-economic analysis (For instance, see, Bhattacharyya and Palit, 2016; Moner-Girona et al., 2016; Palit and Bandyopadhyay, 2016) and lacks an understanding of how these returns are grounded in the social and cultural reality of people's life (Singh et al., 2018; Singh et al. 2015b). Moreover, the existing energy literature on such returns in off-grid settings is primarily limited to discussion on monetary returns (fiat money) and lacks discussions on different types of monetary and non-monetary returns possible and people's preferences for these (ibid.).

We initiated a longitudinal RtD study with the aim to develop a sociocultural understanding of the returns and to address the following two broad research questions: What types of returns givers and receivers invoke when they are given control of an off-grid energy distribution? How are these returns embedded in the social, cultural, and economic life of the villagers? The interactive visualization presented in this paper is based on rich and long-term qualitative and quantitative data collected as part of the RtD study conducted at an off-grid village in rural India for 11 months (for details, see, Singh, 2019; Singh et al., 2018). See Figure 3.

Process

In this section, we describe the process for creating the interactive visualization as part of the RtD study. Broadly, the process consisted of the following three steps: (a) field-setup and data collection, (b) data analysis, and (c) designing the visualization. The process was iterative and the steps involved in the process overlapped.

Step-1: Field-Setup and Data Collection

The field research as part of the RtD study was conducted at Rampur village located in Gaya district of Bihar state in India. India is home to around 1.21 billion people with 68.85% of this population living in rural areas (2011 Census Report, 2011). It is estimated that approximately 300 million people in India lack access to electricity (Jain et al., 2015). Bihar is a federal state of India with 88.7% of its total population of 104 million living in villages (District Census Handbook - Gaya, 2011).

Rampur is an off-grid village, as it does not receive any electricity supply from the electricity grid. Rampur comprises of around 200 households. See Figure 4. The RtD study started with a material intervention at Rampur. The material intervention comprised of an installation of a small-scale off-grid energy distribution infrastructure consisting of solar lanterns, power-banks, LED bulbs, solar panel, and energy routers at a volunteering household (the energy-giver). See Figure 5. This infrastructure facilitated exchanges of 'solar-items,' i.e., solar

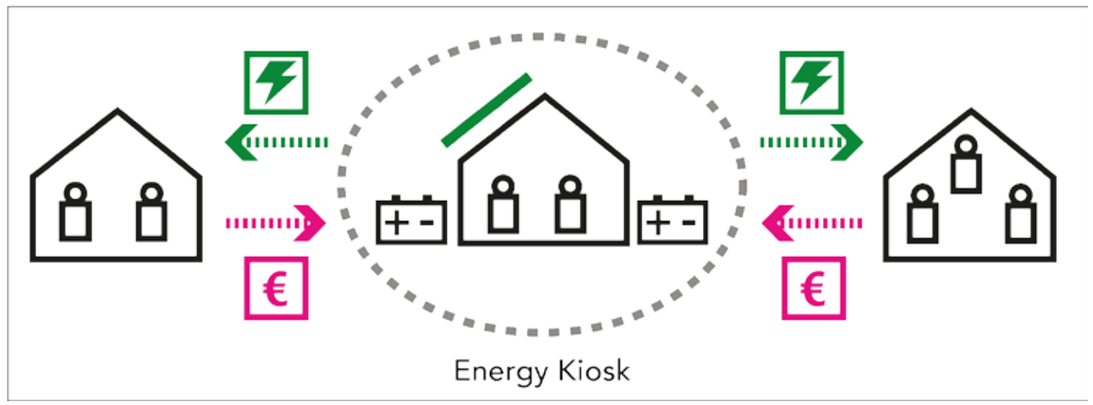


Figure 1. Conceptual diagram of energy exchange in an off-grid village.

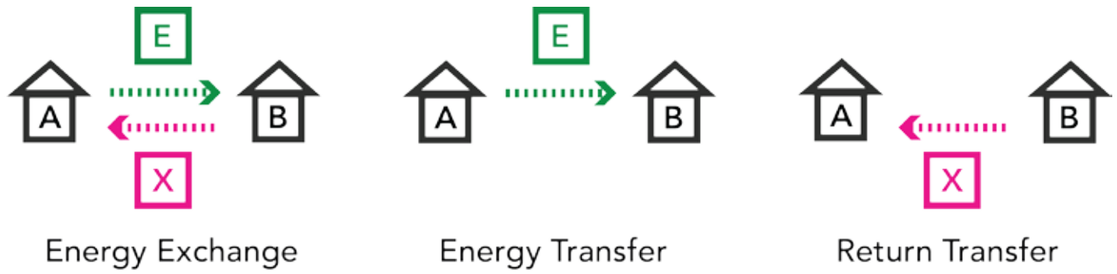


Figure 2. Conceptual diagrams of energy exchange, energy transfer, and return transfer. An 'energy transfer' is a physical or figurative movement of energy units (E) either through cables or storage devices such as batteries from an energy-giver (A) to an energy-receiver (B). In contrast, a 'return transfer' or a 'return' is a counter-movement of an entity X from the energy-receiver (B) to the energy-giver (A) for the energy units provided.

