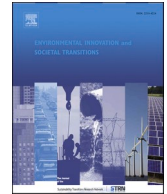


Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

Structural tensions limiting success of infrastructure upgrading: A multi-regime perspective

George Kiambuthi Wainaina^{a,b,*}, Bernhard Truffer^{a,b}, James T. Murphy^c

^a Eawag, Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, CH-8600 Dübendorf, Switzerland

^b Faculty of Geosciences, Utrecht University, Heidelberglaan 2, NL-3584, CS, Utrecht, the Netherlands

^c Graduate School of Geography, Clark University, MA, USA

ARTICLE INFO

Keywords:

Informal settlements upgrading
Multi-regimes
Production
Livelihoods
Structural tensions

ABSTRACT

Unfettered growth of slums is a daunting transition challenge and many upgrading programs fail to sustainably improve the livelihoods of slum residents. This paper elaborates a transitions perspective on structural tensions that may lead to success or failure of slum upgrading programs. We conceptualize slums as urban subsystems, governed by sociotechnical (infrastructure) and socioeconomic livelihood regimes (related to production and social reproduction). The framework permits examination of the tensions due to mis/alignments of rules associated with newly introduced infrastructures, and those that regulate existing production and social reproduction practices of slum residents. This approach extends transition studies by accounting for the multi-system interactions between different infrastructure regimes (e.g., transportation, sanitation) and livelihoods within a local sociotechnical system. We apply this framework to an in-depth analysis of a slum upgrading project in Naivasha, Kenya, which was part of a national urban upgrading program covering a total of 80 slums.

1. Introduction

Governments and development agencies have drawn attention to the over 1 billion urban residents living in informal settlements, mostly in the Global South (UN, 2020). The poverty and deprivation associated with such settlements has prompted municipalities and development agencies to implement upgrading programs to improve dwellers' livelihoods and prevent evictions. Such interventions have largely sought to improve infrastructures (e.g. housing, roads, water, sanitation) with the expectation that upgraded basic services will rapidly improve residents' livelihoods (e.g., WorldBank (2011), Koster and Nuijten (2012)). However, the evidence shows that such investments have uneven results as infrastructure improvements may disrupt residents' livelihood strategies, which in turn may induce quick deterioration of the new infrastructures (Cherunya et al., 2020b). Gains from upgraded infrastructure may be further constrained if the underlying forces (e.g., unemployment, labor precarity, rural-to-urban migration pressures) that perpetuate poverty cycles, and unsustainable practices, are neglected or persist after implementation (Brown-Luthango et al., 2017; Massey, 2014). Needed is an integrated approach that can account for the infrastructure-livelihoods nexus such that we can better understand the mechanisms through which upgrading (sociotechnical) initiatives lead to (or not) livelihood improvements (Calderón and Servén, 2014).

In precarious contexts like slums where access to multiple basic services such as water, sanitation, energy, and transportation is

* Corresponding author.

E-mail addresses: gkiambuthi@gmail.com, george.wainaina@eawag.ch (G.K. Wainaina).

<https://doi.org/10.1016/j.eist.2023.100747>

Received 16 June 2022; Received in revised form 25 May 2023; Accepted 13 June 2023

Available online 17 June 2023

2210-4224/© 2023 The Author(s).

Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Published by Elsevier B.V. This is an open access article under the CC BY license

severely lacking, residents have to develop alternative coping strategies (Gough, 2019; Cherunya et al., 2020a). While infrastructure is very significant for development, there is a limited understanding of how precisely new infrastructure investments impact livelihood activities at a structural level. This gap in our knowledge is significant both practically and conceptually. Practically, many attempts at upgrading informal settlement or slum infrastructures fail to transform communities because designers and implementers understand relatively little about the actual livelihoods of residents (e.g., how, where, and when residents commute to work, what household budgets and spending priorities actually are). The success of upgrading projects depends crucially on the ability of residents to accommodate the structural (rules, routines, and practices) requirements of new infrastructures, aligning these with their everyday livelihood strategies. Such strategies are thus essential to understand given they are unlikely to change quickly even after upgrading as they are often deeply embedded in place-specific contexts.

Conceptually, there is a need to develop frameworks that capture the place-specific structural factors that make infrastructures more or less able to improve livelihoods; i.e. to unpack and explicate the infrastructure-livelihoods nexus. Transition scholars further need to consider the wider sustainability implications of infrastructural innovations and include issues of social justice and improved socioeconomic development (e.g., see Grant et al. (2020), Smit and Musango (2015), Swilling (2014), Swilling et al. (2016)). Tackling these conceptual challenges requires a place based and structural lens, a turn that has been advocated for recently in both socio-technical transitions and livelihoods literature (e.g. see Murphy, 2015; Hodson et al., 2017; Carroli, 2018; Natarajan et al., 2022).

This paper advances and applies a sociotechnical transitions perspective to the study of the infrastructure-livelihoods nexus. Transition thinking has proven effective in highlighting the multiple ways that new technologies align with and shape institutional conditions and practices to generate sociotechnical “configurations that work” (Rip and Kemp, 1998, p. 330). It therefore can enable researchers to conceptualize infrastructure upgrading projects as interventions designed to induce sociotechnical transitions in particular places (Hodson and Marvin, 2010). However, the current dominant approach in transition studies focuses on the development conditions of single technologies (e.g., solar energy, bus-rapid transit), which need to mature and institutionalize in order to better contribute to (mostly environment related) sustainability outcomes. In order to tackle the urban upgrading problem in the Global South, we argue that there is a need to capture the interactions between infrastructures, the associated services of providers, and the everyday practices of users (i.e., residents) (see also (Rosenbloom, 2020; Shove et al., 2012)). In doing so, it will be possible to determine if alignments exist between these actors, infrastructures, services, and practices, and whether the sociotechnical configurations associated with them can improve (or not) both environmental performance and the living conditions of urban residents.

We apply a structural lens focusing on rules that guide behavior to conceptualize informal settlements or slums as subsystems of larger-order urban systems that are governed through configurations of rules associated with sociotechnical (infrastructure) and socioeconomic regimes (Murphy and Carmody, 2019). Sociotechnical regimes govern the use, operation and maintenance of newly introduced (or formerly existing) infrastructures e.g., roads, sanitation - see van Welie et al. (2018), Fuenfschilling and Truffer (2014). Socioeconomic regimes govern the production (e.g., employment, manufacturing, services) and reproduction activities (e.g., house-holding, provisioning, socializing) of settlement residents. Taken together, production and social reproduction activities constitute the livelihood strategies that shape and are shaped by the newly introduced infrastructure regimes. Both types of regime consist of formal and informal rules which are often highly institutionalized and which shape the regularized practices of actors (Cherunya et al., 2020a). Moreover, sociotechnical and socioeconomic regimes are aligned with or interdependent on one another in ways that shape the evolution and development of urban (sub) systems (e.g. slums).

In operationalizing this approach, we view slum upgrading programs as explicit attempts to improve livelihoods of residents through investments in new infrastructures. We take a structural lens to explore and determine how alignments or misalignments between rules that are institutionalized in diverse regime structures generate tensions that can prevent a seamless uptake or potentially lead to the destruction of new infrastructures. Given that specific infrastructure interventions presume particular rules (e.g., for use and maintenance) whose adoption is necessary for successful implementation, the success of slum upgrading programs is thus determined in part by the degree by whether there are alignments between the sociotechnical rules associated with new infrastructure, and the rules governing socioeconomic (livelihood) regimes.

