Designing for the Infrastructure of the Supply Chain of Malay Handwoven Songket in Terengganu

Min Zhang, Corina Sas
School of Computing and
Communications
Lancaster University, UK
{m.zhang18, c.sas}@lancaster.ac.uk

Zoe Lambert
English and Creative Writing
Lancaster University, UK
z.lambert@lancaster.ac.uk

Masitah Ahmad
Faculty of Information Management
Universiti Teknologi MARA, Malaysia
masitah@ns.uitm.edu.my

ABSTRACT

The growing HCI interest in developing contexts and cultural craft practices is ripe to focus on the under-explored homegrown sociotechnical infrastructures in such contexts. This paper explores the creative infrastructural actions embedded within the practices of songket's supply chain in Terengganu, Malaysia. We report on contextual interviews with 92 participants including preparation workers, weavers, designers, merchants, and customers. Findings indicate that increased creative infrastructural actions are reflected in these actors' resourcefulness for mobilizing information, materials, and equipment, and for making creative artifacts through new technologies weaved within traditional practices. We propose two approaches to design in this craft-based infrastructure. First, we explore designing for the social layer of infrastructure and its *mutually advantageous exploitative relationships* rooted in culture and traditions. Second, we suggest designing for *roaming value-creation artifacts,* which blend physical and digital materializations of songket textile design. Developed through a collaborative and asynchronous process, we argue that these artifacts represent less-explored vehicles for value co-creation, and that both them and their sociotechnical infrastructure as emerging sites of innovation could benefit from HCI research.

CCS CONCEPTS

• Human-centered computing • Human-centered computing~Human computer interaction (HCI) • Human-centered computing~Empirical studies in HCI

KEYWORDS

Infrastructure, HCID, crafts, songket, cultural heritage, gender, exploitation, roaming value-creation artifact.

1   Introduction

Che Ku weaves on her grandmother's wooden loom in the front porch of her house. Just down the road, her son is building his own home, supported by her earnings. She is the fourth generation of weavers in her family, and she had often watched her mother and grandmother as they weaved the fine threads using the traditional patterns they knew by heart. Che Ku was twelve the first time she sat down at the wooden loom. Weaving was already in her blood. Until a few years ago, she worked for a merchant who supplied her with the threads, the design papers, and the warp boards prepared by another woman. The merchant paid a small amount for her labor, which was never enough for the one or two months it took her for each piece. But when her husband became seriously ill, she applied for a government business grant to buy her own threads and materials. Now, she owns her own business, outsources the work to other skilled village people and finds her customers. She has regular customers in the local market, but she also sells to a merchant in Kuala Lumpur the songket fabric that are made to order from unique designs. She posts pictures of songket on *Facebook* and *Instagram*, and uses *WhatsApp* to communicate with customers, but a relationship needs to be set up, developed, and maintained, preferably over an iced coffee. Once established, trust is never broken. Che Ku is a part of the emerging rural entrepreneurial weavers in Malaysia who just like seasoned merchants are starting to use mobile and social media technologies for these daily exchanges of their business.

Figure 1. A songket handloom in a weaver's house.

Songket is a woven fabric handcrafted for more than two centuries in South Asia, where the knowledge and skills of hand weaving have been passed down through generations [46]. This unique fabric is woven on a handloom by inserting the colored metallic threads through the silk or cotton threads [28,46] (Figure 1). While traditionally, songket fabric was worn

by royalty and court members [46], today, the exclusive design of handmade songket makes it a desirable fabric worn by most Malaysians at special occasions [29]. Despite its demand, handmade songket weaving is an increasingly endangered practice due to the machine-made songket rising in international South Asia market, and the decreasing interest of younger generations in learning the craft [28,34].

We argue that the growing HCI interest in developing contexts, cultural heritage, and crafts and practices offers a fertile, yet under-explored research space. Of particular interest here is the investigation of local infrastructure supporting this practice, and the emerging roles of mobile and social network technologies transforming it. The grassroots integration of new tools into traditional cultural practices has just started to be explored with findings indicating resourceful and creative infrastructural actions for online selling and buying of ready-made consumer goods in developing contexts [16]. We argue that infrastructures also supporting the making of products, particularly cultural heritage ones such as songket, can offer fresh insights into such creative actions. In turn, these could inform more sensitive approaches for designing technologies that could be seamlessly weaved within such creative infrastructures in developing contexts. In this paper, we report interviews with 92 participants representing key actors in songket's supply chain in Terengganu, Malaysia, well-known for its songket's unique colors, motifs, and quality [12]. We interviewed 28 rural weavers, 26 merchants, 6 songket designers, 2 preparation workers, 3 government staffs working on songket-related programs, and 27 customers. Our study addresses the following research questions:

- What are the *novel tools* that these key actors are engaging with?
- What *creative infrastructural actions* do each of the main actors engage with in order to integrate these new tools within the songket's supply chain?
- What *challenges* do these actors face and how could these be addressed?

2 Related Work

For this work, we draw from prior research on developing contexts and cultural heritage, and crafts and practices in HCI.

2.1 HCI for Developing Contexts

HCI for developing contexts (HCID) [1,2] is a growing research area exploring how technologies can contribute to global socioeconomic development [49] by addressing the needs of marginalized populations [4]. Much of such work has focused on the support for economic empowerment particularly of rural women [14], provision of education and health [19], development of local infrastructure [16], or preservation of cultural heritage [47].