<Figure 3. Map of India with Bihar State and Gaya district highlighted.

lanterns, LED bulbs and power banks, between households in the villages. In total, thirty-three solar-items, i.e., fourteen LED bulbs with power banks and nineteen solar lanterns were available for use and exchange in the village. The total cost of installation of energy distribution infrastructure was 40,000 Indian Rupees (INR) (around 560€).

The household of energy-giver had complete control of the energy infrastructure installed and freedom to structure returns, as they desired without any involvement of the design researcher/ ethnographer (the first author of this paper). The energy-giver and energy-receivers negotiated with each other to create rules and configure and re-configure the energy exchanges that emerged. A typical performance of energy exchanges that emerged at Rampur through the use of the material infrastructure was as follows: an energy-receiver visits the energy-giver's home, obtains an assigned and charged solar-item, judiciously uses the solar-item for few days, once the solar-item was drained of the charge, the energy-receiver brings the solar-item back to the energy-giver's place for charging, and provides a return as mutually constituted by the energy-giver and the energy-receiver. See Figure 6.

At this juncture, it is important to clarify that the material intervention aimed to enable energy exchanges between households for the research investigation to build a sociocultural understanding of returns. Hence, the primary purpose of the material intervention was to facilitate knowledge generation. In this regard, our approach aligns with the discussion in RtD where an 'artifact' (the material intervention in our study) is considered as central to the process of knowledge production (Stappers, 2014; Stappers et al., 2015; Stappers and Giaccardi, 2017).

The energy exchanges that emerged at Rampur were ethnographically investigated for 11 months (1 February – 31 December 2016). The details of ethnographic methods used in this research were published in earlier publications (Singh, 2019; Singh et al., 2018; Singh et al., 2017). Hence, here, we provide only a brief overview of the methods. See Figure 7. We investigated energy exchanges between the energy-giver and each energy-receiver using a family of ethnographic methods, such as participant observation (DeWalt and DeWalt, 2011), interviews and conversations (Bernard, 2011), and field-notes (Emerson et al., 2011). A self-reporting diary was provided to the energy-giver to document information about energy exchange. Such diary-based approaches are beneficial for triangulation (Alaszewski, 2006). The diary entries were discussed and crosschecked during interviews with the givers and receivers. A hand-drawn exchange mapping approach was utilized to (a) to create a spatial map of the energy exchanges, (b) utilize the map to inquire about social relationships between the energy-giver and energy-receivers, and (c) to cross-check preliminary findings from other ethnographic methods and analysis of self-reporting diary entries. The hand-drawn exchange mapping technique used in this research draws inspiration from various visual methods proposed by the Participatory Rural Appraisal (PRA) approach. PRA is a participatory research methodology that utilizes various visual methods to build an understanding of participants' social world (Kumar, 2002; Singh, 2011a; Singh, 2011b). The energy givers and their family members collaboratively constructed the map.

Step-2: Data Analysis

During the study, 27 distinct households at Rampur became energy-receivers, i.e., received solar-items from the energy-giver. Around 1600 energy exchanges were documented in the self-reporting diary. Overall, the study led to the creation of rich ethnographic data comprising of qualitative details and quantitative logs of energy exchanges. We conducted in-depth qualitative data analysis of the field-notes, diary entries, interview transcripts, and hand-drawn exchange maps using NVivo, qualitative data analysis software. This qualitative data analysis consisted of iterative cycles of coding, 'memoing' and creating thematic texts (Emerson et al., 2011; Saldaña, 2016). Coding is relevant for summarizing, reducing and condensing the data (Saldaña, 2016). 'Memoing' captures the analytical reflection, emergent categories, and themes from the data analysis (Bazerley and Jackson, 2013; Emerson et al., 2011; Saldaña, 2016). Quantitative data captured in the self-reporting diary, such as the amount of return provided by each energy-receiver, monthly dues, number of chargings done, was digitized and analyzed using Microsoft Excel. We crosschecked the emergent findings with the energy-giver and energy-receivers by telephonic and face-to-face interviews.

