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Enacting the Last Mile: Experiences of Smart Contracts in Courier Deliveries

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ABSTRACT

Smart contract systems could change the nature of last-mile delivery for the better through enhanced precision, coordination and accountability. However, technological complexity poses a challenge for end-users participating in the design process, making it hard to explore their experiences and incorporate their perspectives. We describe a case study where technological prototypes create smart contract experiences for professional couriers and receptionists, allowing them to speculate about emerging possibilities, whilst remaining grounded in their current practices. Participants enacted a series of deliveries, choreographed by smart contracts, and their responses were explored in post-experience, one-to-one interviews. Working with professionals to explore the potential impact of smart contract technologies, revealed the systemic webs of value underlying their existing work practices. This has implications for design of such technologies, in which increased automation, efficiency and accountability must be delicately balanced with the benefits of sustaining personal values, relationships and agency.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing systems and tools**; **Empirical studies in HCI**; • **Applied computing** → Transportation.

KEYWORDS

Smart contracts, distributed ledger technology, location data, last-mile logistics, logistics infrastructure, delivery, bicycle couriers

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1 INTRODUCTION

The way people and packages move through geographical space is increasingly mediated by location data and the applications that leverage it. Navigation by application has become the norm. Tracking taxis, items out for delivery, and other people in real-time, has enabled us to better coordinate our activities around their movements, increasing convenience and efficiency. Ride-sharing platforms and bike-share schemes have changed the landscape of urban transport, while on-demand delivery services, and internet shopping have revolutionised the way we access products. This shift in how we receive products has resulted in a rapid expansion of 'last mile delivery' services, where goods are brought to large consolidation centres before being distributed to individual residences or organisations via small vehicles. Often last mile delivery is highly inefficient, with more vehicles on the roads now travelling with fewer items [1, 66] and load consolidation has proved commercially problematic [28, 40]. Bicycle courier services offer an environmentally sustainable alternative in urban centres, but the economic sustainability of these services has proved challenging [41]. Technological platforms exemplified by Deliveroo and UberEats have brought economic models to this space, and the courier work here is characterised by on-demand labour and is part of the 'gig economy'. Whilst the flexible nature of this work has brought benefits to some individuals, there are concerns around the broader effects on working conditions [34]. In this study we seek to explore an alternative technical proposition that may add value to bicycle-powered urban delivery, and consider the possible impact on individual experience and work practice.

Smart contracts use data arising from events as part of computational agreements that execute coded actions when specific conditions are met. These agreements are stored and run on distributed ledger technology (DLT) and cannot be adjusted, thus guaranteeing they will execute as agreed. By using location data as part of their conditions we can design applications that require certainty of location and can securely automate resulting events. In global logistics, DLT and smart contracts are already gaining

traction, offering a) increased coordination and efficiency, b) the possibility of cross organisation collaborations resulting in capacity sharing, c) automation of routine tasks, and d) tracking and verification to guarantee provenance of goods. However less has been done to explore the possible benefits of these technologies to smaller scale local enterprises, such as urban courier delivery.

Involving stakeholders in the development of innovative designs with smart contracts has proved challenging. The concepts behind these technologies are abstract, and when we explore their application in real-world contexts, it is not always clear to the participating stakeholders exactly how these systems differ from existing solutions. The new technology may enable anyone to write a smart contract, or make location verification transparent, but what exactly does this mean for the activities and experience of the people carrying out the work? Our aim therefore was to learn from the experience of professionals, in order to design a product for urban courier delivery that would not only improve the effectiveness of the overall courier service, but which would bring benefits to the individual's existing work practices.

For this we employed user enactment, an approach that provides tangible experiences to people working in the field [47] and explored their responses in subsequent interviews. This approach provided grounded ideas about how smart contract technologies might play out in the lives of professional couriers and receptionists, exploring what matters to them as individuals, as well as potential future applications and their specific impacts. The contributions of this paper are: a) a new iteration of the GeoPact assembly to support the study of urban delivery, b) HCI insights on the opportunities and impacts of developing new technologies for courier delivery and logistics, c) considerations for the design of location-based smart contract systems, and d) reflections on user enactments for envisaging smart contract systems.

2 RELATED LITERATURE

Related literature falls into two key areas: work that explores the impacts of technology on transport and logistics, including relevant literature from broader logistics, and work that focuses on methods for exploring the potential application and impact of smart contracts and DLT across a variety of sectors.

2.1 Exploring new technology for transport and logistics

Within HCI and design researchers have explored the role of new technology as part of re-thinking transport and logistic models and considered their potential to bring improvement to both society and individual experience. One approach has been to develop and test new applications. Here, their use in supporting sustainable objectives has been central, through tracking, supporting and motivating sustainable transport choices [7, 24, 25], supporting intermodal travel [17], sharing cycling routes [57] and employing drones for community-led last-mile delivery [16]. These technical interventions leverage location data and greater interconnected-ness, to rationalise routes, reduce journey time, and encourage a shift to more sustainable transport modes. Here, sustainable objectives are achieved through efficiencies: carbon savings are made by reducing journey times, and sustainable choices are supported by improving connections between different modes of transport. Smart contracts and DLT have been applied to logistics and are seen as having potential to improve efficiency and accountability through facilitating collaborative practices and reducing administrative processes in various settings e.g. within shipping [30], port management [64] and supply chain management [36]. However, this work has also revealed infrastructural barriers to smooth integration of DLT in these sectors, where incumbent systems, policies and practices may clash with new processes. Smart contracts and DLT have also been proposed to support urban mobility at an individual level, to incentivise cycling [31] and create walking contracts [32]. Whilst this work presents and explores compelling conceptual concepts around DLT, the impact of putting such concepts into practice is, however, currently absent.

Through ethnographic study and research through design methods there has been significant work to understand the impacts of technologies on individuals' experiences of transport. Studies have explored human experiences within bus driving [51], eScooter use [65], last-mile rural passenger trips [35], real time passenger information [22] and taxi driving, which has a long history of ethnographic study [15] that has continued through to recent studies of ride-sharing platforms [44]. What these studies point towards is the importance of human experience in understanding transport and logistics models. For example, Pritchard et al. [51] describe how location based technologies for regulating bus frequency undermine human relationships, demonstrating the interdependence of technologically supported transport infrastructures and human experience. Work in understanding the role of mediating, ride-sharing platforms has been prolific, and has mapped the dynamics of technological mechanisms to the experience of people working and using these platforms [2, 26, 55, 56, 63]. The impact of on-demand delivery platforms specifically has received less attention, and has been explored in reports such as [29], and as part of work on the dynamics and impacts of platforms more broadly, (e.g. [37]). In much of this work the central theme is similar: while these platforms appear to offer increased flexibility and autonomy, there are complex trade-offs around control, and the requirements for new types of work (e.g. emotional labour [26, 55]).