Previous work has also emphasized the value of information and communication technologies (ICTs) and in particular mobile phones [19] for sustainable development [50] through the increase of the labor market [30], and more effective communication infrastructures [18,21]. ICTs also contribute to women's empowerment [30] by facilitating the selling of crafts. Internet sites such as ONE store[1] and Indigo Africa[2] support women makers to bring their sweet-grass baskets onto the global online market. Such interventions require sensitive design as women in impoverished contexts are particularly challenged when it comes to access ICT-based support [20,24], due to limited confidence, skills, or their time often filled by domestic demands [24].

Apart from scholarly work targeting specific technological solutions, an emerging HCID research agenda argues for engaging with the creation of sociotechnical infrastructures [5,27,39,40]. Such work emphasizes the importance of local physical environment and human infrastructure [38] and the sensitivity needed to account for the cultural asymmetry between the Western researchers and targeted population in these developing contexts [45,51]. Jack and colleagues [16] explored such an infrastructure of online selling shops in the capital city of Cambodia [16], which integrates *Facebook* and mobile payment system with older tools such as paper receipts, featured phones, public buses, and motorcycle delivery services. Authors argued for the value of exploring such homegrown sociotechnical systems where people show resourcefulness and creativity in integrating novel technologies into older cultural practices [16].

We agree with the importance of studying these organically emerging infrastructures in order to inform more responsible design of HCID technologies. Our study extends Jack and colleagues' [16], moving the focus on creative infrastructural actions from online selling and buying of ready-made consumer goods to the distributed making, selling, and buying of ingenious heritage crafts.

2.2 Crafts and Practices in HCI

A growing body of HCI work has examined the digital innovation within traditional handicraft both within Western [8,10,31,48] and developing contexts [47,57]. Such work has explored digital technologies for accessing and storing tangible and intangible cultural heritage [10], particularly in interactive museums [31] to support richer user engagement. Other researchers argued for increasing cultural identity [47] in order to protect cultural heritage. For example, Tan and Blevis prototyped a system to assist villagers to build pride in cultural craft by integrating maps with QR narratives of the craft [47]. With respect to the cultural heritage of songket fabric, Zhang and colleagues [57] conducted interviews with songket weavers in rural Malaysia. Their findings indicate several key actors in songket making practices and the challenges faced by

different types of weavers. With its emphasis on weavers, their work sheds little light on the infrastructure of songket's supply chain, or on how key actors engage in creative actions integrating new tools within this traditional practice.

A rich strand of HCI work has focused on practice-based approaches to research and design [32]. In such work, practice is defined through bodily activities and physical objects [33], or people's competencies of interacting with specific materials through which they develop meaning [6]. While much work has focused on the DIY practices of *making* and *repairing* of both non-electronic [52] and electronic devices [36,41], other scholars have looked at traditional handicrafts such as weaving [37] or knitting [35] with the intention of unpacking their material qualities and their value for the development of hybrid computational objects [42]. Such practice and materiality-based approaches of situated crafts have started to challenge the distinction between the individual and the social, the physical and the digital context [42]. New hybrid computational objects have been designed to explore the augmentation of traditional craft practices with computational capabilities. For example, *Stitch Sampler* is a sew-able musical instrument and craft platform that generates digital tones during hand-sewing when the needle enters the fabric [42], while *Spyn* allows integrating digital messages within the specific places within the knitted fabric, in order to support knitters' communication and reflection on their practices [36]. Another example is *Electronic Quilt*, materializing the invisible work of female weavers for dense storage of information on so-called core memory, i.e., the array of ferrite magnets, a practice consisting of passing a wire through or around magnetized cores [37].

Such illustrative projects suggest an emphasis on digitally augmented craft practices, usually in Western contexts where they are pursued mostly for pleasure, communication, and reflection purposes. However, we know little of how similar gendered craft practices such as songket weaving are digitally augmented in the organically emerging sociotechnical infrastructures in developing contexts, serving more utilitarian functions such as earning an income, empowering women, or preserving cultural heritage.

3 Methodology

The study was conducted over one year within nine villages in Terengganu and involved contextual semi-structured interviews with 92 participants: 28 weavers (26 female, 2 male; age range 25-80, median 45), 26 merchants (20 female, 6 male; 32-75, 50.5), 6 songket designers (4 female, 2 male; 27-64, 36), 2 preparation workers (2 female; 50-56, 53), 3 local government staffs working on songket-related programs (2 female, 1 male; 42-55, 43), and 27 customers (22 female, 5 male; 18-59, 43). All participants were educated at the primary school level and above, and owned a mobile device. Half of the weavers and all other participant groups use smartphones (age

range 25-45, median 39). All participants except 47% of weavers have access to the Internet on their mobile devices. The majority of rural weavers (83%) have bank accounts, but only 8% have online payment experience.

Weavers, merchants, preparation workers, songket designers, and craft-related sector staffs were recruited with the help from the national handicraft government sector Kraftangan and its local branch in Terengganu. Customers were recruited in carnivals and shops in Kuala Lumpur, or via a Malay University emailing system and whiteboard posters. In order to become "*familiar faces*" and "*trusted intermediaries*" [3], prior to completing the interviews, Malay researchers engaged in multiple visits to participants' sites. These semi-structured interviews were conducted in Malay language and face-to-face in participants' preferred settings such as weavers' and designers' houses, merchants' shops or workshops, or customers' houses or offices. Such contextual interviews also allowed for the observation of the songket making practices, including preparation work, songket textile design, and weaving. 7 participants identified being passionate about songket heritage were interviewed by a Western researcher accompanied by a Malay translator. In addition to interviews, we also employed observations of merchants and customers in a local market in Terengganu over two days. Each interview lasted around two hours, was audio recorded, translated, and fully transcribed in English. Each participant was rewarded with RM 50 (Malaysian Ringgit) for their time.