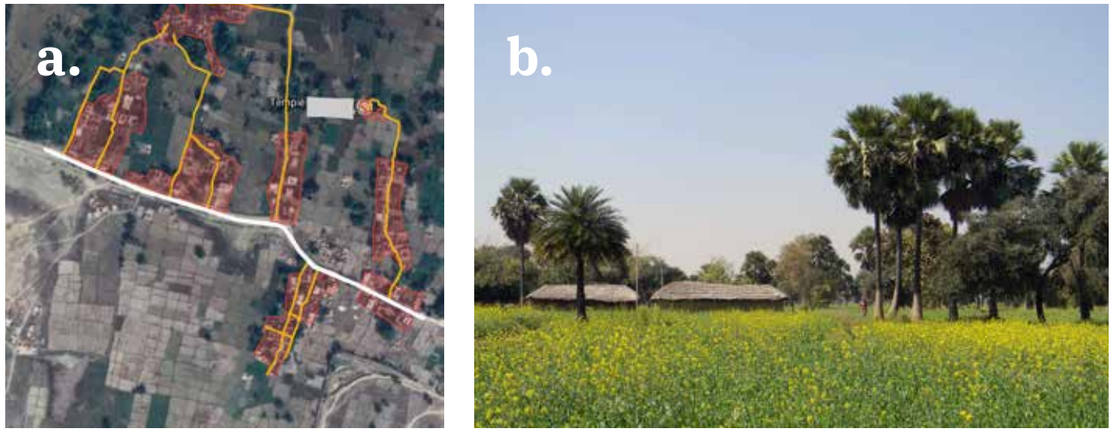


Figure 4 a, b. Photo: Abhigyan Singh. (a) Google map image of Rampur. (b) Photograph of Rampur.

Figure 5 a, b, c, d. Photo: Abhigyan Singh. Energy Distribution Infrastructure. (a) Solar Panel. (b) Energy Router, Power banks, and Solar Lanterns. (c) LED Bulb and Power bank. Each solar item was imprinted with a unique numeric code to facilitate tracking of energy exchanges.

Along with the use of software, we also used various visual means, such as sketches, mind-maps, and diagrams, for analyzing the field observations. See Figure 8. These visual means were not end-points of the analysis instead they were crucial drivers of the data analysis. These visuals also shaped the designing of the interactive visualization and were crucial elements of knowledge construction.

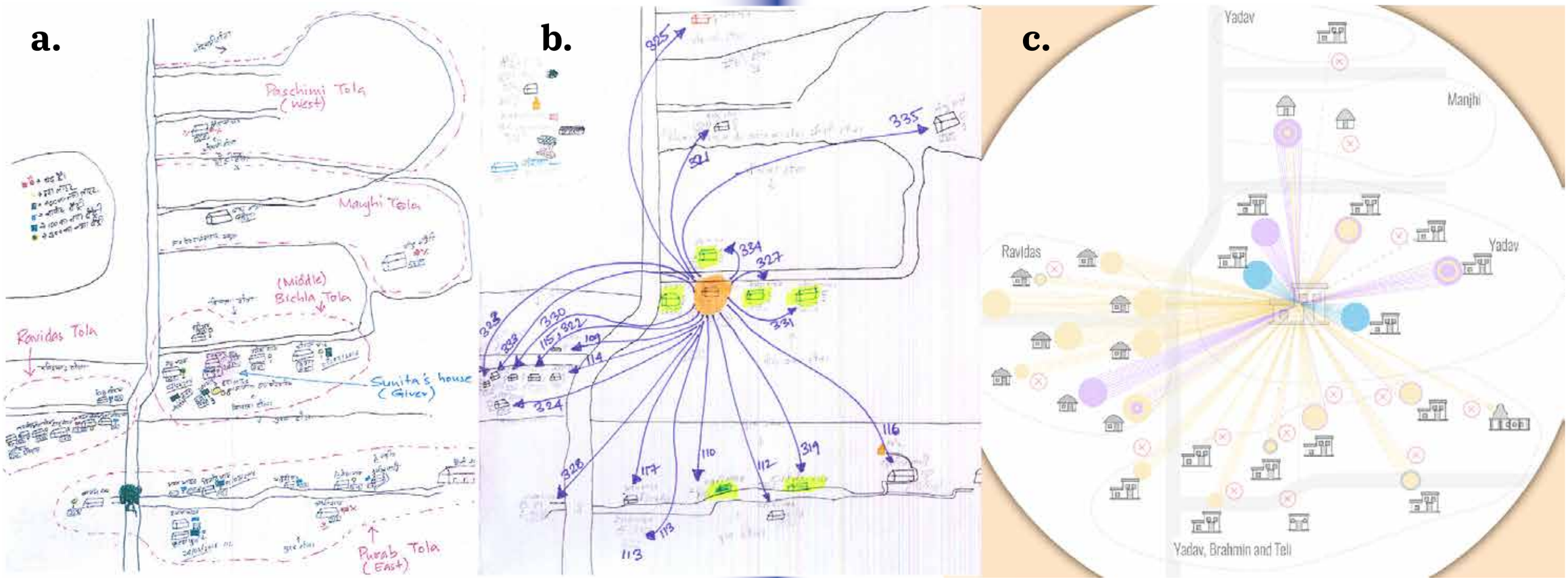
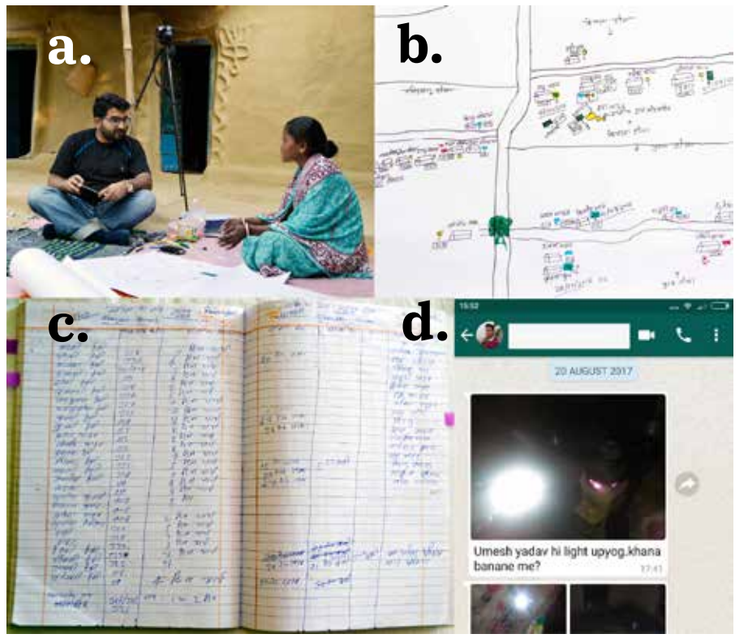