The logistics and freight sector, especially the urban sustainable logistics sub-sector, like public transport, is fragmented and is characterised by sub-optimisation and coordination challenges [58]. Last-mile delivery has been the subject of research seeking to address these particular problems, examining logistical models [5, 9, 62], economic factors and influences [12, 27] and effects of policy interventions on economic sustainability [13, 48]. Bike courier work specifically has also been examined for its potential for economic success [41]. Some attention has also been given to the on-the-ground experience of couriers within the social sciences, with Fincham [23] revealing the 'subculture' of bike couriers. However, there is little research specifically addressing the impact of new technologies. The moment-to-moment experience of working for Deliveroo has been explored by Cant in an autoethnographic study [8]. This work starts to reveal the detailed physical, social and emotional factors of this work, and the effects of platform management on the individual. However, autoethnography performed by a researcher may ultimately differ from experiences of those whose livelihoods depend on such work, and for whom different

factors will have brought them to this lifestyle. Within HCI, work on last-mile delivery has been explored by Bates, who applied HCI methodologies to understand and improve working practices of van drivers [3]. Bates has most recently discussed the difficulties of performing 'Limits' research while attempting participatory design work with bike couriers [4]. What we learn from this body of previous work is that technological developments can bring benefits to last-mile delivery through efficiencies, but attention to work practice is vital as it reveals the human values and experiences, which are part of these complex socio-technical networks. However, these activities and experiences with new technologies can be challenging to access and explore with bike couriers.

2.2 Envisioning distributed ledgers technologies

Distributed ledger technologies (DLT), such as the Blockchain network designed by Nakamoto [45] and smart contracts – described as computational code that runs on DLT [59] – have emerged as a radical alternative to centralised solutions, offering new distributed forms of digital record making and processing. Their potential has been rapidly explored and developed in a number of commercial settings, in particular supporting supply chain accountability (https://www.provenance.org) and tracking provenance of valuable items (https://www.everledger.io). These technologies have been regarded by some as disruptive, proposing entirely new paradigms, rather than fixing existing problems [14]. Understanding the conceptual shift from centralised to decentralised, and the value of computational trust that DLTs are purported to bring, can be difficult for the layperson to grasp. Therefore, engaging stakeholders in considering what it might mean when applied to specific sectors can be problematic. The desire to move beyond immediate commercial benefits and bring positive change has led to a significant effort within HCI to understand and communicate these technologies through design methods. Elsden et al. [19] mapped the landscape of work across commercial, academic and artistic settings and concluded that HCI should engage with this technology to help shape its role in future applications. A number of artworks have responded to the possibilities of DLT and envisaged radical new artefacts [10, 18, 38, 39, 49]. Design workshops have been particularly important, where tangible representations of DLT have been used to scaffold participant understanding and facilitate collaboration [43, 46], and a role-playing game introduces participants to decentralised identity management networks [54]. Designed artefacts have played an important role in envisaging new futures as part of HCI practice, and have been employed to explore possibilities through drama [52], and empirical study of the lived experience of these artefacts [53, 60]. These studies have moved from general ideas of how smart contracts might be useful or interesting, into a grounded exploration of what future implementation might mean in practice. The artefacts themselves present new experiences through re-design of familiar consumer products: coffee machines [60], hair dryers [52] and electric kettles [53]. During the study period, participants were able to temporarily embed these objects into their lives and experience how the new activities demanded by these objects challenge existing practices and values. For example, the study of the blockchain-enabled coffee machine, 'Bitbarista', that revealed data on coffee provenance, demonstrated a tension between participants' ethical concerns and their desire for a quick coffee. The potential for DLT to support new modes of community collaboration has been explored in relation to the sharing economy and platform cooperativism [11, 21, 42, 50], with the aim of supporting skills and resource sharing, and the social benefits that arise from this. While the specific use of smart contracts is implied in some design work exploring DLT, there is less that has engaged it overtly. This niche focus on smart contracts has also been driven by collaborative principles and work has explored their potential in charitable giving [20], mediating building access [6], supporting community tool sharing [21] and finding walking partners [33]. We continue in this vein by exploring the use of smart contracts within delivery services.

3 SMART CONTRACT ENACTMENT FOR COURIER DELIVERY

For this study we chose the enactment methodology to reproduce as closely as possible the practical issues confronting professional couriers in the course of their working lives. While it would be valuable to embed these technologies into courier practice longer term as earlier studies of DLT supported designs have done, this would be highly disruptive to a small courier business. Through carefully designed activities we aimed to provide grounded experiences through which participants could enact a wide range of possibilities in a relatively short space of time.

We set up a series of smart contract mediated deliveries for couriers and receptionists to enact using the GeoPact assembly. Smart contracts coordinated the delivery process using messages to a smartphone app and a smart, delivery lock-box. We took a case study approach, working with one local courier company, Zedify[1]. This enabled us to produce, through the enactments, a highly sophisticated and realistic experience, embedded in and closely emulating the participants' working practice. Their responses to the technology were thus established in the context of everyday routine, and moment-to-moment thinking. Such grounded responses to realistic activities can improve the accuracy around speculations on the future [47].

3.1 GeoPact overview

GeoPact is an assembly of technological and physical objects that together enable the creation and execution of location-aware smart contracts. It was first employed in public exhibitions in early 2019 to engage publics in understanding and speculating on futures for location-aware smart contracts [61]. Here, we provide an overview of the new key interactive components used in this study: a redesigned, more robust lock-box, smartphone application and smart contracts (Figure 1). A detailed description of the GeoPact system architecture is beyond the scope of this paper.

Smart lock-boxes: We designed and built portable smart lock-boxes to be used by the participants for the secure transportation of goods. The main features of the box design were an outward facing screen and single-button user interface; an electronic locking mechanism; a concealed microcontroller

[1] https://www.zedify.co.uk/

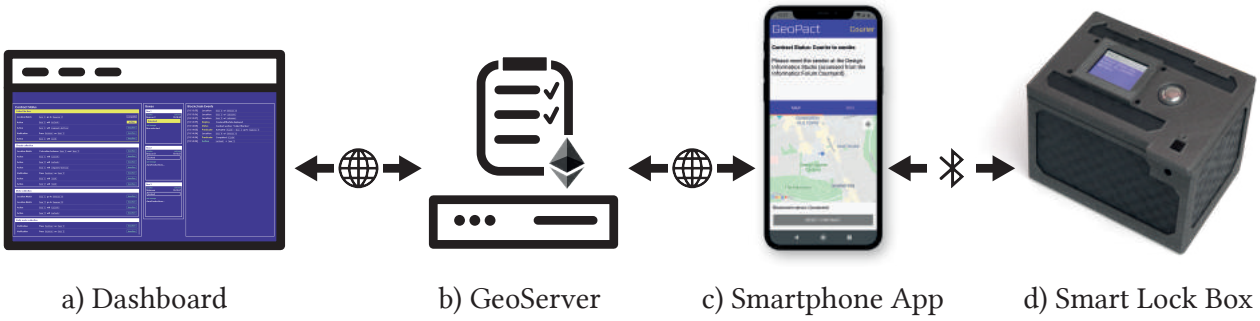


Figure 1: Overview of key GeoPact components

with Bluetooth capability; and a battery. The display screen provided basic feedback on the status of the smart contract (e.g. "contract in progress") and on whether the box was currently locked or unlocked. The button on the box enabled participants to verify that they had completed stages of the contract involving the box (e.g. confirming drop-off or pickup of the box). The electronic locking mechanism allowed the box to be remotely locked/unlocked based on contract events. Communication between the box and the smart-phone app was achieved via Bluetooth.