To qualitatively understand these alignments, and the infrastructure-livelihood nexus more broadly, we develop a systematic approach to identify intersections between infrastructure (sociotechnical), production (socioeconomic) and reproduction (socioeconomic) regimes that will be shaped by or recursively shape settlement upgrading interventions. Our focus is on the rules governing regimes and the ways in which these are effected by, or influential on, the development outcomes that accompany an upgrading intervention; namely whether it can foster a sustainability transition. In doing so, we extend transition frameworks beyond the sociotechnical (infrastructure) realm to embrace broader questions related to livelihoods and community wellbeing in the Global South (i.e., the infrastructure-livelihoods nexus).

The framework is applied and illustrated through an analysis of recent slum upgrading initiatives in Kenya. Our focus is on Kasarani informal settlement on the outskirts of Naivasha town in Kenya’s Great Rift Valley, northwest of Nairobi. Kasarani’s roads, water, solid waste, footpaths, drainage and lighting were upgraded in between 2012 and 2018 as part of a nationwide program that targeted informal settlements in and around secondary towns in Kenya. Drawing on field research, we assess the impacts of these investments on livelihood strategies of resident groups in the settlement, focusing on whether there are alignments between the rules associated with the production, reproduction, and infrastructure regimes observed in Kasarani. The analysis shows how alignments led to livelihood improvements and how partial or misalignments meant that some infrastructure interventions failed to provide or sustain their envisioned benefits for residents.

The section that follows explores the nexus of infrastructures and livelihoods by explicating insights from livelihoods and transitions literatures. The third and fourth sections elaborate the qualitative and abductive approach employed to the present paper and the appropriateness of Kasarani informal settlement for analysis. Section five and six present and discuss the main findings; namely

that the sustainability of upgrading initiatives depends on whether there are alignments between the rules associated with new infrastructures, and those associated with the extant socioeconomic regime. More broadly, we argue that our conceptual approach is not limited to informal settlement upgrading but can instead be applied to a wide range of transition processes that link urban infrastructures to livelihoods.

2. The infrastructure-livelihoods nexus

Livelihoods research, a long-established area in development studies, has led to the development of frameworks that account for the intersections between the productive and reproductive activities of individuals, households, and communities in the Global South, and the political-economic and vulnerability contexts they are situated in (Bebbington, 1999; Chambers and Conway, 1992; Rakodi and Lloyd-Jones, 2002; Scoones, 1998). Livelihoods analyses are place-based, grounded, and often applied works that seek to “put the last, first” through research that explicates how marginalized or poor communities mobilize multiple assets – i.e., human, physical, financial, political, social, and natural capital – in order to survive, accumulate, and improve their well-being (Chambers, 1997; Rakodi and Lloyd-Jones, 2002). While early livelihoods research focused principally on rural areas, it has been increasingly deployed to examine the strategies of urbanites in Southern cities, particularly those who live in informal settlements and slums (Rakodi and Lloyd-Jones, 2002; Saharan et al., 2019). Some of these works have focused explicitly on infrastructure and its contribution to livelihoods at household level through the provisioning of essential resources and services such as water, energy, and housing (Rouse, 2006; Crawford and Bell, 2012; Mangíra et al., 2019).

While livelihoods research offers a substantive means through which to assess the conditions, needs, and opportunities of communities throughout the Global South, it remains more of a tool to take stock of assets, constraints, and vulnerabilities rather than providing a conceptual approach to understand development pathways. It can thus help to highlight critical areas of intervention but tells us little regarding how development (e.g., infrastructure) projects and trajectories shape or are shaped by established livelihood practices, strategies, and path-dependencies. Moreover, its focus at the household level often tells us little about how livelihoods are shaped by structural factors at wider geographic scales, such as that of the community, city, and the nation state (Natarajan et al., 2022). We believe that these limitations can be addressed through an engagement with transitions perspectives that take a socio-technical, systemic view of place-based development.

2.1. Informal settlements as sociotechnical subsystems

Following Murphy and Carmody (2019), and Murphy’s (2022) work on urbanization pathways in Africa, we conceptualize informal settlements as subsystems of urban sociotechnical and socioeconomic systems. Urban and settlement (sub)systems are realms of technological, material, social, and economic life whose development trajectories are shaped by infrastructures, economic forces, technologies, and livelihood strategies governed by infrastructure and socioeconomic regimes (Shove et al., 2015; Schot et al., 2016; Geels, 2004; Markard et al., 2012). Regimes are constituted by institutionalized formal and informal beliefs, values, norms, routines, regulations, practices and capabilities that mutually construct and are constructed by actors in a system (Fuenfschilling and Truffer, 2014). These constitutive features are built into the rules governing and structuring their everyday operation; the focus of our analysis here.

Infrastructure regimes are *sociotechnical* in nature, very much aligned with conventional views of regimes from transitions scholarship (e.g., see van Welie et al. (2018), Canitez (2019)). They are governed by the rules that guide the use of and provision for basic service infrastructure and technologies, such as sanitation, transport, energy, water, and other collective goods that are vital for the survival and well-being of urban residents. Infrastructure regimes regulate, sanction against or create the negative externalities that are associated with basic services such as congestion, safety concerns, public hygiene, and pollution, among others, issues that can have significant impacts on productivity, health, and the quality of livelihoods. In informal settlements, infrastructure regimes are often governed by private (market), informal, and/or communal interests that function outside the (rational, modernist, statist) expectations, practices, and rules that planners expect, thus seeming illegible or irrational to formal authorities (Achokwa, 2016; Jones, 2019). Moreover, as van Welie et al. (2018) demonstrate, there are often distinct service regimes that govern the provisioning of specific services (e.g., sewerage sanitation versus pit latrines) that are embedded within particular sectoral regimes (e.g., sanitation). Our conceptualization of infrastructure regimes builds on this work to incorporate both service and sectoral regimes that are associated with different kinds of collective goods (e.g., transportation and energy sectors). This combined analysis of several infrastructures is a useful departure for transition studies since it allows study of multiple regimes as opposed to single regimes that have been the norm in most transition studies (Rosenbloom, 2020).

In contrast to infrastructure, production and reproduction regimes are principally *socioeconomic* in nature and capture the livelihoods dimension of the infrastructure-livelihoods nexus. Production and reproduction regimes are manifest of the rules that govern the practices of making a living, providing for oneself and a household, and being part of a community. Production regimes are rules that relate principally to the income generating activities that informal settlement residents conduct to meet their material needs (e.g., work in nearby industries, microenterprises, hawking). Core production rules are those that relate to formal and informal employment, entrepreneurship, microenterprise, and economic upgrading (e.g. skills, wage increases). They dictate who does which production activities, and when, how, why, and where such activities are conducted.

Reproduction regimes entail the rules associated with everyday life in households (e.g., cooking, childcare, provisioning, socializing, leisuring). Reproduction regimes dictate how and where individuals go about meeting basic needs and being part of a community (Cherunya et al., 2020a; Geels et al., 2015; Warde, 2005; McMeekin and Southerton, 2012). In informal settlements,

reproduction regimes are commonly characterized by resilience and survivalist rules given the myriad challenges that force residents to develop innovative, affordable means to access basic goods and services (Jones, 2019; Van Horen, 2000). These rules are anchored in social relations and they play a key role both in sustaining livelihoods and providing opportunities for social upgrading.