In order to explore the value of technology for the songket's supply chain and its practices, we asked each actor group about their materials, tools, and logistics. We also inquired about their motivations for engaging in songket practices, their challenges, and perspective regarding the songket practice in Malaysia. The online ethnography was also adopted for exploring merchants' *Facebook* business pages and *Instagram* accounts.

4 Context

Terengganu is one of the three states of the East coast of Peninsular Malaysia, and is inhabited by 1.2 million people. With a predominant agriculture-based economy, Terengganu experiences a high incidence of lower income and poverty compared to the whole country [44]. Although the Malay culture is collectivist and patriarchal [13], previous work suggested a rather high status of women in Peninsula Malaysia as they tend to be economically active in trade and agricultural production [15]. With a steady annual growth, the importance of the textile industry has been recognized through increased governmental investment [25]. This has also focused on skill training for rural development, including Terengganu, which is recognized for the quality and distinct songket design [12]. Despite such initiatives, most songket weavers are women in rural areas earning a very low income, often below the poverty line [44]. Similar to the rest of Malaysia, Terengganu shows

high cellular phone penetration rate, which however is lower in rural areas [23] where feature phones tend to be used mostly for text message and phone calls. With connectivity available nationwide, Internet use is also high, particularly for the social network, such as *Facebook* and *Instagram*, and e-commerce, still with considerably lower levels in rural areas [24]. While people between 20 to 39 years old show increased interest in technology adoption, those over 40 have less interest [24]. In addition, although most Malaysians own a bank account, those in rural areas make little use of online payment [11].

5 Findings: Sociotechnical Infrastructure of Songket Practices

This section describes the songket's supply chain and its infrastructure. We illustrate the findings with quotes from participants' interviews, i.e., C1-C27 for customers, D1-D6 for designers, G1-G3 for government staffs, M1-M26 for merchants, W1-W28 for weavers, and P1-P2 for preparation workers. We focus on the power asymmetry among different actors and the challenges faced by them.

Study findings focus on how Malaysians use ICTs and social media technologies for songket's supply chain and its practices. A striking finding, however, is the high number of diverse materials and tools that many social actors engaged with within the infrastructure. Such materials and tools represent a creative blend of traditional ones such as handlooms and other small equipment, as well as threads, dyes, papers showing songket design, feature phones, and contemporary ones such as computers, smartphones or tablets. Within the supply chain, raw materials such as threads and dyes are bought mostly in local shops but also online through websites such as *Aliexpress*, which provide delivery services and online payment facilities. Songket weaving also requires equipment such as a wooden warp board which is bulky and heavy, hence bought mostly from local villagers' for which people tend to pay cash, and travel to collect by cars.

Apart from these raw materials and equipment, another key material serving as input into the songket making process is the *songket design*. This is a creative artifact that tends to be outsourced to skilled artisans and travels among other actors throughout the entire supply chain. A songket design is materialized into a range of forms: from hand drawings on grid papers, computer-supported drawings, copies and prints of drawings on grid paper, to being embedded within the warp board and finally songket fabric.

As a precious textile that people prefer seeing and touching before buying, songket's practices are arguably strong candidates for resisting technology adoption. The buying and selling of songket takes place either online but mostly in physical marketplaces or shops, or at national craft venues such as carnivals. A growing number of merchants have a presence on *Facebook* or *Instagram* for their individual business to showcase their songket stocks, and on *WhatsApp* to engage privately in one-to-one communication with their customers. People bargain and barter, and after the agreement is reached, payment tends to be made via bank transfer, while the delivery is done by courier services such as *POS express*. Most Malaysians still use the cash payment, as "*the material supplier will trust cash more than credit card or other transfer such as check*" [W27]. For logistics that facilitate the movement of these tangible materials and products among the actors, people rely on public or personal transportation including buses, private cars or motorbikes, with private vehicles being preferred due to the underdeveloped transport system. They also rely on delivery services such as *POS express*, or if they can afford, flying to the customer's place to deliver the most expensive songket fabric.

We now offer an overview of the key sociotechnical actors within songket's supply chain. An important finding is that besides the clear division of labor among the traditional roles such as weavers, merchants, and customers, new actors and their roles become apparent throughout our study, although these have been limitedly mentioned in the state-of-the-art. Thus, we extended the study by also interviewing preparation workers, designers, and government staffs working on songket-related programs. Actors are not homogenous, including distinct subgroups with different motivations for engaging in songket practices, and different competencies to work with its materials and tools. For example, our findings confirm the previous distinction between end weavers, commission weavers, and entrepreneurial weavers [57]. This taxonomy reflects an increased autonomy from end weavers to entrepreneurial ones, as the latter benefit from the capital to purchase raw materials, the ability to travel and to find customers, and subsequently making a profit from other weavers' work.

Another important finding that received little attention in previous work is weavers' competencies: while all can complete basic songket weaving involving 2-3 colors, a much smaller number of weavers have both the competencies and the motivations of engaging in high-end songket weaving involving more than 5 colors and bespoke motifs. While the basic songket takes about 3-4 weeks to complete, the high-end songket takes about 6 weeks. Weaver's income for one piece of basic songket is between RM 500-800, while for the latter is RM 1800-2000. Based on the size of their business, findings also indicate two types of merchants: small-scale merchants have a smaller customer base and a smaller pool of weavers working for them (1-10), and tend to buy their materials and sell the songket locally. Large-scale merchants have a larger customer and weaver base (at least 30), even a workshop or shop, and normally buy materials and sell songket both locally, but also nationally and even internationally.