Smartphone application: The main participant interaction with GeoPact was through an app, with a map showing live locations of participants and objects in the system and Bluetooth connections to the smart objects. As participants progress through the steps of the contract, each party in the contract can see the steps execute in the app. The app had a custom view for each of three roles: courier, recipient and sender. Couriers were presented with functions enabling them to accept contracts and where given instructions to make pick-ups and drop-offs. Recipients were alerted that a smart contract with a delivery to them had been initiated, and were provided with instructions on completing the contract once the lock-box had co-located with their smartphone. The sender interface was similar to the recipient's, but it also allowed them to initiate the contacts.

GeoServer: The smart contracts and local blockchain instance were run on a server, which we named the GeoServer. The smart phone app communicated with the GeoServer via a web connection (4G or WiFi). We used Solidity[2] to write the smart contracts. In essence, these contracts consisted of a set of predicates, if-then statements, and associated state variables. For example, IF the predicate requiring the courier to be in the same location as the box is satisfied, THEN unlock the box. The smart contracts were implemented on a local instance of an Ethereum blockchain, created using Ganache[3]. We created 4 contracts specifically for this study, these are described in detail in the following section.

Dashboard: A web-based dashboard was built to provide an overview of the contract steps, and the current contract status. It also showed the data recorded into the Ethereum blockchain. The Zedify manager watched the dashboard while one of the couriers worked through their contracts. The receptionists did not see it at all, while the couriers did get to have a look at it once they'd completed their contracts.

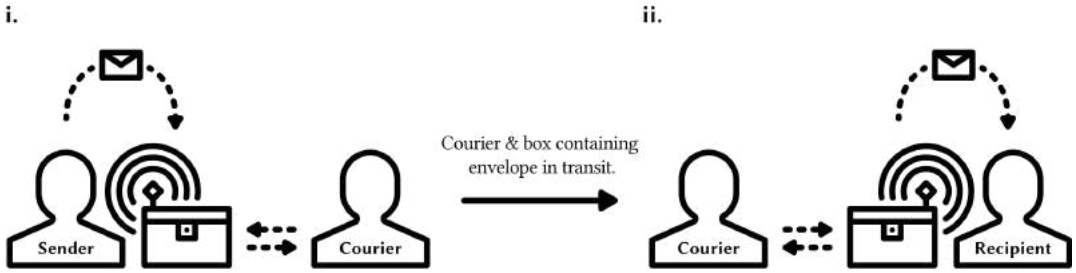
Hubs: These were clearly labelled, branded stands, for the lock-boxes to slot onto. One was positioned in an external spot and the other inside a university building. They were important to support conversations and thinking around unstaffed, automated hubs.

3.2 Smart contracts for delivery

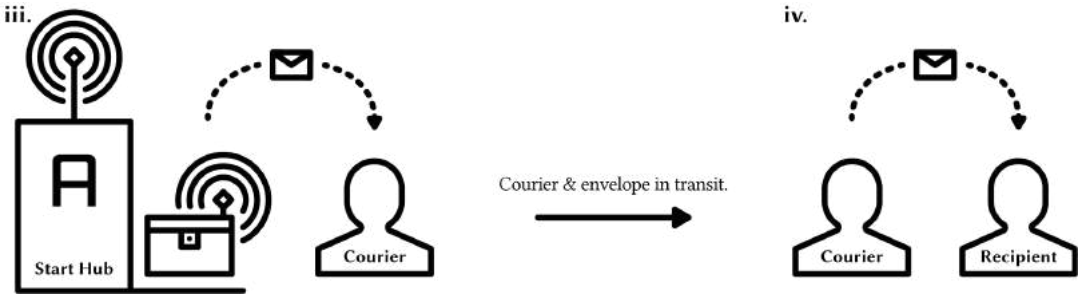
We created four smart contracts to illustrate different logistical scenarios. In the first contract, called 'person-to-person', couriers take an item in a lock-box from a sender directly to a recipient. In the second and third scenarios couriers to pick up from and make deliveries to lock-boxes temporarily locked to unstaffed hubs, called 'hub-to-person' and 'person-to-hub' contracts. In the fourth contract, called 'hub-to-hub', couriers move a lock-box from one hub to another, while the box remains locked. In this study all contracts were deployed by a sender (a researcher). Messages with instructions for the participants are emitted by the smart contract, and appear on the GeoPact phone app, with the exception of requests for button pushes on the box to verify when it has been loaded.

Once the sender has initiated a contract it appears on the participating courier's GeoPact phone app, and they can accept it. In the person-to-person contract (see figure 2a), the courier is instructed to take their empty lock-box and meet with the sender at their current location. In exchange i) the courier is instructed to hand the lock-box to the sender. When the box is in proximity with the recipient's phone, the box unlocks and the sender loads their item in the box. The sender verifies this has been done by pressing the button on the box and the box locks. The sender is instructed to hand the box back to the courier. The courier is directed to take the box to the recipient's location. On arrival in exchange ii) the courier is directed to pass the locked box to the recipient. Once the box is in proximity with the recipients' phone, the GeoPact app directs them

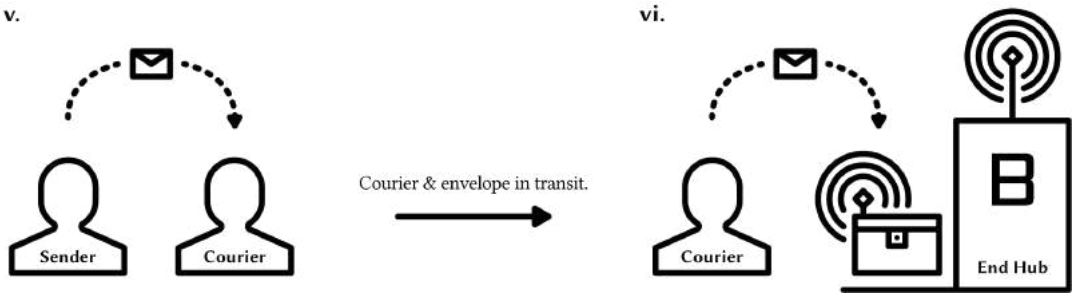
[2]https://solidity.readthedocs.io/
[3]https://www.trufflesuite.com/ganache