Figure 8 a, b, c. (a) and (b) are samples of visual artifacts created during the design process of the visualization. These are scans of a hand-drawn exchange map made by the villagers with annotations of energy exchange data by the design researcher for the purpose of analysis. (c) is the resulting screen in the information visualization. Notice how various visual elements from the sketched elements result in the final screen design.

<Figure 6 a, b, c, d. Photo: Abhigyan Singh. Various benefits of the solar-items. (a) Lighting interiors of a house. (b)Cooking after sunset. (c) Mobile phone charging. (d) Mobility after sunset.



<Figure 7 a, b, c, d. Photo: Abhigyan Singh. Various research methods used in the study. (a) Interviews and discussions. (b) Hand-drawn exchange mapping. (c) Self-reporting diary. (d) Digital media for self-reporting.

Step-3: Designing the Visualization

In the process of analyzing the data for the visualization, the design researcher distilled various characteristics of returns into three conceptual categories. These three types of returns were labeled as in-cash, in-kind and intangible returns. See Figure 10. Furthermore, the design researcher analyzing the temporal span of the three types of returns recognized a link between people's preference for a type of return and nature of their social relations and caste identities. The social institution of 'caste' is an aspect of Indian social structure and plays a significant role in everyday life of Rampur. We decided to design a visualization that communicates the temporal aspect of the longitudinal ethnographic and qualitative data in an interactive and engaging way.

We invited a user-experience designer and a web developer to join us (design researchers) to become part of the team that co-created the visualization following an iterative process. Overall, we decided to implement the following key design features and associated strategy to provide rich visualization of the temporal dynamics of people's preferences of type of return in connection to their caste identities and social relations. See Figure 9 and Figure 11.

Timeline: A central feature of the visualization is a 'timeline.' We designed and implemented the timeline to illustrate changes in returns over 11 months of the study. When a user clicks on the 'play' button, the visualization starts an animation displaying the temporal spread of the data. A user can also click on a particular month/s in the timeline to view the configuration of returns invoked in that particular month. This feature allowed a user to compare returns between various temporal spans.

Filters: We implemented two filtering options, i.e. 'type of return' and 'caste,' to facilitate users to explore the longitudinal data and to gain more focused insights from the data. The filters enabled a user to combine options within the 'types of return' and 'caste' filters. This facilitated users to probe and see patterns, such as, use in-kind returns by different caste group, or what is the predominant type of returns utilized in energy exchanges with a particular caste group.