Songket designer is a particularly interesting role of which we know little from previous work. Usually commissioned by merchants, designers prepare bespoke designs either with traditional or contemporary motifs. Such creative work

requires high-level skills together with the knowledge and respect for the cultural heritage of songket weaving. Our findings emphasize designers as important actors within the songket practices, as about half of songket fabric sold on the market have been woven based on bespoke designs ordered by customers either for basic or high-end songket. Designers tend to work between 3 to 10 days on one design and are paid RM 80-400, and this role can be played by established weavers, experienced merchants, or young people with an interest in songket and increased digital or graphic design literacy.

Findings indicate another distinct role mentioned by both merchants and weavers, namely the preparation workers, who prepare the warp threads, wind the bobbins and warp frame, warp threads to warp board, insert threads through the reeds, and tie the buttons to shift patterns from paper to threads. These steps require distinct skills and special equipment such as a warp table and thread winder, and as a result, they are often performed by different professional workers other than the weaver [26].

Our infrastructure approach to the exploration of songket practices through interviews and observations of multiple actors has broadened the understanding of such materials beyond the songket weaving, extending it towards both its preparation and distribution channels. This, in turn, allowed the identification of a richer and more nuanced flow of materials and information among the key actors, and how different technologies become organically appropriated to assist this flow. Such appropriation extends the use of already adopted technologies such as smartphones and popular social networks, i.e., *Facebook*, *WhatsApp*, and *Instagram*, for everyday exchanges of the needs within songket practices over space. Key roles of such ICTs and social media platforms include supporting the ongoing coordination of actors' actions before, during, and after the songket handcrafting. We now describe in detail the key elements within the supply chain by focusing on songket's materials, design, making, and distribution.

5.1 Songket's Materials and Equipment

The raw materials used for songket production include cotton or silk, and colored metallic threads, dyes, together with specific equipment consisting of handloom, warp board (warping threads on the frame), and other small pieces of equipment such as shuttles and reeds. Such equipment tends to be handmade by local villagers, durable and can be used for a long time (i.e., 40 years). Most merchants purchase threads and dyes from local shops. With regard to provenance, such threads are either made locally, or imported from China, Japan or Thailand: "*most of the raw materials can be found in a Chinese shop at Kuala Terengganu*" [M10]. Most purchases of these raw materials are made through face-to-face transactions and collection in person by merchants or their employees [M5, M8], and transported by one's car. Such purchases could also be delivered to merchants' places through delivery services such

as *POS express*, albeit these tend to be expensive [M12]. Large-scale merchants are most likely to engage in online purchases of raw materials, usually in bulk from China: "*yarns made in China are much cheaper comparing to other countries*" [M4, M16-18]. While online shopping comes at a lower cost, it also comes with constraints regarding the minimum order: "*some sellers require bulk orders of at least 10 tons*" [M18]. The delivery of such larger orders of threads is usually done by lorries [M17], whose cost is offset by the reduced price of the bulk order [M16].

Weavers' access to the raw materials is limited [W1, W8], occurring mostly when they are asked to weave for their community, i.e., family or friends. In such rare cases, they may travel by car or motorbike to the local shop to buy threads for which they pay cash. Some weavers may be also entrusted by the merchant to purchase threads from their local shops for which they receive advance cash [W20].

5.2 Songket Design

Songket design is crucial not only for weavers but also for the preparation workers who need to count on the design while tying the buttons on the threads. The songket design is separated into three parts: *head*, *body*, and *foot* [29,46]. Designs could be created by merchants, designers, or weaver's family members or friends.

5.2.1 Songket Designer. Designers have specialized skills and this role tends to be performed by experienced weavers or merchants. Preparation workers can also do such design work. However, if other designers focus primarily on the songket *body*, preparation workers can also focus on the design of motifs and patterns for songket *head* and *foot* [P1]. Outsourced songket design will take between 3 and 7 days to complete, and costs between RM 80-400, depending on the complexity of the motif. Therefore, both professional designers and preparation workers usually keep the design paper in a portfolio (Figure 2, left) for reuse.

Designers can also be younger people with an interest in songket who also have design skills. They could be government staff working on songket-related programs. For example, such designers in Kraftangan engage in computer generated songket design using, for example, *Microsoft Paint* or *Adobe Photoshop/Illustrator*. Their aim is to create innovative designs, both traditional and contemporary, that can are shared at no cost with merchants registered with the Kraftangan Malaysia. The digitalization of songket designs offers the advantage of being quickly produced. In order to be shared with interested actors, such designs need to be printed on a large grid paper [D1] (Figure 2) via special printers available in printing shops or cybercafe. Some merchants also have their own printers and spread the physical design paper to preparation workers or weavers, who can count 'dots' carefully on the grid paper to move motifs onto warp boards, or weave motifs with the correct size and color.

Figure 2. Preparation worker showing her collections of design (left); Weaver pointing to the stickers on the protected paper-based design (right).