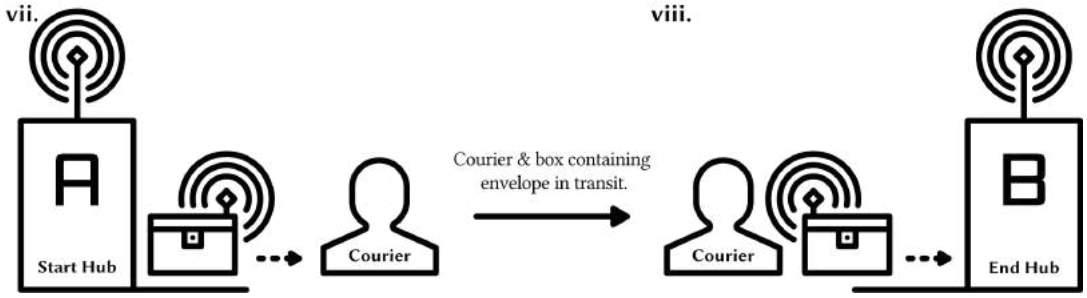
(a) Person to person: the courier passes a lock-box to a sender, who loads it. The courier transports the loaded lock-box, and hands it to the recipient who takes their item.



(b) Hub to person: the courier collects an item from a lock-box at a hub, and transports the item to the recipient.



(c) Person to hub: the courier collects an item from the sender, transports the item to a hub, and drops it into a lock-box there.



(d) Hub to hub: the courier collects a lock-box from a hub, transports the lock-box which remains locked, and drops it at another hub.

Figure 2: Overview of smart contracts used in the study: person to person, hub to person, person to hub, and hub to hub.

Figure 3: The receptionist pushes the button on the box to confirm she has received it, this action together with the colocation will unlock the box

to verify they have the box by pressing the box button (see figure 3), after which, the box unlocks. The recipient takes their item, verifies they have done this by pressing the box button again, the box locks, and they are instructed to return the box to the courier. The courier keeps hold of the box for their next delivery. In this contract the courier has no contact with the item. The deliveries in contracts shown in figures 2a, 2b, 2c and 2d work in a similar way. In the person-to-hub contract the courier picks up an item directly from the sender, transports the item and drops it to a box at a hub (see figure 4). In the hub-to-person the courier collects an item from a hub and transports it to the recipient. Notable in these two contracts is that the lock-box stays locked to the hub and the item is not transported inside it. Finally, in the hub-to-hub contract the courier picks up a box at one hub (see figure 5) and drops it at another hub (see figure 5).

Standard issues of usability were addressed with informal testing throughout the development process prior to the study, ironing out issues around interface design and contract messages in particular.

4 STUDY PROTOCOL

This study took place in Scotland (UK) and ran over three days, with individual couriers participating in either a morning or afternoon session, in which deliveries were enacted using GeoPact. The research team sent packages from a studio space, across the University of Edinburgh, to be received either by a receptionist or left at a hub (as detailed above). The study participants were aware that these packages did not contain items of value and were not considered 'real' deliveries. However, they understood that for this trial we were asking them to treat them as real. Distances between the pick-up point and drop-off were between buildings, and deliberately

Figure 4: The courier has unlocked a box at a hub and drops the package into it

Figure 5: The courier has arrived at a hub and is instructed to collect the lock-box

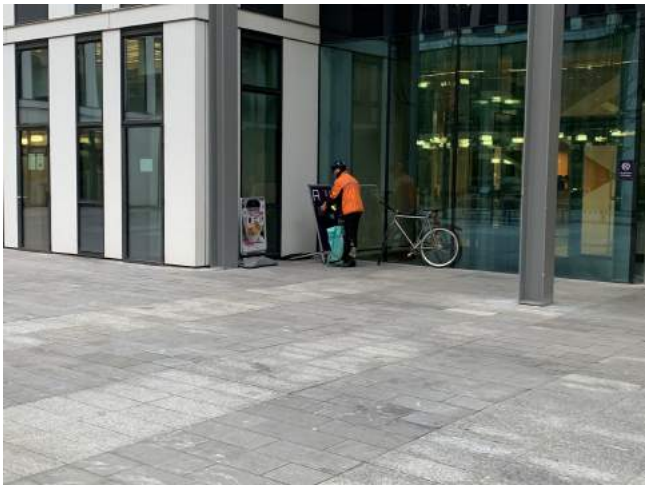


Figure 6: The courier has arrived at a hub and placed the lock-box onto the hub

short (max 10mins journey) as we were interested in experiences of handovers rather than journeys. All couriers completed all four contracts described above in the same sequence. The first contract was initiated within the studio space, with research staff present. Subsequent contracts were initiated – and received by couriers via the GeoPact App – at the end point of the previous contract. So, couriers would receive a request to participate in the next contract either at a reception or at a hub where they had made their previous drop. Couriers were interviewed immediately after the enactment session and reception staff were interviewed on subsequent days. The Zedify franchisee and manager for Glasgow and Edinburgh, observed the second enactment session on the final day, and was interviewed directly after the final courier. While research team members were stationed to observe and assist at receptions and hubs, the findings in this study are drawn solely from participant interviews.

4.1 Participants

Zedify is a courier company operating in a number of UK cities centres, providing efficient, low-carbon courier services, often for high value or secure items. In Scotland they currently operate in Glasgow and Edinburgh, where they have been investigating creating innovative, bespoke boxes for their bikes, as a parallel with the smart lock-boxes we detail above. We specifically chose to work with Zedify because of their high level of professionalism as couriers, and their interest in innovation. Participants included: six couriers (C1- C6), the Zedify franchisee and manager for Edinburgh and Glasgow (M11), and four reception staff at 2 different University of Edinburgh receptions (R7 - R10). All couriers were all male, and receptionists were female. Whilst this seems unbalanced, it is representative of the current gender divide within these professions in the UK (see https://careersmart.org.uk/occupations/receptionists and https://careersmart.org.uk/occupations/postal-workers-mail-sorters-messengers-and-couriers). Couriers were assigned time with GeoPact as part of Zedify work, and Zedify were paid a standard rate for their time. Receptionists fitted interactions with the system and interviews around their normal work, and were given a £20 gift token as a thank you for their participation.