From an epistemological point of view, it is important to accept that regimes are often implicit, taken for granted and therefore only observable in everyday practices (Shove et al., 2015; Jones and Murphy, 2011; Reckwitz, 2002; Shove et al., 2012). Practices are stable and recurring patterns of behavior that reflect the explicit and implicit rules governing sociotechnical and socioeconomic regimes. As such, they offer an epistemological object that can reveal rules and their potential alignments or mis/partial alignments as they relate to new infrastructures. Insights from practice-oriented approaches have been absorbed in earlier transition studies focusing on informal settlements. Specifically, van Welie et al. (2018) conceptualizes regime structures in informal settlements as manifest in the following practice related dimensions: ways of dealing with artefacts and infrastructures, organizational modes, structuring of time and space, mobilized rationales and social interaction.

Artefacts and infrastructures represent physical components of technologies such as pipes, taps, roads among others, organizational modes represents actor arrangements in order to access and provide a given service while time and space represent when and where services are conveniently offered or consumed. In addition, rationales reflect the reasons why actors choose to provide or use services and are mobilized in the carrying out of everyday activities. In informal settlements, access, provisioning, and use practices are often transactional in nature and conducted through social interactions and relations. Taken together, the “practical” dimensions of regimes provide avenues for concrete observation and analysis of the rules governing them, especially if implicit. Therefore, the nature of alignments of socioeconomic and Infrastructure regimes/rules can be analyzed by observing practices along these regime dimensions. Such rules include how the provision or use of the service is organized—organizational mode rules—, where the use occurs—spatial rules—, when the use occurs—temporal rules—, how access to the service is coordinated – transactional and interactional rules –, and what rationales are expected in relation to existing or new infrastructures.

All told, informal settlements entail the patterned constellation of socioeconomic and infrastructure (sociotechnical) activities that are governed by rules that are observable in interconnected practices of production, reproduction and infrastructure use. To explicate the livelihoods-infrastructure nexus, it is necessary to conceptualize and analyze the particular ways in which regimes align with one another in a settlement. To do so, we focus on the rules associated with infrastructure regimes (established or emerging), and their alignments with the rules embedded in livelihoods (production and reproduction regimes).

2.2. Alignments, partial alignments and misalignments of regime's rules

Investments in new infrastructures as conceived by actors from outside a settlement (planners, implementers, politicians, etc.) will typically be accompanied by anticipated ways (e.g., organizational modes, rationales) that they will be used and maintained. Adoption of new infrastructures often requires changes to the livelihood practices of residents; changes that need to align with the social contexts where residents live. Social contexts shape the rules of reciprocity in communities, household relationships, and cultural norms, as well as the conditions of, and opportunities for, earning a living either through formal or informal means. The new rules of use and maintenance associated with upgraded infrastructures are typically defined by planners and implementers and are often oriented toward a technocratic understanding of how infrastructure should be governed and used. Adoption will be relatively seamless in cases where infrastructure rules align effectively with those guiding (re)production regimes and if they enhance livelihood strategies of the residents (e.g., if they increase (re)production capacities and/or capabilities). If, however, infrastructure and (re)production related rules are poorly aligned, residents will have to deal with the tensions that ensue and this, in turn, may hamper livelihood strategies or lead to the misappropriation of the infrastructure. Stated another way, settlement residents will use, maintain, ignore, sabotage, and/or transform new infrastructures in line with their material realities and the pre-existing rules and practices that are part-and-parcel of their livelihood strategies. Misalignments therefore may result in varying outcomes. These adaptations may not always have negative impacts on the livelihoods as residents may be creative in repurposing material and infrastructural artifacts for extending their livelihoods options.

There are a few studies that highlight (implicitly) such inter-regime tensions in the context of slum upgrading initiatives. Patel (2013), for instance, elaborates a successful upgrading of Zwelisha, an informal settlement in Durban, and attributes its success to the implementers focus on the livelihoods of residents through genuine community participation throughout the project's implementation. In contrast, other and most upgrading exercises result in infrastructure sabotage, displacements through gentrification and/or abandoned and unused infrastructures even if structurally well-built. Such examples are widely reported in diverse informal settlements in Kenya and Brazil among others (Libertun de Duren and Osorio Rivas, 2020; Yeboah et al., 2021). Lastly, instances of borderline successful upgrading also occur and lead to hybridization of (new) infrastructure regimes. In such cases, residents may redefine infrastructures for additional and multiple uses or accommodate them into their extant livelihood strategies. For instance, Massey (2014) explores instances of hybridization in two informal settlements in Cape Town where women extended their newly provided houses making space for road-facing shops and using roads as meeting spaces. She argues that hybridization, referred to as a form of “counter conduct”, stems from previous practices and is traditional and socially based. While these studies implicitly highlight the importance of inter regime alignments for the success of slum upgrading projects, they have not been explored systematically. This paper aims to fill this gap.

To offer an analytical starting point for identifying structural tensions resulting from slum upgrading, we introduce a strong simplifying assumption for now, namely that residents' livelihoods, capabilities, and life conditions do not vary all too dramatically within a specific informal settlement. While this assumption may only hold in few real world cases, it nonetheless enables us to manage the complexity and diversity of slum communities by providing a consistent and robust set of analytical objects (i.e., sociotechnical and

socioeconomic rules) for examining the infrastructure-livelihoods nexus. That said, we acknowledge that informal settlements typically host a wide variety of resident groups with varying livelihood practices, interests and livelihood challenges. Residents typically differ in terms of financial and social resources, capabilities, earning opportunities, land entitlements (e.g. as landlords and tenants of plots in the settlement). But also variations in terms of ethnicity, age, gender, health status, political allegiance, time of residence, etc. might have an impact on the actual livelihood strategies that are available to any specific resident. This diversity will lead to different exposures to newly introduced infrastructures – both in terms of opportunities and constraints – as some might find it easier to accommodate new infrastructure requirements, while others might be challenged or even dispossessed by the same intervention. As consequence, we might expect diverse tensions and conflicts to emerge among the residents, thus making it difficult to judge a specific intervention as a success or failure, in general.

We claim, however, that a consistent set of structural rules will also be present in the diverse livelihood settings that characterize informal settlements – particularly as they relate to the general governance of sociotechnical and socioeconomic regimes (i.e., the basic rules, norms, assumptions, and beliefs associated with them). As such, we instead elaborate a bird's eye view on the emerging structural tensions associated with upgrading projects by assuming rather uniform regimes in order to illustrate the challenges associated with rule alignments. Our focus will therefore be on the generic tensions and less on the diversity of impacts on individual residents. We acknowledge that the methodological choice of reducing the internal complexity of diverse resident groups incurs an analytical cost in terms of the empirical details presented below. However, such a choice is necessary in order to demonstrate the conceptual value-added of our framework as it relates to the livelihoods-infrastructure nexus. Potential extensions beyond the approach taken are elaborated in the conclusions.