Interestingly, most weavers have limited input into the songket design, as their job often starts after the design is completed. Sometimes, they are offered the choice of designing the more structured part of the songket, i.e., *head* and *foot*, which many of the wavers enjoy; they tend to use traditional motifs such as *mangosteen* and *bamboo shoot*. Weavers have tacit knowledge of the basic traditional motifs so that they seldom exterrnalize such designs by drawing them on paper [W6-7, W9]. Although some weavers also have the more complex knowledge required for designing songket *body*, they seldom do so as "*it is really hard to make, especially for the exclusive songket*" [W20], where a high level of creativity is required: "*it is really hard to come out with new designs*" [W16, W21]. Therefore, only a few designers are able to take on these tasks locally [W19].

5.2.2 Bespoke Design. Findings indicate customers' preferences for bespoke songket designs, as 89% mentioned that they are not happy to wear a songket fabric with the same design as others. Most customers tend to travel to merchants' to discuss such preferences. Customers' inspiration for such design comes from online photos of songket [C11] or by browsing through the songket pieces showcased in the merchants' shops or market stalls [C4]. Apart from such face-to-face interaction, the communication between customers and merchants regarding the bespoke design can also take place remotely through phone calls as well as through *WhatsApp* for sharing the photos about the desired design [C15, C24]. Such communication may require several exchanges to ensure that customer's requirements are understood [C16] and to avoid mistakes [C3], especially for expensive songket. Sometimes, customers provide drawings for merchants to understand their requirements [C9, C15]. Customers need to pay a deposit when they place the bespoke order. High-end customers engage differently in this activity: they tend to call merchants to bring songket fabric to their houses or offices [M6]. By browsing these samples, these customers work with the merchants to co-create new bespoke designs. Usually, merchants sketch the design for the customer [C27] and refine it based on the customer's direct feedback [C28].

Apart from this direct involvement in the creation of the bespoke design, other customers are happy to entrust their merchants to come up with the songket design [W12]. In most cases, customers will request the background color, so that it matches the color of the event where they will wear the songket [C2, C6, C21, C23, C28]. For instance, "*during Eid Mubarak celebration, my family will choose one color theme to wear*" [C6, C23]. Customers' preferences vary from traditional to more contemporary motifs [C23] or patterns [C26].

Weavers seldom get involved in the bespoke design directly with customers. "*I do not design. I do not want to make a wrong songket*" [W21]. The customer requirements travel among different actors many times. "*Sometimes, my merchant provides me with a sample or picture of songket, then she will ask me to find the designer, so I just pass it to my friends then my friends will design it for me*" [W29]. However, the representation of the design requirement is in verbal expression during the face-to-face communication. It is difficult to describe the desired color in language. Thus, "*sometimes, it is hard to achieve what customers want*" [W25].

5.2.3 Design Paper. The design paper is normally a 74 cm x 50cm grid paper. For contemporary *body* design which is not symmetric geometrics, the design paper is fully covered by dots, while for *head*, *foot, and* traditional *body* design, only one repeated unit is needed to be drawn or copied on the A3 or A4 grid paper. Because many songket pieces can be made based on one design, the design paper can be reused many times, maybe by different weavers. After preparation work and songket weaving are completed, merchants come to the artisan's place to collect products and design paper, then allocate them to different artisans. Sometimes, design paper with the new design is covered by a plastic bag (Figure 2, right), to protect the fragile design paper and to indicate color codes of different motifs. Some merchants or designers copy the design on the white paper by going to the cybercafe in town. The duplicated copy of design is sold to merchants at a cheaper price. Merchants bring the duplicated design paper to different weavers, who decide the colors of motif combination.

To protect the design, some designers leave their names under their designs [D6]. Some weavers mentioned that "*the design paper must be destroyed after the design is used*" [W15]. Weavers are expected to keep the design confidential: "*weavers will hold the secrecy to us. So, they will never leak any information*" [M26]. Although weavers or merchants claimed that each songket is unique [W6, W15], however, based on our observation and interviews, we found most merchants lack "brand uniqueness" because they may buy the design paper from the same designers. Only large merchants are able to hire their own designers and mark their design work under their business brand [M14].

5.3 Songket Making
Apart from design, songket making involves collaborative work of both preparation workers and weavers. Both their activities

are intricate and labor-intensive requiring attention to details and patience [W15, W22], often considered feminine virtues [26]. Findings suggest strong ambivalence towards the songket craft, although an icon of local cultural heritage [46]: "*there are no other places that can produce songket like us* [in Terengganu]" [M16], many weavers lack the incentive to preserve the craft: "*my mother does not really encourage me to do songket; not big money. She rather encourages me to go to school and get a formal education to get a good job*" [W4]. These quotes indicate merchants' more positive perception of the value of songket craft than the weavers'.