4.2 Interviews

One-to-one semi-structured interviews with all participants were conducted by a member of the research team. These interviews lasted 40 minutes for couriers, 15 minutes for reception staff and 75 minutes for the Zedify manager. The shorter time for receptionists reflects their smaller role in interacting with the system and the need to fit these around other work activities. Interview questions were different for the two groups. All interviews began with a discussion of the participants current work practices and problems they commonly encounter. We then explored their responses to the GeoPact system. For couriers, the discussion focussed on a) overall perceptions, b) preferences around the different example contracts and situations in which particular contracts might be useful, c) ideas for new services or logistics models, d) benefits and the challenges of making this system work, and e) impacts on their work practice and experience. The couriers were shown the diagrams of the example contracts (shown in figures 2a, 2b, 2c and 2d) as a memory aid and enabled researcher and participant to discuss potential future applications around common concepts. Receptionists were asked a shorter set of questions, focusing on a) overall perceptions, b) and ideas for new services, and c) impacts of their work practice and experience. All interviews, with the exception of two with receptionists (R9 and R10) were audio recorded and transcribed. For R9 and R10 who did not want recordings made, we took detailed written notes. In the following analysis these were treated in the same way as quotes, but we have not used any direct quotes within the findings.

4.3 Analysis

We conducted a qualitative, textual analysis, of the participants' responses, taking a broadly thematic approach. The first author began the process of coding interview transcripts by filtering quotes that didn't relate to delivery work or the study experience, and converting salient quotes into short phrase summaries. These summaries were written on post-it notes and used in a collaborative, thematic sorting process with other authors. We began to construct themes bounded by the studies' focus, in which particular nuances reveal participants' emphasis on subjects important to them.

5 FINDINGS

5.1 Participants current work practices

While at its root courier work is a set of predefined interactions between a sender, courier, recipient, and a courier company, in practice it is varied and challenging. There are a surprising range of configurations and specifics for working with organisations with differing requirements and security measures. The Zedify couriers described delivering blood, teeth and thousands of pounds in cash; throwing a parcel on the floor of an out of town, unstaffed warehouse in the small hours of the night; and dropping a single, small and valuable item to one of a bank of 600 secure lockers. Courier work was seen as more than just a job, with C3 working as the

inhouse mechanic and constructing custom bikes and containers and C2 regularly participating in international bike courier championships. The couriers often need the flexibility of weaving together work from different organisations, with 5 out of 6 having worked for Deliveroo and UberEats. This 'platform work' was seen as lower status than proper courier work, and *"is this weird kind of entity that... it's not very manned [...] it's just up to the restaurants and to the riders"* [C2]. When things went wrong – whether finding people or inappropriate packaging from restaurants – there was limited support for resolving the situation satisfactorily.

The majority of Zedify work is conducted by coordinating deliveries from a custom tricycle with a large container on the back – built by C3 from a converted rickshaw – with other couriers doing 'point to point' delivery on standard bicycles. The couriers described how communications with other couriers and the dispatcher enable them to work collaboratively, leading to increased efficiency, accountability and security, as everyone in the team knows where they are and what they're doing.

The reception staff worked at busy University receptions, providing a human face to visitors and overseeing entry and exit. They all perform delivery work as a part of their normal role, providing a drop-off point in up to 50 deliveries per day as well as organising pick-up of outgoing packages for employees. As an intermediary in this process reception staff are often involved in communicating with the courier and courier company to ascertain when an important delivery might arrive. They provide a personal service to many staff going beyond receiving mail to checking the contents and eliminating any unwanted or junk mail items.

In the discussion of deliveries, a strong theme was the 'handovers', moments at which an item being delivered changes hands, leaving the possession of one individual or organisation, and transitioning to another. It is at these points when couriers and receptionists meet that social interactions take place, and crucially, where responsibility for the item shifts. These moments are central to participants in the delivery process. The couriers all described not being able to execute a handover in reasonable time because the delivery was not ready, or the recipient was unavailable, creating knock-on effects for other deliveries. Receptionists had complementary issues, for example deliveries arriving without a named recipient, and felt a sense of responsibility for other people's packages. The couriers were particularly sensitive to times at which current possession is not clear, the transition doesn't go as planned, or records are inadequate.

5.2 Information sharing and coordination

These moments of handover were an immediate focus for couriers and receptionists during their experience using the GeoPact technology, with all participants valuing coordination around a complete, agreed plan for the delivery. Participants noted that the example smart contracts used a high level of information sharing between the recipients, particularly around the moment of exchange, and saw how breaking a contract into detailed, defined steps would improve coordination and efficiency: *"if you're in here and the box is down at reception and I drop something off that you've been waiting on and it pops up on your phone, oh, your courier's just dropped off, you just run downstairs straight away, get it straight away"* [C6]. The ability to coordinate delivery times better would give receptionists less of a feeling of being tied to their desks *"cause sometimes if we need to go away, I don't know, nip up to the library or something. Obviously, if we had the app and we're following it, we thought, we'll need to wait 'til that comes in and then go and do it"* [R8].

Location tracking was seen as positive by both couriers and receptionists, improving accountability, security and coordination. However, couriers were concerned that visibility of their movements might give the wrong impression to people waiting for a package as they wove together different deliveries: *"You wouldn't want to deliver it late but... I'm saying it's more just about doing other stuff while going A to B"* [C2]. Couriers valued as much tracking as possible while on the job, but with a strong distinction between working and not working: *"I wouldn't like it if I wasn't working, that's a different... totally different kettle of fish but while I'm working, yeah, you can strap a camera on me for all I care, it doesn't bother me at all"* [C1].

Several handovers in the study involved the use of secure, autonomous hubs that enabled couriers to securely drop items to a specified place, without the need to interact with a person. This relaxed coordination as *"there doesn't have to be receptionists [...] at the same time as I need to be there"* [C4], and made life easier as *"you could just leave [the delivery] in a box on the bottom floor for them [courier], it saves you [recipient] coming down the stairs, it saves them going up the stairs"* [C2]. Based on this, the couriers speculated about how autonomous technology could support existing high precision deliveries, such as a current bank job that *"has to be 3 pm, not one minute to three, 3 pm"* [C2] by providing an autonomous box so that *"if say multiple people are dropping into the box throughout the day, they can't... the courier can't come early and pick it up before everyone's had a chance to drop their mail"* [C2]. They were interested in how information sharing could help with access issues, for example a door that *"recognises that a courier's outside it, and rings the office"* [C3].

Whilst receptionists saw benefits to automated hubs in reducing their workload, they also expressed a desire to retain oversight of what was happening. R9 described how hubs might work well if receptionists were able to see the contract completing so they would know what was in the hub waiting to be picked up.