Taking all these caveats into account, we may now summarize our explanatory claim as follow: inter-regime alignments, or a lack thereof, can offer a means to examine the structural tensions of a reconfiguring infrastructure-livelihoods nexus. Alignments can either entrench existing socioeconomic regimes or, ideally, drive transitions toward new, improved, and more sustainable basic service distributions and more resilient livelihood strategies. Partial alignments may lead to new hybridized infrastructure regimes that are shaped by prevailing production and reproduction practices. Such changes could be for the better or worse, but they might not reflect the imagined/idealized goals envisaged by upgrading implementers. Lastly, misalignments often lead to limited or even negative net benefits from upgrading interventions and may even lead to the rapid deterioration of the newly provided infrastructures. It would therefore be preferable for planners and implementers to be aware of these structural tensions from the outset. We will now demonstrate how this framework can elucidate the prospects of success of informal settlement upgrading interventions, drawing on the case of a project in Naivasha, Kenya.

3. Methodology

The analysis presented here is based on the case of the Kasarani informal settlement at the outskirts of Naivasha town in Kenya's Great Rift Valley. The rapid urbanization currently experienced in the country, with an annual urban population growth of 4.3 percent, is synonymous with many countries in the global south (The World Bank, 2019). Absent adequate resources and rapid urban growth have led to the sprawl of informal settlements throughout Kenya (UN Habitat, 2016). Kasarani was selected since its infrastructure had recently been upgraded under a countrywide informal settlement upgrading program – the Kenyan Informal Settlement Improvement Program (KISIP). KISIP made investments in 80 settlements nationwide (WorldBank, 2011). The investments comprised six types of infrastructure – water supply, roads, footpaths, storm water drainage, solid waste management unit and street lighting (floodlights).

With respect to its production and reproduction regimes, Kasarani is a compelling case study. It has diverse socioeconomic activities ranging from local, translocal and international scales that benefit from the cheap labor of the residents. It is also a vibrant, diverse community in terms of its ethnic and religious composition, as well as with respect to household composition. While some dwellers claimed that the community is united, politically fueled ethnic conflicts often arise during election years (Lang and Sakdapolrak, 2015). While all the above signals diversity, what is common for all residents is that they utilize a consistent set of general rules that govern their infrastructure use and (re)productive activities. This consistency justifies our approach to select the settlement as a unit of analysis despite its diversity, on the basis of interfaces of infrastructures and livelihoods. Kasarani was studied against background knowledge of another fifteen informal settlements throughout Kenya that the first author had visited. All of these settlements were part of the KISIP initiative (WorldBank, 2011).

Qualitative data was collected in Kasarani between November 2019 and end of January 2020 by the first author. This included 5 full day visits to the settlement from early morning to late evening and an additional six spot check visits on different days. The data collected included observations of how dwellers conducted production and reproduction activities as well as how they accessed, used, and managed infrastructure. The first author observed how residents conducted their day-to-day lives while using infrastructure at different times. At the same time, the author engaged in multiple informal conversations to gather further information as to how and why residents organized their livelihoods as they did. Nine key informant interviews complemented these two data sets. The informants were individuals actively involved in the upgrading project and included two government officials and seven individuals who had resided in the settlement for over ten years. The two government officials were selected due to their deep knowledge of the settlement, one because they extensively did research and both because they actively participated in the upgrading of the settlement. The rest were selected randomly since they conducted varied productive activities in the settlement ranging from running small businesses in different sectors while at the same time residing in the settlement. Three respondents were male and four were female, all between 40 and 60 years old. The interviews offered better opportunities for probing questions that yielded in-depth information based on prior observations and secondary literature. They also offered an opportunity for capturing both verbal and nonverbal cues while the respondents answered the questions. In addition, six project reports and a master thesis specific to Kasarani were reviewed to

empirically assess conditions in the settlement prior to the upgrading.

This study employed an abductive approach, which allowed for the theoretical framework, empirical fieldwork, and case analysis to evolve together and in a manner that advanced the conceptual approach (Dubois and Gadde, 2002). Qualitative (coding) analysis was conducted using Nvivo© data analysis software. The data were coded to reconstruct before and after assessments of the slum's operation, with a particular emphasis on what changed after the slum upgrading project. In doing so, we identified points of interaction between production, reproduction and infrastructure activities and the implicit underlying rules that regulated these regimes. Advanced coding then focused on the mis/alignment of the rules associated with the infrastructure regimes and the rules associated with the socioeconomic regime and subsequent livelihood implications. In addition, the assumptions/presumptions of upgrading project implementers were coded and compared/contrasted with those associated with the actual practices of settlement residents.

4. Slum upgrading in Kasarani: a history

Kasarani was initially owned by Tarabete cooperative society who later sold it to a white settler, the municipal council and four others in the 1980s (MLHUD, 2014a). Beginning in 1988, the Naivasha municipal council leased plots to residents who were mostly descendants of workers from neighboring international flower farms (Kioko, 2012; Kuiper, 2019). Over time, the settlement grew and was characterized by influx of migrant workers working in flower farms from diverse ethnic communities (Kuiper, 2020). Ninety percent of the residents rented their homes at the time of the upgrading which took place between 2010 and 2019 (MLHUD, 2014b). A section of the land was still owned by the government until the tenure project was initiated to issue people with title deeds from 2012 (Interviewee 1). The settlement's population density was 8929 people per km² and it occupies an area of about 14 hectares. Monthly household income for most residents was typically way below the poverty line (US\$2.15 per person per day), amounting to about 274USD monthly per household (MLHUD, 2014a; MLHUD, 2014b). Secondary data and interviews showed that about 88% of the residents made less than 100USD per person per month from precarious jobs such as low wage jobs at the international flower and vegetable farms (Kuiper, 2017), as compared to at least 20USD rent charges required monthly.

Prior to the upgrading Kasarani's basic infrastructure was of poor quality as depicted in Fig. 1. Secondary data and interviews indicated that roads were available as open spaces, but were characterized by encroachments and unpaved surfaces that were impassable especially during the rainy season (MLHUD, 2014a; MLHUD, 2014b). Some alleys were only passable on foot. These characteristics limited the number and type of public service modes of transport that could access the settlement. Only motorcycles, donkey carts and vehicles with significant ground clearance could use the roads. To the residents, roads were governed as communally owned spaces for multiple activities based on time and need. Their use for trade and leisure was based on who settled in which space first, both on a daily basis and for longer periods of time, and involved negotiation, compromise and accommodation based on dweller relations. This applied to all spaces/land that was available in the settlement and is depicted in Figs. 1 and 2 where production activities such as free-range goat rearing and drying cereals along the road pavements is observed. Reproduction activities, such as children playing on roads and road pavements being used as dumping grounds, followed implicit coping rules for space appropriation and dumping respectively. From the implementers' perspective, the roads did not have any amenities or road signs to enable coordination of the few transport modes that came into the settlement, and they thus targeted them for upgrading (MLHUD, 2014a). The roads were to be paved, including footpaths and road signs, with the aim of improving mobility within and outside the settlement as well as the link to the main road towards Naivasha town.

Beyond roads, other infrastructure investments were made to address drainage, lighting, waste management, and drinking water



Fig. 1. Unupgraded section of Kasarani Informal settlement.