We now describe the rather complex relationships between weavers and their merchants, built on trust and loyalty over generations: "*my mother also dealt with merchant's mother in the same way in the past, I just continue this tradition*" [W6]. Many merchants claim that they treat weavers as their own relatives, for example, helping single-mothers [M14] or the younger jobless by offering them training and songket orders [M8, M11, M13]. In addition, weavers are always paid, sometimes in advance [M14], even when occasionally their weaving has imperfections [W6]. In turn, weavers are grateful: "*I know her* [merchant] *since young; we are really close. I consider her as my sister because she always helps me when I have no money. I believe that she can help my family*" [W18]. As a result, most weavers are motivated to work for merchants. First, they appreciate that this can ensure a consistent source of income, advance payment when needed [M14], as well as protection from the risk of dealing with bad customers: "*there are buyers who asked to take the songket first, but never come back to pay. With a merchant, I can guarantee I get the money*" [W6]. Second, weavers, especially the elder ones, are happy to trade their low-paid income for flexible working hours: "*my body hurts when I sit on the handloom consistently for a long time. So I only work for two hours in the morning and afternoon*" [W20]. Third, because of domestic labor [W18], most weavers have limited mobility to travel for work outside the house. Thus, they are happy to trade off the low paid income for the flexibility of working from home: "*working in the city is difficult because I have small kids and his brother is still in school, so I decide to learn to weave and work from home*" [W29]. Such positively portrayed relationships are abundant in participants' answers reflecting also the Malay collectivist culture, where respect for authority is valued. Despite this level of *care*, weavers' work takes place through informal casual contracts with limited welfare provision for retirement, maternity, or illness. In particular, women weavers who need to take a few-year break to raise their infants run the high risk of not resuming their work, as the merchant will choose other available weavers to replace them. For example, M2 used to be a home-based weaver who could no longer weave at the normal speed after delivering a baby, and subsequently, the merchant refused to give her any further songket orders. However, due to her husband' illness, she had to support the whole family and hence started to become an entrepreneurial weaver. A few participants also provide accounts suggesting that these relationships are in fact exploitative: "*the merchants will be unhappy if they know weavers sell songket by themselves*" [W8, W16-17]. We now describe different activities involved in the songket making.

5.3.1 Preparation Work. The preparation for the weaving process is laborious and requires specialist skills, therefore, few weavers are competent and interested in doing it. Thus, merchants usually commission such jobs to skilled preparation workers. Merchants bring the warp boards (reusable), threads and design (a piece of grid paper or just a piece of songket sample) to preparation workers' house by car. Sometimes preparation workers themselves buy the warp boards and threads from local markets or shops, and the merchants refund their costs. When the preparation work is finished (normally in one week), the preparation worker contacts the merchant by mobile phone, arranging for the latter to collect (usually by car) the ready-to-weave warp boards from the preparation worker's house with cash payment. The large business merchants hire their own preparation workers, especially working on more expensive songket such as *Limar* songket.

5.3.2 Weaving. After the preparation work is completed, merchants bring the warp board and other small pieces of equipment, design paper, and threads, even the handloom [W2, W19, W21, W29], to weavers' houses by car. During the process of weaving, merchants or their representatives regularly (once or twice a week) check the progress and quality by visiting weavers' houses, with the aim to eliminate mistakes at an early state, and also to build prestige among villagers. Although the conversations between merchants and weavers tend to be face-to-face, sometimes merchants commission the check on songket's quality and its progress to local master weavers, or ask the weaver to take photos of their work in progress and send them via *WhatsApp*.

The time taken for weaving one piece of songket fabric depends on the pattern, motif, and color of the songket design, as well as the weaver's skills. For example, one piece with a simple design and silk background will take one month to complete; an intricate design may take 2-3 months. Cotton warp is easier to weave than silk, so it takes less time because "*silk is very fragile and soft*" [W2] and more concentration is required [W9]. Weavers will work harder to complete one piece quickly to get their salary early when they need money urgently [W6-W8]. Due to a long pay circle, some weavers also run other business such as selling household goods [W18] and sewing [W20], and merchants never push them to work quicker, even when weavers produce fewer pieces than others [W16, W18]. After a piece of songket is completed, weavers notify merchants by a phone call or *WhatsApp*, and they agree on the collection date. Weavers will spend another 2 to 3 days to make songket finer by cutting threads before merchants coming for collection and paying the piece-based salary. The weaver is normally paid RM 500-2000 for one piece of songket, depending on the complexity of songket. The income from

songket weaving is often used to pay for a house or car [W4-5, W15], household expenses [W3, W14], or children's education [W6-9, W15].

5.3.3 Authentication of Cultural Heritage Handicraft. To control the quality of handmade songket, government authority developed standards for authenticating it. The assessment service is freely offered to anyone who would like to apply, and the test contains 8 steps such as measuring the size of cloth, the density of threads, the color resilience, and the light/wash/water/perspiration/friction characteristics. People whose songket cloth pass the assessment will get free "*Authentic Songket Terengganu*" labels with serial numbers (Figure 3, left) and a certificate (Figure 3, right). However, only a few merchants apply for this authenticity assessment, because the assessment process requires cutting a songket fabric into small strips, which means destroying the fabric [D1]. In addition, merchants who already have a customer base and customers' trust no longer need such a certificate and labels, unless they want to attract new customers [M25]. An interesting finding is that while small-scale merchants sew the label onto the edge of songket fabric when requested by customers, large merchants sew it together with their own brand's logo to promote their business.

5.3.4 Government Support. To preserve the cultural heritage, the government craft sector established a *National Handicraft Institute* to provide formal training for songket making and entrepreneurship [D6]. However, the effectiveness of such training has been questioned [M11], as only a small number of people completing it are hired by merchants [46].

5.4 Songket Distribution

Various actors such as merchants, local or urban retailers, or local government or NGO sectors, contribute to the songket distribution, each with their own channels and marketing strategies. Unlike these actors, home-based weavers only occasionally sell to their own customers [W4, W15, W24, W26] usually reached through family or friends: "*I have customers from Johor and Kuala Lumpur, who come here and never ask for discounts because they know the normal price is higher in the market. So I can sell them at a higher price than I get from my merchant*" [W15].