5.3 Responsibility

All participants had a strong sense of *felt* responsibility around deliveries, in particular the shifts around handovers. Tracking was seen as vital in providing evidence of courier actions, and they welcomed the potential for the GeoPact system to provide a verified record, ensuring that if *"things go missing or things don't get delivered or whatever, at least then you've got all that tracking and that to prove that you did do"* [C1]. The reliable log of events was particularly important when having to quickly decide what to do when a recipient is not available, because: *"if you've been told to leave something somewhere and you've done everything that you've been instructed to do, then I'm not responsible, [...] the accountability is on someone else"* [C6].

All receptionists also described a sense of personal responsibility for deliveries, and a need to ensure they are in the right place whenever an important delivery is due. They felt positive that

the contracts could alleviate this need as *"it puts the responsibility of the tracking and the package on them [final recipients], not on me"* [R7], with a hope that the recipients could track and take responsibility for their own packages, getting them faster [R7, R8, R10] and preventing unnamed deliveries [R9].

Even though all couriers saw how automated hubs could provide them with a fast convenient way to leave deliveries without the need to locate or deal with recipients. Some couriers were dubious about leaving high value items at them, and preferred the feeling that they had delivered directly to a person who would then assume responsibility: *"because if I was sending something that was high value, I'd want it to be placed in someone's hand and signed for and not be left, even though it might be secure not with the person"* [C6].

5.4 What's in the Box?

The use of boxes that could autonomously lock and unlock themselves prompted discussion of what was inside packages and what happened to it. Couriers talked about how they would rather not know what was in a delivery, as this increased their sense of responsibility. They saw the technology as changing the relationship with recipients who *"want to know what's in it before they sign for it. They don't understand that you're just delivering it. So, if it's in an actual box, you're like, I don't know, the box is for you to open, I don't know the contents"* [C5]. This was particularly relevant with sensitive documents for exacting clients *"like, banks or law firms, they get really unhappy if it's, like, the slightest thing, then you can just be like, yes, it's locked. I don't know what's in it"* [C5].

Couriers saw the possibility that the trackable lock-box meant they did not risk being accused of tampering with the contents, and could not be held responsible for how it had been packed, as *"if I get it to the customer, and they open the box, they're the only one that can open the box, then there'd be no doubt about me. If that responsibility was taken away from me, that would bring less risk to me"* [C4]. For high value delivery to banks, the lock-boxes could *"be opened from another place which has its own security verifications with cameras and all that sort of thing"* [C2], so the recipient knows *"I haven't touched the money; they know I have not switched it with fake notes"* [C2]. The contracts where items were carried outside the box (in figures 2b and 2c) were seen as less secure with more potential for things to go wrong, as *"who's to say that this man's took diamonds out before he's given them to me and then they're blaming me in between"* [C1].

Couriers worried about their own safety with valuable items, as it is *"quite unsettling that if somebody finds out that you're making those kinds of runs then you can be in danger"* [C2], and saw possibilities in the technology that *"if people knew I had some sort of...I had a secure package on then it would be good for that"* [C2]. Conversely, if the boxes become a visible indicator of something valuable being carried it could draw attention to its value which might make it more vulnerable: *"people will get curious about what's getting moved about"* [C5].

5.5 Balancing values

Both couriers and receptionists described the value of social interaction during deliveries and the potential for isolation: *"I think just because I like the human interaction, because a lot of my time I'm just alone on my bike and the nice part of my job is that I get to chat to other people"* [C6]. So while they saw the possibilities of technical efficiency – *"if I can make more drops doing that which means making more money, then I'd rather be doing that"* [C6] – they worried that technology, especially autonomous hubs, could reduce or remove the need for social interaction as well as being dehumanising: *"It could be really boring, not dealing with anyone. You feel like a bit... you feel like a drone enough of the time anyway"* [C4]. R9 was interested in maintaining social values alongside efficiency, with automated hubs placed where reception staff could see couriers making drop offs, enabling them to keep an eye on what's going on and also have a quick chat and a wave. More often though participants settled on the idea that working this way would be acceptable provided it brought benefits to them through efficiency, and they wouldn't be forced to work this way all the time.

Participants described how social connections brought practical advantages as clients and couriers get to know each other and build trust. This brings efficiencies, as couriers have the relevant key fobs and procedures for accessing buildings, and reception staff are happy to hand over items without extra security checks: *"I've been introduced as a member of the company. So if a stranger was to walk in and ask for it, they'd probably have to phone the boss to make sure this person is allowed when collecting it"* [C2]. One courier described how the GeoPact system might shift these boundaries of trust with autonomous boxes accessed through the system, so that: *"I could be anyone walking in and just lifting those documents, so in my head I'm thinking, now, if they had a box and they put their documents in the box and I came and opened the box and then took the documents out and moved them without the box"* [C6]. This sense of trust was important in adapting when things go wrong, for example: *"there's multiple businesses in the same office, and then sometimes, they'll be happy to accept it, and usually, there's like some kind of connection with businesses that work in the same place. So, they'll be like, oh, I'll take it"* [C4]. Receptionists described how knowing people was part of their job, keeping a track of who and what is coming and going from the building [R9]. They help with deliveries by checking incoming items, and suggested they would need to have some knowledge of, or be able to see inside the box [R10].

Couriers take pride in their work, and for some it is a vocation. They are creative in how they achieve efficiency through challenging and changing conditions, whether environmental or when *"someone says actually we've upgraded the priority on this one, so you need to deliver it by a certain time, so you have to go out of your way to make that delivery, and then go back"* [C3]. They innovate in vehicle and container design [C3] and through finding new systems to support activities [C6], developing procedures to pack items correctly for their route *"by structuring it with the way you pack it [...] It is pretty fun actually, yeah. We get that algorithm working in the morning"* [C4]. The couriers needed flexibility to respond, but also saw creation of efficient work as their key professional skill: *"When I'm doing courier work, I get to kind of just choose my own routes and choose my own way of doing things because I've got different kinds of timings"* [C2]. Most couriers would rather avoid automation and rely on their own skills and knowledge for the creative planning aspects of their work: *"I didn't need it [software] to plan a route for*

me, 'cause that inevitably changes, it is faster to do it yourself, than rely on software doing it for you" [C3].

5.6 Real-world speculations

As a design led study, we were interested in the ability of the participants to engage with the emerging technology.

Most of the couriers talked about how the technology could integrate with their practices, in particular how they would weave different jobs together. They speculated about technology automatically registering items they've packed for delivery, to make sure they have actually picked up the correct items [C3], and ensure the items they receive on a pallet to distribute are all present and correctly listed [C4]. C5 also described how this might help to keep track if delivering multiple items with one lock-box, *"you pick up teeth from loads of different dentists, you could go round all of them. And if there was a way that each… like, many people could interact with that one box, so you could drop something off and then you'd know how many items you had in and you'd just drop it off at the last spot"* [C5].