Fig. 2. Upgraded section of Kasarani Informal settlement

Caption: The roads and footpaths being used as spaces for drying beans and other cereals leaving one lane open for vehicles, spaces for children to play, makeshift stalls, dumping spaces depending on the time of day.

concerns. A functional drainage system was nonexistent. As a result, the settlement was prone to flooding during the rainy seasons, which exacerbated the already poor living standards of the dwellers (MLHUD, 2014a; MLHUD, 2014b). To improve the situation, drainage channels were proposed for construction along the roads. Dwellers did not know what the channels would look like nor how they would integrate them in their daily lives. Similarly, there was no street lighting at night and residents had to be indoors by nightfall for safety reasons. This prompted a proposal for installation of security streetlights in the settlement to improve security conditions.

In addition, solid waste management infrastructure was also unavailable and dwellers had to cope without it—see Fig. 2—(MLHUD, 2014a). To ameliorate this challenge, the implementers proposed to build a solid waste sorting and recycling unit that was to be operated by resident-run community-based organizations. This was envisioned to provide a new source of income for the few who would manage the unit and reduce negative health and environmental impacts that are associated with unmanaged solid waste. Access to piped, quality and sufficient quantity of drinking water was also highly limited, delivered to parts of the settlement via a community project that only a few dwellers were connected to and which they paid a monthly fee for (MLHUD, 2014a; MLHUD, 2014b). Most dwellers had to access water from the nearby kiosk during its opening hours, fetch at the lake or buy from vendors during the day. Water quality was poor due to fluoride contamination of ground water and pollution of surface water at Lake Naivasha. (Kioko, 2012). Implementers proposed and improved the capacity of the supply system to serve more residents without changing the management structures.

All told, there were numerous challenges that the residents of Kasarani experienced just before the upgrading project delivered the infrastructure interventions highlighted above. We now demonstrate the structural tensions that the infrastructures brought about due to their mis/alignments with the livelihoods of the residents.

5. Alignments between infrastructure and socioeconomic regimes and subsequent development outcomes

Prior to the upgrading program, rules associated with the socioeconomic and infrastructure regimes were observed and reported in Kasarani informal settlement. Production activities included employment in flower and vegetable farms that produced for international export, as well as fishing and subsistence farming (Kuiper, 2019). Additional activities included small licensed and unlicensed businesses such as renting one-room structures to dwellers to live in or conduct business, transport services using donkey carts, bicycles or motorbikes and other, extralegal businesses such as fish poaching, sale of illicitly produced alcohol, robbery and prostitution as reported by Kuiper (2017) and observed by interviewees and the first author. Production activities both within and outside the settlement heavily influenced the rhythms of the dwellers daily lives.

5.1. Explicating the infrastructure-livelihoods nexus in Kasarani

Production activities were shaped by rules that existed long before the upgrading happened. One rule reported by a resident defined who could set up small businesses in the settlement, a practice that made it difficult for non-residents to do so. The consumption rules of residents further constrained non-residents given the former preferred to buy from people they knew and trusted. Restrictions were also present on who could conduct fishing in the nearby lake with seasons determining when fishing could be done. With regard to

housing, landlords determined times when they collected rents and tenants had to abide by these rules. Extralegal business activities were conducted mostly at night while small, legal businesses were largely opened after working hours (e.g., after work from flower farms) and closed after night fall. Public spaces were used flexibly and in multiple ways in support of productive activities. For instance, footpaths and other mobility spaces could also be used as areas to set up small shops or to sell goods. Lastly, transactions for basic commodities and services for daily use were on basis of trust with extended credits or part payments over time as reported by a shopkeeper who was interviewed.

Reproduction activities and their associated rules (i.e., regimes) included those conducted by families at the household level (e.g., cooking, eating, seeking water, sheltering), and those conducted collectively within the settlement (e.g., group worship, leisuring, schooling). Such activities were organized around membership in either family, community groups or religion and were sanctioned by leaders of these groupings. All reproduction activities followed the time cycles of production activities and were always secondary to production activities. They were practiced either early in the morning or late in the evening within the houses or outside in open or shared spaces that were often co-located with production activities. (Kuiper, 2019). Where residents spent their income and did transactions was determined by familiarity, payment modalities and social relations.

The two socioeconomic regimes discussed above shared common practices that shaped the rules of infrastructure use. These were commonplace, observable and included dumping and commuting. As reported by all interviewees, waste was dumped in public spaces at night or during the day if small quantities were involved, otherwise it was dumped in owners' compounds (MLHUD, 2014a). These wastes included organics from households such as food by-products and feces (animal, human), and inorganics such as polyethene packaging materials and plastics. There were no monetary costs or transactions associated with dumping and the effort required was negligible. One interviewee stated that the dumping all over was a "mindset that was difficult to do away with". Residents' objective was only to ensure that the waste was outside their premises or put in a consistent location within owner compounds. Dumping was associated with negative impacts on health and the clogging of drainage systems which caused floods.

Commuting for reproductive and productive purposes also shaped infrastructure regime rules. This was generally organized around those who owned transportation means (often individuals from outside the settlement) and residents in need of transport. Transport alternatives included walking, using bicycles or motor vehicles on available pathways and roads that were also used for other purposes. Commuting was paid for in cash and was negotiated by users based on social relations. Use of roads for commuting and transport was characterized by negotiation in available spaces (roads) at times dictated by owners of the commuting modes. Times for commuting were relatively long due to the poor roads and the congestion caused by other productive activities that were conducted on roads (e.g., hawking, drying beans [see Fig. 2]). Such delays had knock-on effects with regard to the length of the working day (production regimes) and the coordination of household activities (reproduction).

The impacts of upgrading on the infrastructure-livelihoods nexus: rule alignments and livelihood implications in Kasarani

The effectiveness of the infrastructures installed in the settlement varied. The variation was dependent on the nature and extent to which the new infrastructure's rules aligned with the rules of the extant socioeconomic regime. This section examines the (mis/non) alignments associated with the different infrastructures implemented in Kasarani.

5.2. Misalignments: solid waste unit and storm water drainage

A solid waste management unit was installed during the upgrading exercise in order to collect, sort, transport, and manage the waste in the settlement. Extant rules for solid waste had been characterized by minimal effort and cost input. A very small proportion (5%) of residents had a locally organized group to collect the waste from their households twice a month at a cost (MLHUD, 2014a). Beyond these individuals, the vast majority of residents relied on functionally efficient rules and infrastructures that were less demanding in time, efforts and costs as compared to the solutions provided by implementers. Specifically, the rules associated with the new solid waste unit required residents' to actively coordinate waste collection, sorting, transporting and managing at the settlement level. Given extant rules and practices, there was a clear misalignment between the new infrastructure related rules and those associated with existing (re)productive regimes.

In specific terms, misalignments were observed in three ways. First, a new organizational mode was expected for management of the solid waste unit and at the settlement level, which contrasted the extant individual oriented set up. Second, it required more time and effort from the dwellers to individually organize waste collection, processing, and transporting to the unit, and to collectively manage the unit as a community based organization. The dwellers did not consider waste management activities as immediate when compared to other production and reproduction activities and thus were not willing to commit time to the effort. Third, and related, the expected efforts by residents in waste management activities were considered a cost in kind, an economic tax or penalty that would further constrain their already precarious livelihoods. Residents resented this and instead opted to retain existing solid waste management arrangements; despite the negative health and environmental impacts associated with them. Ultimately, and despite the implementers' intentions, residents were unwilling to engage or utilize the solid waste unit even two years after its construction. Because the unit was relatively small and did not significantly disrupt space use rules the residents just ignored it.