Findings indicate clear differences between new-starter entrepreneurs and established merchants, with the latter having stronger customer base, weaver workforce, and reputation. Because songket weaving takes time, with the average a weaver being able to complete no more than 12 pieces with a simple design a year, and 5-6 pieces with complex bespoke songket, this amount is not enough for a weaver to start selling in a market stall, where merchants' tend to hold stock of at least 100 pieces of songket. The novice entrepreneurs also sell the products to retailers or big merchants. For retailers, entrepreneurs call the shopkeeper first to ask about their needs of stock, and after they agree on

the price and delivery date, entrepreneurs will send the songket to retailers' stores by car.

Figure 3. "*Authentic Songket Terengganu*" labels (left) and certificate (right) shown by a merchant in Pasar Payang market.
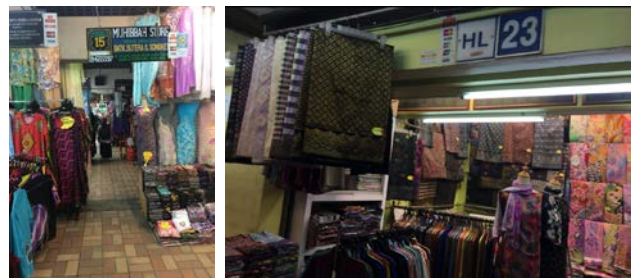
Figure 4. The *Pasar Payang* market in Kuala Terengganu, the capital of Terengganu state.

Some merchants travel by car and sell songket door-to-door, while a few have their own shops in the city [M16, M22] or local markets such as *Pasar Payang* (Figure 4) [M5, M8, M17]. Another popular channel to get new customers is to attend carnivals [M14] that are two-week events organized by the local government or NGOs throughout the year to promote handicrafts. However, only merchants registered with the local government or NGO sectors are invited to attend, and their costs for renting a stall are subsidized by the government.

5.4.1 Social Media Promotion Channel. Findings indicate that many merchants make use of social media such as *Facebook* (70%), *WhatsApp* (75%), and *Instagram* (30%) for online songket promotion [M1, M9-10, M12, M14, M16-17, M19]. We also looked at merchants' online profiles promoted on *Facebook*: this reveals its use as an online shopping service for which, however, online payment is poorly supported. Malaysian customers have three options of payment for online shopping: cash on delivery, bank transfer, or check. Online payment tends to be used only when the trust between customers and merchants has been established [C21]. On *Facebook* or *Instagram*, customers can make comments to review songket items, while communicating (i.e., bargaining) directly with the seller takes place mostly through *WhatsApp* or *Facebook*'s private *Messenger*. Merchants also build their own customer networking via *WhatsApp* group [M14], to promote new products and customer care. It is indicated that middle-

and upper-class Malaysians are more likely to order the songket fabric with a customized design. Usually, such high-end songket fabric is delivered to a customer's house who will pay cash. However, given a large amount of money involved, such payment can also be digital, as some merchants bring along a card reader to enable payments by credit card [C21] or online bank transfer.

5.4.2 Trust that Customers Build on Merchants. Despite the lack of standardization of songket production, customers deeply trust the songket's quality, based on merchants' reputation [C6] with whom they continue to engage in the future: "*customers normally go directly to famous sellers and even pay a higher price*" [W15]. Such a reputation may be inherited from the family business: "*which has sold songket for a long time; there are no problems in terms of trusting them*" [W26]. In such contexts, it is easy to see the challenges faced by a weaver who would like to become entrepreneurial.

6 Discussion

Our exploration of the Malay handmade songket's supply chain and its organically emerging sociotechnical infrastructure extends HCI recent insights into similar infrastructures in developing contexts [16]. However, while previous work has focused on infrastructural actions of online selling and buying of imported consumption goods, our study explores an infrastructure involving a richer network of actors (merchants, designers, preparation workers, weavers and customers) focusing not only on the online selling and buying but also on the making of heritage artifacts. Without a central infrastructure designer, these diverse and geographically distributed actors (local villages and cities, capital, overseas) are particularly resourceful in mobilizing their flow of information, materials, equipment, and creative cultural heritage artifacts. Alongside the traditional approaches consisting mostly of face-to-face communication and cash as a payment instrument, these actors seamlessly have started to integrate new devices and technologies across the entire supply chain into their practices. These include smartphones, computers, and social media technologies such as *Facebook*, *WhatsApp* or *Instagram,* to promote the songket products and communicate with customers, online buying of threads, *Microsoft Paint* for songket design, digital payment for threads and songket fabric, and courier services for songket delivery.

A key finding is that this technological layer emerges from within a long established social infrastructure shaped by traditions and culture. Thus, social actors such as weavers, preparation workers, designers, and merchants are hierarchically organized in a pyramid shape structure (Figure 5), with merchants (as opposed to weavers) benefiting from the highest level of mobility, skills, knowledge about the market, visibility on the market, and capital. Findings indicate the invisibility of rural weavers in both the physical world, and the digital sphere, as their relationships with customers are predominantly mediated by the merchants. Such invisibility of craft workers and their forms of production has been previously suggested together with their limited control over the distribution chain [43]. Our findings also confirm weavers' limited awareness of their vulnerable position, because of their longstanding relationships with the merchants [26]. Findings also indicate that weaving is a gendered practice shaped by a range of factors contributing to rural weavers' economic vulnerability such as high demands of reproductive labor that limits their mobility from home, limited education and access to alternative jobs, as well as lack of ownership of their means of production, i.e., raw materials and equipment.
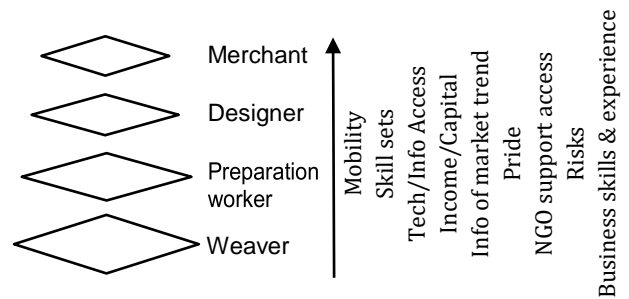
Figure 5. The hierarchy of actors involving in the songket production chain.