Layers: We decided that the information visualization by default would visually present an overview of energy exchanges. The descriptive and explanatory details of energy exchanges between the energy-giver and a particular energy-receiver will be displayed in a descriptive layer only when a user clicks on a house-icon in the visualization. The descriptive layer provided details such as name, caste information, entities constituting a return, nature of energy-receiver's social relation with the energy-giver, and a brief explanation of energy exchanges or any significant event.

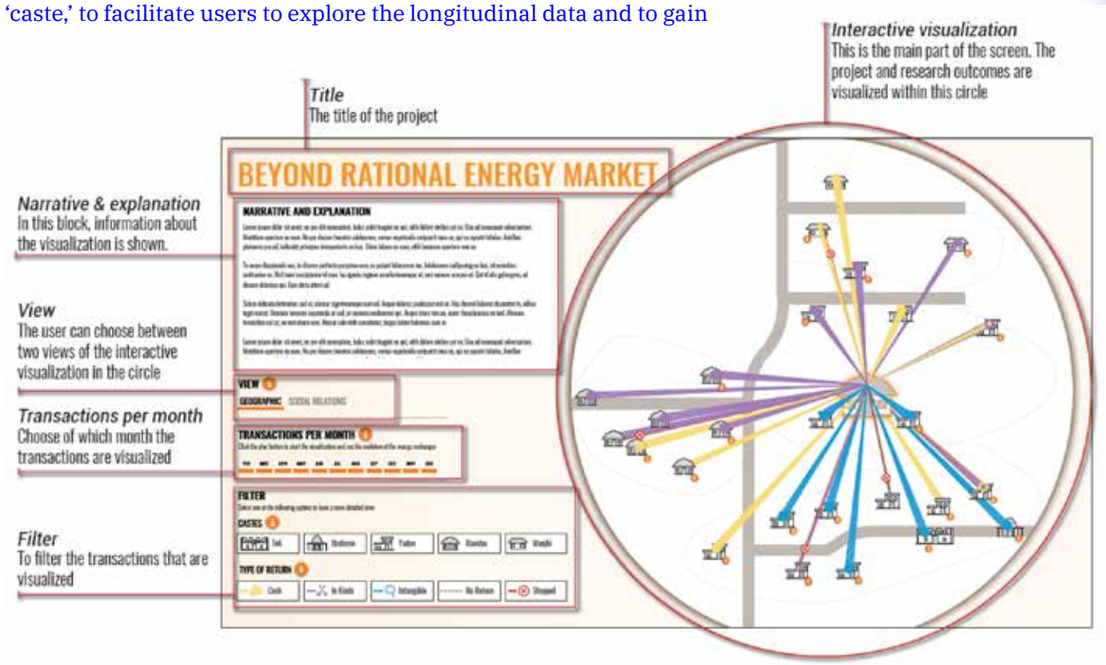


Figure 9. A wireframe of the visualization indicating its various elements.

Views: To highlight the role of two factors, i.e., social relations and caste identities, in people's preferences for a type of return, we implemented two distinct 'views' in the visualization. These are a 'Social Relations' view and 'Caste' view. See Figure 12. The 'Social Relations' view showcases the type of returns used concerning social relations between energy-giver and energy-receiver. 'Caste' view showcases the data based on caste profiles of the energy-givers and energy-receivers. A user can switch between the two views of the visualization by clicking on the respective labels.

Overall, the interactive visualization showcases, in a designerly manner, that there is more to energy exchanges and returns than what dominant rational techno-economic perspectives describe. The visualization enables an understanding that energy exchanges in such an energy system are shaped by diverse forms of social relations, cultural values, and incorporate both monetary and non-monetary returns.

<Figure 10 a, b, c, d. Some examples of returns. Photo: Abhigyan Singh. (a) Energy-giver calculating in-cash return provided by an energy-receiver seen in the background. (b) Access to a tractor as in-kind return. (c) Two spades made by a receiver as a return. (d) Access to a diesel-powered pump-set as a return.

<Figure 11 a, b, c, d. Some of the design features of the interactive visualization.(a) Descriptive Layer. (b) Views. (c)Timeline. (d) Filters.