The new drainage system faced similar challenges particularly because the new infrastructure rule associated with it was that it needed to be clear of all blockages at all times. Because such infrastructure took up public space, and was not present in the settlement previously, residents still considered drainage spaces as open spaces and continued using them as such. Some built kiosks on them and hawkers spread their sales wares over them as they had used these spaces earlier. There was a misalignment with the socioeconomic regime in two ways. First, the new rules sought to reconfigure the organizational mode by bringing in actors from the municipal government to manage the drainage systems. Their actions were ineffective and alienating as they demanded that residents obey new rules that went against extant ones. Second, and related, the municipal government sought to make drainage areas single-purpose

spaces, contrary to the existing, flexible multipurpose use of such spaces for productive and reproductive activities. Tensions between the different regime structures emerged and the drainage system barely served its purpose; it was always blocked and, in some instances, led to more flooding exacerbating the public health issues in the settlement.

5.3. Alignments: floodlights and water connections

Floodlights were also installed to improve security and increase lighting hours in the settlement. The regional government managed them with operational rules that included their being remotely turned on and off at predetermined times and periodically maintained in case of break down. These rules were enforced remotely by the regional government without any cost to, or initiative needed by, the residents. In other words, the new rules for use and management of the floodlights did not demand any new organizational requirements in the settlement since the residents were passive users and because personal security remained a personal initiative. However, the lighting did increase nighttime socioeconomic activities since security and safety were improved. Moreover, because the floodlights occupied a minimal footprint (space) in the settlement, they did not disrupt existing production and reproduction spaces. Floodlights thus enabled, at no cost to residents, an overall increase in socioeconomic activities and subsequent improvements to their livelihoods. All told, there was a clear alignment between the infrastructure (lighting) and socioeconomic regimes in the settlement.

Upgraded water connections were also well aligned with the settlement's socioeconomic regime. Implementers increased the capacity of the existing community managed water supply system and improved the water quality available to residents. In doing so, the extant rules for water service provisioning did not need to be changed. These rules revolved primarily around payment and water access. Payments were typically made monthly with prorated payments available to those residents who could not afford to pay in lump sum. Access rules entailed when water kiosks were open for those who used them and governed the use of underground pipe networks for other residents. Overall, there was an alignment with the rules of the socioeconomic regime given that the existing organizational mode for water management remained the same and because no new actors were introduced to the regime. In fact, the improved water connections increased the time that water was available for households, at the water kiosks and for other businesses, and they did not reduce the affordability of, or payment mechanisms associated with, water access. They also did not disrupt spaces for other socioeconomic activities as pipes were fitted underground. The net result was improved livelihoods for the residents.

5.4. Partial alignment and hybridized rules: roads and footpaths

The roads and footpaths that were constructed presented a unique case among all the infrastructures. They demonstrated partial alignment with the rules associated with the socioeconomic regime. This resulted in hybridized rules for infrastructure use where dwellers adopted rules that only suited them but disregarded those that went against the rules of their socioeconomic regime.

Implementers envisioned that conventional traffic rules associated with the use of roads and footpaths would be strictly followed. The implementation of new road works commenced with the relocation of structures that were on wayleaves. These included structures where residents had small businesses or lived—in other words, where the socioeconomic regime was already functional. Using contractors, implementers built the roads and footpaths to bitumen standards, similar to those in nearby towns on spaces that were previously used for mobility, productive and reproductive activities simultaneously. The key rules that were associated with use of these roads from the implementers' perspective included: use of the left-hand side for motorists, obeying road signage, traffic lights and road markings where available, driving at recommended speed limits in residential areas, keeping roads and footpaths free of obstruction, prohibition from driving or parking on footpaths, maintenance mandated to the government among others. These rules sought to limit the use of roads to mobility purposes, ignoring the multipurpose productive (e.g., hawking) and reproductive activities (e.g., drying beans) that had long been in existence.

As a result, residents (especially traders) ignored many of the implementers' rules and continued to utilize roads and footpaths as public spaces for socioeconomic activities. They acknowledged the role of roads in improving commuting and transport services but needed to maintain or recreate rules for their appropriation based on their existing socioeconomic regime. After implementers finished the construction of the roads and footpaths, traders, residents and children reestablished their small business structures on them, conducted household chores in them (e.g., bean drying and playing [see Fig. 2]), and even used sections of the road as meeting points for different social groupings. This was entirely based on space appropriation rules that included: occupation of space on first come-first serve basis, setting up smaller businesses on busy roads in the evening, and the disposing of waste on roads and foot paths. Space appropriation rules were shaped by a production regime that maximized profits without necessarily accounting for negative externalities, and a reproduction regime that secured the basic needs of residents. The appropriation rules were a stark contrast to intended use rules by implementers who relied on enforcement by outside authorities.

The end result was partial alignment leading to hybridized rules. Residents partially adopted traffic rules established by implementers while maintaining their space appropriation rules. They only partially adopted use of the left side by motorists but at the same time obstructed roads and footpaths with their business practices or living structures. Motorists from outside the settlement had to conform and negotiate use on these roads since enforcement of traffic laws was minimal and sometimes impractical. One resident explained this hybridization implicitly as follows:

"We know, what each one of us does for a living, so I know what they deal with. Even if someone dries his or her beans outside (*pointing to the road in Fig. 2- a production activity*), I do not mind so much, as long as it does not inconvenience me so much. When one vehicle stops and goes along (*on a lane blocked by a dweller doing business or kids playing*), this has not inconvenienced anyone in any way, so you just continue with what you are doing. If your kiosk is on the road, I know who you are; I would not go there (*to the authorities*) to call for your removal. So that bond of friendship and knowing each other has lead a lot of things go wrong, but we are

very accommodative ...” Resident, Kasarani

The hybridized rules led to a partial reconfiguration of the rules governing the organizational mode that managed the mobility infrastructure and commuting as a service. The roads attracted transport operators from outside the settlement who supplemented transport services with new and multiple modes of transport. This negatively impacted the few existing transport operators but increased options for mobility for most of the residents. At the same time, actors from the government could now engage in maintenance services, a positive change for all residents. Commuting times and planning subsequently became more predictable and this freed up time for other livelihood activities. Road spaces were only partially reconfigured as their use remained very flexible and fluid for a variety of productive and reproductive activities, in contrast to the single-use (mobility) expectations of implementers. Transaction modes and payment rules for commuting did not change but the prices for commuting decreased due to better roads and more mobility options; to the benefit of the residents. Overall, the hybridized road appropriation rules impacted the settlement by partially enhancing mobility as a result of prevailing production activities within the settlement. Table 1 illustrates and summarizes how each infrastructure impacted the socioeconomic regime in Kasarani.

6. Discussion

The five infrastructures installed in Kasarani provide key insights for most infrastructures and infrastructure combinations that can be installed while upgrading informal settlements. Upgrading is characterized by two integrated aspects: rules that accompany the use of newly installed infrastructures as envisioned by implementers and extant rules that characterize the socioeconomic regime that the new infrastructure has to be aligned with. Alignments between these rules significantly shape the prospects for a new infrastructure regime to come into being.