These factors have led to the commodification of their labor for which weavers benefit from limited welfare provision [56]. They are also unfairly paid merely subsistence wages with a disproportionately large share of the surplus value appropriated by the merchants (up to 8-10 times more for high-end bespoke songket). In addition, many merchants operate as monopoly providers of songket orders in a specific village, usually through strong historic roots and tacit claims over the exclusivity of their weavers' labor power. The paradox of exploitation characterizing merchant-weavers relationships is interesting and requires careful consideration. Indeed, despite their rather exploitative nature [22] these relationships are in fact consensual and perceived as beneficial by most weavers. Our findings thus extend the concept of *care for the customers,* highlighted as relevant to sociotechnical infrastructures in developing contexts [17] to include also *care for makers.* The latter is fundamental in infrastructures focusing on making, as it contributes to what appears to be *mutually advantageous exploitative relationships.* Wertheimer [54] described these relationships through offers which can make one better off than without, albeit worse than what one is entitled to from a fair share of the surplus. While such relationships received less attention in HCID, we argue that they should be considered in HCI for good [9] while designing for economic justice in developing contexts.

We argue for a departure from the Western-centric design for such contexts and their relationships, and towards a more encompassing global HCI, grounded both in local values and HCI global ethics. For this, we can draw from ethics research

about the grounds which might "*justify interfering with consensual and mutually advantageous exploitative transactions*" [55]. Soft paternalism is one such approach consisting of informing the disadvantaged of the less exploitative, available transactions, such as in our case, weavers' option to weave for their own customers. Any such technological solutions will increase weavers' visibility in the market. However, it will also need to account for the fact that gaining independence from the merchant takes time; and that in order to protect weavers from the risks of wage loss, such solutions should harmoniously coexist for a while alongside the current exploitative relationships. Designing for such solutions will go beyond technical innovation as it may also require rethinking the role of the merchant in these more fair relationships and potentially new business models supporting such roles.

The approach described above is one possible way of addressing Monteiro and colleagues' question of how to move from design of *artifacts* to design of *infrastructure* [27]. To acknowledge however the absence of a central designer, we propose instead the *design for infrastructure,* and beside the approach outlined above which focuses mostly on the social relationships within the infrastructure and their inequalities, our findings indicate another approach. This focuses on the technological design for a key value-creation artifact within the infrastructure of songket's supply chain, namely the bespoke textile design of songket fabric. An important outcome is that this highly creative product emerges through extensive collaborative design practices bringing together pairs of social actors: most often the merchant with each of the others, i.e., customer, designer, preparation worker, and weaver, respectively. Designed collaboratively and asynchronously through an iterative process, the songket creative design is both tacit and tangible. Hence, it becomes progressively materialized in different forms: computer-aided design (using *Microsoft Paint*, *Adobe Illustration/Photoshop*), collections of photos, hand-drawings on grid paper, copies or prints of these drawings, embedded within the warp board, and ultimately within the woven songket fabric. Such design artifacts and the design knowledge underpinning them travel in all these forms among the infrastructure's social actors. Similar to Jack and colleagues [16], our findings also indicate that this blend of physical and digital materials used to capture and communicate the songket design is brittle [53]. For instance, hand-drawn designs may incompletely capture customer requirements, while creating bespoke designs from customer's preferred songket pictures is problematic. In addition, printed designs are fragile requiring protection from theft and the elements, the warp board offers a physical footprint of the design, which is too large to store, being thus often destroyed to protect the design, while the authentication of songket fabric is appropriated by the merchant rather than the weaver.

We argue that such value-creation artifacts are key for the infrastructures focused on the production of crafts, and that they have qualities seldom recognized by the traditional HCI design approaches. Borrowing from the concept of roaming objects [7] as interactive systems for resource sharing in groups such cooperatives, we argue for the importance of designing *roaming value-creation artifacts*, which we define as hybrid objects that can better support the capture, co-creation, selective sharing, and protection of the outcomes of the collaborative design practices taking place in such infrastructures. *Roaming value-creation artifacts* are crucial for shaping such craft-based infrastructure as sites for collective innovation, with the potential to further challenge the binary division [16,42] between the practices of physical and digital design.

7 Conclusion

Our extensive study investigates the emerging infrastructure for Malay handwoven songket's supply chain in Terengganu. The increased creative infrastructural actions found in songket's supply chain rely on the resourcefulness of its distributed actors in mobilizing information, materials, equipment, and craft products by integrating smartphones and social media technologies into their traditional practices. Our work advances the research agenda of shifting from artifact-focused design to infrastructure-focused design. Particularly for craft-based infrastructures, we suggest opportunities for HCI researchers to engage in the designing for its social layer of *mutually advantageous exploitative relationships*, and for *roaming value-creation artifacts*. The latter are key for supporting such organically grown infrastructures as emerging sites of innovation.

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