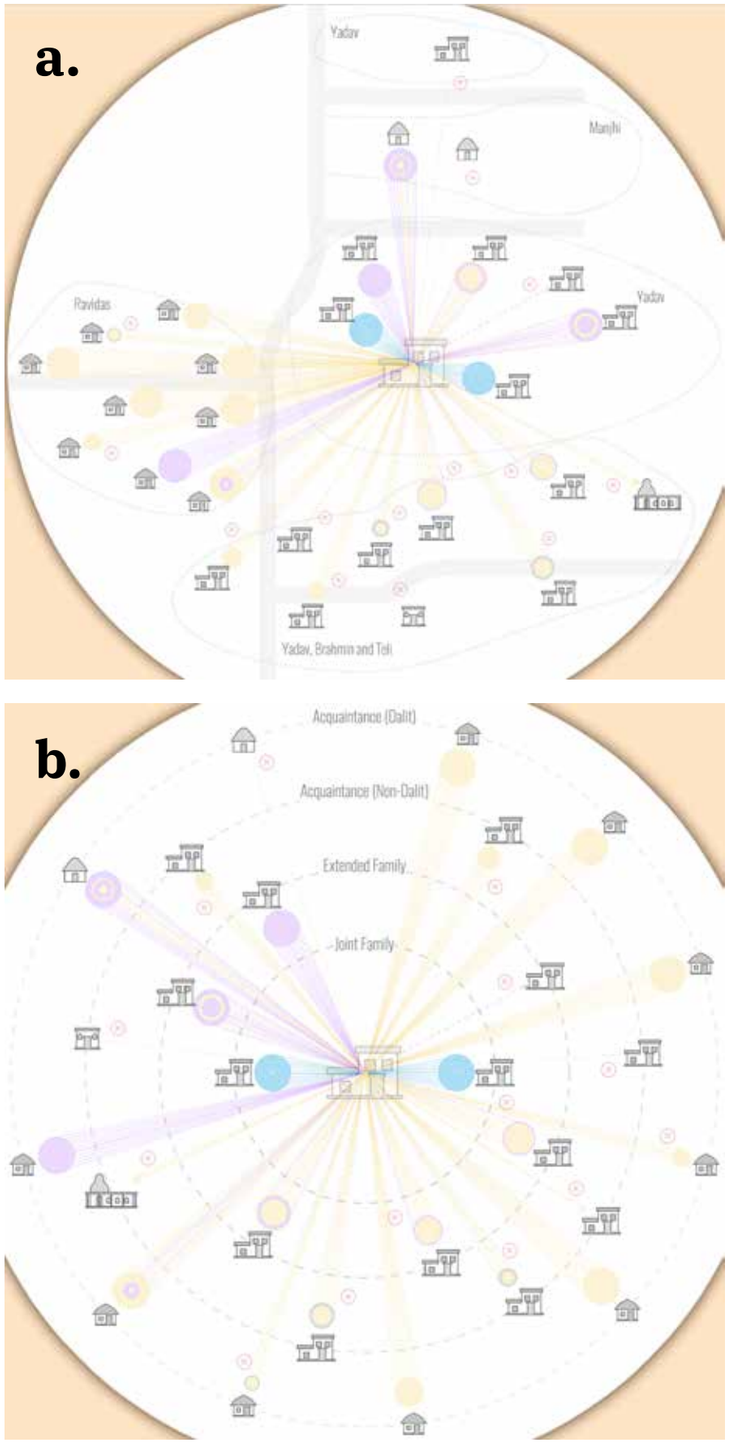


Figure 12 a, b. (a) Caste View. (b) Social Relations View.

Discussion

In this section, we reflect on how designing the visualization as a process as well as a tool, played three significant roles in the RtD study.

Designing of visualization as a process of data analysis

The process of working towards the visualization helped us to select, reduce, and summarize qualitative and quantitative data and findings as we forced ourselves to design a simple visualization in a limited visual space. The process of designing the visualization helped in abstracting from particular ethnographic descriptions leading to the identification of three categories of returns, i.e., in-cash, in-kind, and intangibles. Further, this process helped us to conceptualize association between preference for a type of return with nature of social relations between energy-giver and energy-receivers and their caste identities. Furthermore, the temporal analysis done as part of the designing of the visualization helped us in developing a better understanding of variations in uses of returns over time, which would have been very difficult to realize otherwise. For instance, some energy-receivers consistently utilized the same type of returns, while some other receivers switched between different types of returns with changes in their life situations.

Moving along with the designing of the visualization, we initiated writing of a manuscript of a scientific journal article. The temporal analysis of the longitudinal data in the process of creating the visualization eventually led us to development of a conceptual model of 'returns continuum' that was published in a journal in the domain of energy studies (see, Singh et al., 2018). Hence, we recommend to designers and design researchers to consider designing visualization and associated temporal analysis as a useful approach for condensing, selecting, reducing, and analyzing longitudinal data for oneself and others. We consider our recommendation to be in-line with developing arguments in RtD literature where visual materials are considered to have an assistive, summarizing, provocative, speculative, and theoretical role in design research (Stappers and Giaccardi, 2017).