The Kasarani case demonstrates three ways in which new infrastructure and services reconfigure existing socioeconomic regimes. First, the rules for use can align with the extant socioeconomic regime resulting in limited structural tensions. This in turn leads to infrastructure adoption by residents whose livelihood strategies are enhanced by the infrastructure. The security lighting and the water supply infrastructure exemplify this. Such an alignment in informal settlements manifests as a non-disruptive (security lighting) or non-intrusive (water supply infrastructure) set of new infrastructure rules. The two examples demonstrate that livelihoods can be improved through anticipating regime alignments. As Cherunya et al. (2020a) note, community participation exercises can increase the capacity of implementers to understand existing rules and livelihoods practiced by residents, and to subsequently account for these such that buy-in from residents is more likely. When such considerations are met, a transition to improved livelihoods is achieved in the long term as exemplified in Patel (2013).

Secondly, new infrastructure rules may partially align with the extant socioeconomic regime resulting in hybridization. This in turn influences the socioeconomic activities positively to some extent but barely reconfigures the socioeconomic regime itself. Such is exemplified by roads and footpaths in Kasarani. In hybridization, residents only co-opt those appropriation rules for the infrastructure that align with their existing socioeconomic regimes and ignore those that present tensions. While hybridization can also improve

Table 1
Outcomes of installed infrastructure regimes and their impacts on the socioeconomic regime and associated livelihood implications.

Infrastructures	Rules associated with the infrastructure regime	Disruption or extension of practice dimensions of the socioeconomic regime due to new infrastructure				Livelihoods
Upgraded infrastructure <i>Equivalent unupgraded</i>	<i>New rule sets</i>	<i>Organizational mode</i>	<i>Temporal</i>	<i>Spatial</i>	<i>Transactional</i>	<i>Livelihood implications</i>
Flood lights <i>None</i>	New rules; automated turn on and off. They did not prompt dwellers to accommodate them in any way	New but remote actors thus no disruptions of actor relations in the settlement	Extended light hours for production and reproduction activities	No space use disruption due to minimal footprint	Payments handled remotely and not done by dwellers thus no disruptions	Largely improved production and reproduction activities in the settlement by increasing available time for these activities
Water connections <i>Water connections</i>	No new rules; followed existing community water project rules	Actor network remained the same	Extended times of water access due to household connections	Minimal space occupied since pipe networks were underground	Community water project had capabilities to handle payment mechanisms	Contributed to production and reproduction activities while at the same time releasing time for other production activities
Storm water drainage <i>Open spaces</i>	New conventional rules for drainage use conditions that were never adopted by dwellers	New external actors that failed in reconfiguring previous actor network that was settlement oriented	Reduction of time used to counter flooding shocks occasionally experienced in the settlement	Reconfigured spaces partially for specific exclusive use i.e. drainage	No payments in cash or kind was expected thus no disruption	Minimal positive outcomes that were hard to sustain due to dumping from production and reproduction activities
Solid waste unit <i>Open spaces</i>	New conventional rules for collection, sorting, conveyance, treatment and disposal envisioned but not adopted by dwellers. Coping was more functionally efficient for them	No new actors were expected. However, new actor constellations in solid waste management were expected. Implementers planned to engage existing community based organizations	New time allocation for solid waste management related activities at households and businesses	Minimal spatial footprint of the unit was nondisruptive of space use rules	Dweller efforts were required for the additional work of collecting and sorting waste and transporting it to the unit	No positive outcomes since the infrastructure never embedded in the settlement
Roads, foot paths <i>Open spaces</i>	Hybridized rules: both space appropriation rules by residents and formal traffic rules were at play (Figure 2)	New external actors partially reconfiguring previous actor network that was settlement oriented	reduced access times due to better roads	Reconfigured spaces partially for exclusive use i.e. commuting	Payment methods remained the same, transport costs reduced	Hard to sustain positive outcomes due persistent activities done on infrastructure and linked to both production and reproduction
Key						
	Alignment					
	Partial alignment/Hybridization					
	Misalignment					

livelihoods to different extents, it can limit the lifespans of infrastructures and thus livelihood gains may not be sustained in the long term. Hybridization can result in mixed livelihood outcomes as basic service needs of residents remain unmet while new socioeconomic opportunities emerge in response to new infrastructures. A transition can only occur after hybridization if follow up interventions to alleviate tensions on the socioeconomic regime due to the infrastructure.

Lastly, infrastructure regimes can fail to align (misalignment) due to structural tensions resulting to non-adoption of the infrastructure by the residents. Such is exemplified by the solid waste unit and the drainage system in Kasarani settlement. A key challenge to improving these infrastructures' performance was the inability of implementers and residents to align the new infrastructures' rules with the extant socioeconomic regime. Such infrastructure is consequently bound to be vandalized, ignored, and/or to decay. Total misalignments will not reconfigure regimes nor have any positive impact on livelihoods. In some instances, they can even lead to the deterioration of livelihoods.

In the Kasarani settlement, we by-and-large observe mis/partial alignments. However, two infrastructures, roads and footpaths, indicate that misalignment does not necessarily have to be observed on all regime dimensions. Even one regime dimension (e.g., space or organizational mode) could lead to partial alignments and subsequent minimal implication on the residents' livelihoods. Where there are full alignments – water connections and flood lighting – the upgrading intervention is likely to sustain its positive livelihood implications assuming the implementer (e.g., regional government) is able to maintain it. Beyond such positive outcomes, however, Kasarani remains largely on an unsustainable trajectory as the underlying infrastructure-livelihood nexus was not significantly reconfigured by the upgrading interventions. Achieving regime alignments or at least identifying and mitigating the risks likely to cause misalignments is essential to achieve improved livelihood outcomes/effective upgrading outcomes.

7. Conclusion

We sought to understand how livelihood improvements do, or do not, occur following infrastructure upgrading initiatives. We employed a sociotechnical approach to understand how tensions due to alignments or misalignments of regimes condition the infrastructure-livelihoods nexus. Insights from the case of Kasarani's infrastructure upgrading intervention led to the following conclusions. First, the success of upgrading initiatives depends on the structural tensions exhibited by the strength and quality of the alignments (inc. misalignments, partial alignments) between the rules (e.g., temporal, spatial, organizational, transactional) structuring extant infrastructure regimes, those of the new/desired infrastructure regime, and those of the socioeconomic regime through which different livelihoods are realized by different residents. Partial alignments generate structural tensions leading to hybridized rules where residents only accommodate the rules that are in line with their socioeconomic regimes while ignoring the rest. Alignment ensures sustained upgrading outcomes with limited structural tensions while misalignment leads to extreme tensions resulting in unused infrastructure or even its rapid deterioration. Second, upgrading initiatives are likely to fail if the new, desired regime configuration that is mis- or partially aligned is not reconfigured by implementers in a participatory and reflexive manner after the initial intervention.

The findings are significant for the transitions literature as it integrates concerns about livelihoods, places and multiple socio-technical systems into a single framework; ideas that have been elusive in transitions scholarship to date (Rosenbloom, 2020). The paper demonstrates that transitions through infrastructure interventions need to be place and people centered for them to be effective and just and should aim to reduce structural tensions that emerge from new interventions. A further implication is that transition scholars should extend their analytical foci beyond a particular sociotechnical sector (e.g., energy, water) and into the realm of the socioeconomic and spatial aspects of transitions. In doing so, studies can move beyond a focus on the adoption or use of new infrastructures and technologies as the key indicator of "transition", and into more general, cross-sectoral concerns regarding community development and well-being as manifest in livelihood changes.