They were able to develop a balanced picture of possibilities, with concerns that the infrastructure needed would be *"massively complex"* [C6], balancing the possibility of non-couriers performing delivery [C5] with an awareness that inexperienced riders supported by technology may cause accidents. There were speculative concerns about how the system would deal with technological breakdown - signal loss in basements or loading bays, malfunctioning components, and *"Let's say your phone dies and you've got a box on you, what happens?"* [C5]. This grounded speculation extended to imagined applications of the technology: C3 and C6 talked through an idea of placing un-staffed lock-boxes on trains – an idea Zedify had considered previously – but C6 recognized that while the system may help coordinate actions, the time window for taking the box off the train (47 seconds) may still be too short in practice.

While the contracts experienced were simple, couriers saw how the system might enable new forms of collaboration such as intra-city deliveries with inner-city hubs [C3] or moving items using multiple delivery networks [C4]. They saw it making secure delivery services *"more accessible to everybody because you can be… if you're either sending [or] receiving something, you can be anywhere and it's all secure"* [C1]. [C6] imagined a secure service could be provided by an individual courier with a lock-box, and saw this as attractive as it might be a way to earn more money. [C4] said he thought it might enable drones to better perform deliveries, while recognising that *"you can't wrestle the box off me without a fight, but the drone might give it up quite easily"* [C4].

5.7 Courier business operator reflections

Interviewing Zedify's manager (M11) revealed perspectives on integration, economics and operational possibilities. M11 saw smart contracts as continuing on an existing trajectory in delivery models, in which increasing control over the terms of the delivery is passed to the recipient, *"so, there're options and that the recipient has a bit of power as well as the sender"* [M11], and that this would be more efficient. M11 was enthusiastic about the blockchain log of events, as *"there's a lot of benefit to it being able to see everything that's happened"* [M11]. To work well in the real world, the smart contracts should be flexible, so courier companies can add in clauses and branches and *"tweak it and being able to say, right, say we've got to our stage in the contract, if we're able to add in a stage"* [M11].

He described how secure lock-boxes managed by a courier company solved simple but regular problems, so that rather than accessing a high security mailroom early in the morning, if *"there was a lockable box [...] in the morning we could go round and put the mail in the box and then at the end of the day take the mail that's going back out the other way [...] that would be a very useable product for us pretty much straight away"* [M11]. He suggested that this would need to work within a trusted relationship between courier team and clients, *"because you're leaving items unattended and picking up unattended items from the point of view of human supervision"* [M11]. In this model he imagined Zedify would responsible for the security of the box: *"So, if you book something through my company the deal is a courier will turn up with a box, you will open it, put your item in it and lock it and know that it can't be opened again until it gets to the recipient, but that's on me as the owner of the company"* [M11].

6 DISCUSSION

6.1 HCI considerations in last mile delivery

Whilst there has been some exploration of courier work from an autoethnographic perspective, there has been little previous work engaging bicycle couriers in the development of new technology. This study gives a platform to real professionals in the field of last mile delivery. Their skills and understanding arise from experience and identity, and meant that, for example, some of the efficiencies suggested as improvements to courier delivery in previous studies of delivery work [3] were straightforward for this team of couriers. So, their experience, and willingness to engage with smart technologies, gave us valuable insights into the potential impact of smart technologies in this sector.

The technology was viewed through a very critical lens, the participants constantly assessing how it would impact their lives and affect their ability to make a living, rather than promises of what it might do. This was not a purely economic question; while avoiding time-wasting and stress was a valued objective, the loss of social interaction and agency was troubling. Better coordination was a key theme, arising from the real-world frustrations of missed deliveries, and an appreciation that smart contracts would ensure that all parties in the process would have a specified plan of actions, and would adhere to this.

As others working in this area have observed [4], efficiency is desirable but not at the expense of increasing isolation, or reduced opportunities to build trust. A factor like efficiency has numerous dimensions, mixing personal autonomy and creativity with measurable metrics and can be experienced in both positive and negative ways. It is not only the result of efficiency but the experience of it, that is important to people doing this work.

This was part of a more general concern that automated or predefined aspects of the system could mean a loss of the specialist skills that couriers bring to their work. For them, creating and practising efficiencies are key parts of their trade, and they take pride in it. It can be a creative and competitive act and at present is something

they *do*, not something that is *done to* them. Receptionists also have values around working with delivery processes, a sense of care and responsibility for people inside the building, and maintaining professional oversight of operations important to their work. Is it necessary for couriers and receptionists to exercise their skills within the defined parameters of their position, and to know what to do when there is a need to step outside the system and both groups focussed on protecting their professional values in the face of technological change. For couriers, the solution to working with programmed delivery infrastructure was to ensure that it did not constitute all their work, so they could mix and match this style of work with other less technically mediated activities. Both groups proposed models in which they could maintain their oversight of the system, and keep the potential for brief social interactions. Reducing time spent in social interactions around deliveries may increase efficiency by reducing delivery time, however it is liable to have a negative impact on beneficial dynamics, such as trust and know-how, that grow between individuals and actually improve efficiency in the longer term.

This study also revealed a complex picture around tracking location and sharing this data with others. Receptionists enjoyed the flexibility of tracking deliveries, but were not tracked themselves, while couriers had a sense that deviating from a specified route would be questioned – and indeed, the research team did ask "what are they doing now?" during enactments if they did not appear to be following an expected route. This articulated the tension between the reassurance of documentation that proved they performed key tasks correctly, liberating them from the burden of responsibility, versus a need for autonomy and flexibility about how they manage their own work. Couriers were acutely sensitive to the differences between dropping items at autonomous hubs or handing them to people. Even with the knowledge that this was the agreed final action for them, there was a desire to feel that the job had been correctly completed. This went beyond accountability and responsibility, and into a sense of pride around doing a good job as a courier.

With this enhanced understanding of the concerns of participants, and the dynamics of their experience, we should be able to design systems to support positive experiences. For example, the multiple requirements around a clear shift of responsibility for an object in transit indicates the need for more sensitive handovers. Engaging with these complex tensions will help us to create platforms and technologies that are not just more efficient, but protect and uphold workers' values around autonomy, flexibility and creativity.

6.2 Smart contracts and design for empowerment in last mile delivery

This study revealed the potential for smart contracts to address a number of current practical problems in last mile delivery. The *contractual nature* of the technology regulating the moments of exchange implied better coordination, a high level of transparency and increased certainty, traceability and security around the item. Indeed, the potential for the system to not only increase the security around the item, but also improve the personal security of the couriers was welcomed. The study format enabled participants to envision the application of contracts to more complex systems and in ways that supported or enhanced their existing practices, but with an eye to the design challenges of these applications.