Interactive visualization as a tool of disseminating longitudinal data

The interactive visualization was exhibited at Mind the Step exhibition at Dutch Design Week 2017 where a large number of visitors interacted with it (see Figure 13). Similarly, the visualization has been part of various presentations made by the authors. The interactive visualization enabled dissemination of knowledge in a creative, engaging, and interactive way to a diverse audience consisting of people from academia, business, government, activists working in the energy sector, designers, and common public. Various users of the visualization after interacting with the visualization speculated on their choices of utilizing different types of returns if such an energy system becomes a reality in their neighborhood. In this way, the visualization also served as a useful tool for the general public to reflect on future energy possibilities of their neighborhoods. These reflections by people provided useful comparative and notional insights to the design researchers. The interactive visualization as a tool became a useful means of disseminating longitudinal data. The interactive visualization has the ability to stimulate curiosity amongst the users and towards a temporal exploration of longitudinal data to gain insights. The built functionalities of timeline clubbed with filters, and layered descriptions enabled users of the visualization to interact and appreciate the temporal spread of data spanning eleven months. Similarly, utilizing interactive visualization as an approach has the potential to make various patterns in longitudinal data to become visible upfront, which facilitates communication of various complex insights (see Figure 14). For instance, many (non-academic) users, such as policymakers and people from the industry have remarked on how the visualization has made them quickly see the key findings and patterns. In this regard, the visualization was successful in making the 'rich' longitudinal data digestible for them. Similarly, layering of data provided different levels of engagement ranging from numeric descriptions to rich contextual explanations.

Interactive visualization as a boundary object

As already mentioned in the previous section, the visualization was exhibited and presented at various venues and to diverse audience group. In these discussions and meetings, the visualization was interpreted in different ways. For instance, the visualization was considered by many users as a 'finished product' or an 'outcome' of Research through Design study, while simultaneously it was seen as an 'unfinished research tool' or a 'probe' for researchers to gather reflections from people and for further Research through Design activities. Similarly, a computational social scientist viewed it as a 'base' model for developing large-scale agent-based simulations. In total, the visualization facilitated multiple and varying interpretations by experts from different disciplines. Hence, the interactive visualization as a boundary object provided 'interpretative flexibility,' a feature of boundary objects (see (Star, 2010)). Its meaning and use was negotiated and appropriated in different ways by different audience groups (for 'boundary object,' also see (Star and Griesemer, 1989)).

Interactive visualization as a boundary object facilitated interaction, cooperation, and collaboration amongst designers, design researchers, engineers, and anthropologists. It mediated in developing new research and design ideas. For instance, the first author, using the visualization as a base started a collaborative project that aims to design a blockchain technology based payment solution for decentralized energy systems. At the time of writing of this paper, the authors are working with these domain experts to develop a concept for research and design proposal (for 'boundary object' and design research, see (Singh, 2011a; Singh, 2011b)).

Conclusion

This paper reported on the development of an interactive visualization that explored a designerly tool and process to analyze and communicate longitudinal data. The visualization was developed to

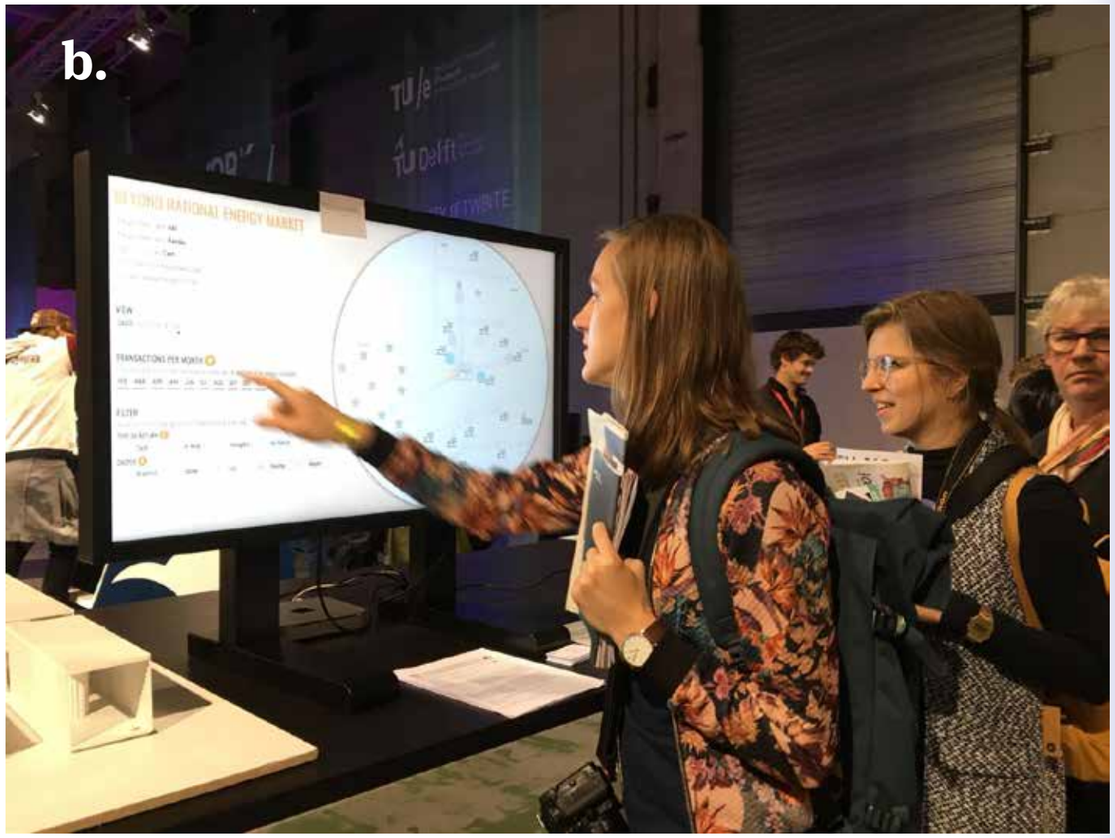
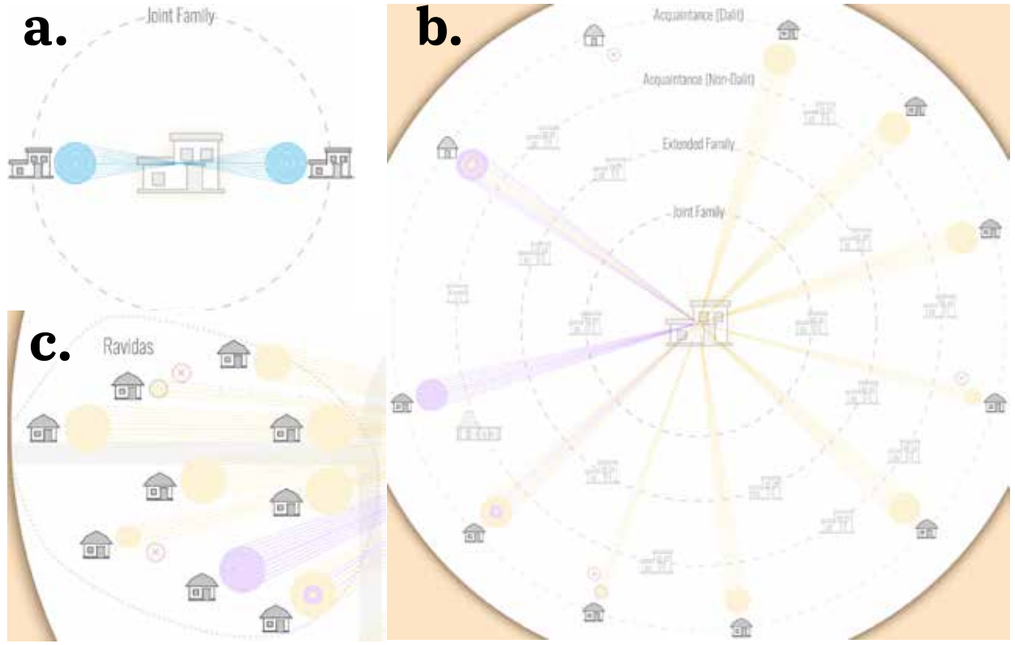


Figure 13 a, b. (a) The visualization exhibited at a European Design Festival. (b) Some vistors at the design fesitival interacting with the visualization.



explore how a designerly tool and process could help in analyzing temporal aspects of longitudinal data in RtD studies. We conclude that such process and outcome has multiple benefits such as it could facilitate focused data analysis, serve as an accessible dissemination tool and means for collaboration. Overall, we suggest to the design research community to consider designing of an interactive visualization as a way to make sense of longitudinal data collected in a RtD study and to utilize their design skills for such creative ways of analysis and knowledge dissemination.

Figure 14. Examples of patterns discoverable through the visualization. (a): prominence of intangible returns with members of joint family. (b): Predominance of in-cash returns with Ravidas Caste group. (c): types of returns utilized with households belonging to 'Dalit' caste (lowest caste group).

Description of artifacts to be exhibited at RTD 2019

We will exhibit the Interactive Data Visualization on a 42-inch touchscreen (987 x 578 x 74.5 mm; 24.6 Kgs) at the RtD2019 conference. A visitor will be able to interact with the visualization and gain several insights by using 'filters,' 'views,' and clickable items present as part of the visualization.

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