There is huge scope in writing smart contracts that support a wide variety of delivery types, and agreements could include terms that are either broad or specific, depending on requirements. For example, a contract could require a courier to deliver to any reception within a building or company, or to a named recipient only. Contracts around banking or law firms require very precise timing and execution, and highly specified smart contracts could be prioritised across a coordinated team of couriers for the right price. For more general deliveries, participants could imagine coding in agreed conditions that would allow space for minor deviations such as meeting receivers *near* an agreed drop-off point by using the location tracking. There is likely to be a tendency to write highly specific terms for smart contracts, because this leverages the potential for certainty and security, creating trust that the delivery will happen in a particular manner. However, study participants were concerned that rigid specificity could infringe on their flexibility and freedom, so these clauses should be given careful consideration, with specificity limited to where it is necessary, reasonable and helpful. Poorly considered use of specific clauses may hinder the input of professional staff and therefore reduce the overall quality of the services.

Whilst the content of smart contracts is entirely open for design, one fixed characteristic of the technology is that once contracts are written and committed to the blockchain they cannot be changed. With flexibility of the contracts a key concern we considered the possibility of coding alternative pathways into the contracts and expressing a richer set of outcomes than current systems cater for. Forking pathways were suggested as a way of providing get-out clauses, so for example if a specific recipient is not available at the right time, then couriers can trigger an alternative clause that enables them to leave an item with a receptionist. Participants were all aware that understanding between the actors, and knowledge of familiar situations, creates an elasticity when coping with unforeseen change, and any smart contracts should work with this by supporting bottom-up models rather than attempting to impose rigid top-down structures.

While the questions of compliance and penalties for non-compliance were not explored in this study, there was a sense that it is more often the senders and recipients who do not comply with the terms, creating difficulties for couriers. The use of smart contracts could shift the balance of power, allowing couriers to do exactly what they are required to, without having their time wasted, and knowing that they will be paid – in contrast to the current uncertainty they feel, especially when the burden of proof is passed to them.

The need to consider specificity and flexibility leads then to the question of contract authorship and instantiation. This study did not attempt to get the couriers or receptionists to author their own contracts, as this was a large stretch beyond their current ways of working. Couriers assumed that the contracts would arrive to them pre-written, codifying certain kinds of delivery. While this is a likely scenario, smart contract systems could involve couriers or client organisations checking and contributing to the contract. Zedify's manager (M11) described how current logistics are taking a positive shift towards models in which the recipient has more

control over the delivery, dictating terms to suit themselves. This way couriers are more likely to make successful deliveries, and that is what all parties want. Smart contracts were perceived as a way of addressing the issues of collaboration by creating a common framework for delivery which all parties involved in the transaction sign up to, with a more even power balance between all participants. The question of agency of couriers, receptionists and others conducting smart contract activities is particularly important. They must not only be able to dictate certain contractual terms, but also be supported in carrying out activities which they know how to do best.

6.3 Reflections on user enactments for envisaging smart contract systems

In this study, we made smart contract technology tangible through technological objects, in line with previous work on experiences of DLT [52, 53, 61] and found that presenting these to participants through enactment provided detailed feedback on participants' grounded experience of the technologies. To create a sense of reality around the enactments and make them relatable, rather than revealing the smart contract technology explicitly, we presented it through its application (the lock-boxes and smartphone app). This demonstrated features such as enhanced automation, tracking and security, which are common in proposed applications within transport and logistics. We found, perhaps inevitably, that this somewhat constrained the potential to directly interrogate the specifics of the smart contract technology. The findings on participants' experiences in this study relate to these features, for example, human interaction is reduced by improved coordination and automation, and while this dynamic is not specific or unique to smart contracts, it is exactly these experiential qualities of living with smart contracts that we wish to highlight. Indeed, as an enacted experience, the underlying technology somewhat disappears, and it is the experiential qualities that are in the end felt by participants.

In comparison to the specific, grounded enactments in this study, design activities in this space often work with broad brush ideas of what a technology *might* do, magically solving a lot of problems (such as security and compliance). It is then a big jump to consider how these might manifest in the world and ground thinking in the exigencies and particularities of operation. In this study method we had the opposite problem, in that something so specifically realised caused participants to run into a multitude of problematic practical considerations while attempting to speculate about potential new concepts. For example, it was suggested it might be interesting to use a gyroscope to track the orientation of food deliveries as proof of careful handling, but how can we design a box at reasonable cost that will fit such deliveries in them? In addition, the close relationship of these enactments to the participants' work activities may have encouraged their tendency to articulate responses through detailed descriptions of their current practice. This sometimes made it difficult to gather direct evidence of their views of the system itself. However, such responses are an essential part of understanding the future impact and ultimate success of designs in this area, as pragmatic on-the-ground problems are likely to remain a real part of these activities. In the same way that the study of the Bitbarista [60] revealed that coffee drinkers' desire for a quick hit of caffeine often trumped considerations around coffee provenance, coping with recipients who aren't where they said they would be, is real and fundamental part of performing courier deliveries now and most likely in the foreseeable future, and should therefore be factored into the design of smart contracts.

Although the focus on practical issues did occasionally inhibit speculation, most of the time participants were able to move beyond the artefacts and scenarios we presented, for example considering different box designs, as well as new types of contracts and business models. Rather than view the enactments as a final destination in the future, participants approached the technology as a developed prototype, with a sense it could be aimed towards deployment, but understood that the forms and operations were only examples, and not fixed products. Working with a functioning version of the technology, through both novel and familiar objects, enabled participants to respond to the system as a real proposition, imagining potentials and considering impacts that would have been hard to reach without the combination of enactment and interactive prototypes.

7 CONCLUSIONS

In this paper we have described an expert-driven enactment, to speculate around the future possibilities and impacts of smart contract mediated courier deliveries. We have found that while both couriers and receptionists saw the benefits of increased coordination, and clear boundaries around responsibility, they had concerns around effects on the quality of their work lives, their social interactions, and the application of their specialist skills. This study has also revealed the multidimensional nature of efficiency. For couriers, it is a creative thing they *do* and is part of their identity, rather than something that is *done to* them by a logistics system. Considering the *experience* of efficiency as well as the imposition of it will be important to the introduction of technologies in logistics more broadly, where creating efficiency is often the central goal.

We see the design and control of contract operations as an avenue for the future, exploring ways to support ground-up, collaborative models of work. With an understanding of the experiential factors of these contracts, we will be better able to support what is important to participants, and thus leverage rather than override their core skills.

Working with logistics infrastructures is complex, as it requires thinking around broad economic and infrastructural issues as well as intricate interactions between humans, technology and geography. Personal values are sometimes in conflict, and couriers are always balancing these out as they make decisions about which jobs to take and how to weave them together. In designing for DLT and smart contracts for this sector we must always be aware of retaining space for people.

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