The regime approach was useful in assessing how infrastructures and livelihoods interact to shape the overall development implications and trajectories of informal settlements. However, the use of the approach is not limited to informal settlements, it has a broader relevance and can be used in other fields and geographical areas to anticipate and assess how different technologies and infrastructures shape people's livelihoods and their likely development implications. Future research could focus on qualitatively comparing how alignments of sets of infrastructures in different locations impact residents. In addition, planners need to be aware of the tensions that new infrastructures present. In Kasarani, for instance, since roads were used as market spaces while the designated market space remained unused, it would be worthwhile to incorporate business stalls along the roads instead of allocating market space elsewhere.

An important limitation of our conceptual approach relates to the real-world diversity of livelihoods situations among different resident groups in the empirical case. We only related generally to different strategies of settlement residents and did not attempt to fully explicate the livelihood-infrastructure nexus in great detail. Future studies should elaborate on these complexities and embrace issues of divergent impacts on different resident groups, opening up the analysis towards considerations of winners and losers, conflict, power and local politics. This will, in particular, require a more differentiated approach for evaluating the impact of infrastructure interventions in terms of positive or negative outcome for who and over which time periods. Notwithstanding these particular limitations, we maintain that the basic types of tensions identified in this paper are accurate and consistent, and that they offer the basis for a better understanding of how/why infrastructure interventions can have a positive (or negative) impact on the livelihoods of residents.

Finally, we want to emphasize that this study was limited to the settlement level with a focus on structural tensions that result from (mis)aligned rules and regimes. This, rather static perspective, should be complemented by a deeper analysis of processes of appropriation where residents try to resolve the tensions by using, ignoring or reshaping the delivered infrastructures, potentially modifying

their differentiated livelihood strategies in the process. Finally, our approach is limited by the time span of our analysis given our focus was only up to two years after upgrading. Other processes (e.g., gentrification, land disputes, housing market dynamics) that may occur later and lead to the displacement of original dwellers by economically more powerful ones, and thus fundamentally undermine extant livelihood strategies and outcomes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Acknowledgments

This research was funded by Eawag Discretionary fund.

References

- BEBBINGTON, A., 1999. Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. *World Dev.* 27, 2021–2044.
- Brown-Luthango, M., Reyes, E., Gubevu, M., 2017. Informal settlement upgrading and safety: experiences from Cape Town, South Africa. *J. Housing Built Environ.* 32, 471–493.
- Calderón, C., Servén, L., 2014. Infrastructure, Growth, and Inequality: an Overview. The World Bank.
- Canitez, F., 2019. Pathways to sustainable urban mobility in developing megacities: a socio-technical transition perspective. *Technol. Forecast Soc. Change* 141, 319–329.
- Carroli, L., 2018. Planning roles in infrastructure system transitions: a review of research bridging socio-technical transitions and planning. *Environ. Innov. Soc. Transit.* 29, 81–89.
- Chambers, R., 1997. *Whose Reality Counts*. Intermediate technology publications, London.
- Chambers, R., Conway, G., 1992. *Sustainable Rural livelihoods: Practical Concepts For the 21st Century*. Institute of Development Studies, UK).
- Cherunya, P.C., Ahlborg, H., Truffer, B., 2020a. Anchoring innovations in oscillating domestic spaces: why sanitation service offerings fail in informal settlements. *Res. Policy* 49, 103841.
- Cherunya, P.C., Truffer, B., Samuel, E.M., Lüthi, C., 2020b. The challenges of livelihoods reconstruction in the context of informal settlement upgrading. *Environ. Plan. A*, 0308518X20926514.
- Crawford, C., Bell, S., 2012. Analysing the relationship between urban livelihoods and water infrastructure in three settlements in Cusco, Peru. *Urban Stud.* 49, 1045–1064.
- Dubois, A., Gadde, L.-E., 2002. Systematic combining: an abductive approach to case research. *J. Bus. Res.* 55, 553–560.
- Fuenfschilling, L., Truffer, B., 2014. The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Res. Policy* 43, 772–791.
- Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory. *Res. Policy* 33, 897–920.
- Geels, F.W., Mcmeekin, A., Mylan, J., Southerton, D., 2015. A critical appraisal of sustainable consumption and production research: the reformist, revolutionary and reconfiguration positions. *Glob. Environ. Change* 34, 1–12.
- Gough, I., 2019. Universal basic services: a theoretical and moral framework. *Polit. Q.* 90, 534–542.
- Grant, R., Carmody, P., Murphy, J.T., 2020. A green transition in South Africa? Sociotechnical experimentation in the Atlantis Special Economic Zone. *J. Mod. Afr. Stud.* 58, 189–211.
- Hodson, M., Geels, F.W., Mcmeekin, A., 2017. Reconfiguring urban sustainability transitions, analysing multiplicity. *Sustainability* 9, 299.
- Hodson, M., Marvin, S., 2010. Can cities shape socio-technical transitions and how would we know if they were? *Res. Policy* 39, 477–485.
- Jones, A., Murphy, J.T., 2011. Theorizing practice in economic geography: foundations, challenges, and possibilities. *Prog. Hum. Geogr.* 35, 366–392.
- Jones, P., 2019. The shaping of form and structure in informal settlements: a case study of order and rules in Lebak Siliwangi, Bandung, Indonesia. *J. Reg. City Plan.* 30, 43–61.
- Kioko, E.M., 2012. *Poverty and Livelihood Strategies At Lake Naivasha, Kenya: A Case Study of Kasarani Village*. Universität zu Köln.
- Koster, M., Nuijten, M., 2012. From preamble to post-project frustrations: the shaping of a slum upgrading project in Recife, Brazil. *Antipode* 44, 175–196.
- Kuiper, G., 2017. *The Flowers are Carrying Us: Agro-industrial Labour and Migrant Workers' Settlements at Lake Naivasha, Kenya*.
- Kuiper, G., 2019. *Agro-Industrial Labour in Kenya: Cut Flower Farms and Migrant Workers' Settlements*. Springer.
- Lang, B., Sakdapolrak, P., 2015. Violent place-making: how Kenya's post-election violence transforms a workers' settlement at Lake Naivasha. *Polit. Geogr.* 45, 67–78.
- Libertun de Duren, N.R. & Osorio Rivas, R. 2020. *Bairro: ten years later*. IADB: inter-American Development Bank.
- Mang'ra, P.K., Mbathi, M., Obiero, S., 2019. Understanding tenure security, infrastructure and livelihoods nexus in slum upgrading. *Res. Human. Soc. Sci.*
- Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. *Res. Policy* 41, 955–967.
- Massey, R.T., 2014. Exploring counter-conduct in upgraded informal settlements: the case of women residents in Makhaza and New Rest (Cape Town), South Africa. *Habitat Int.* 44, 290–296.
- Mcmeekin, A., Southerton, D., 2012. Sustainability transitions and final consumption: practices and socio-technical systems. *Technol. Anal. Strat. Manage.* 24, 345–361.
- MLHUD 2014a. *ESIA: the Proposed Infrastructure Upgrading Project in Kihoto, Karagita, Kamere and Kasarani Informal Settlements*.
- MLHUD 2014b. *Kenya Informal Settlement Improvement Project: resettlement Action Plan(RAP)*.
- Murphy, J.T. 2022. *Urban-economic geographies beyond production: nairobi's sociotechnical system and the challenge of generative urbanization*. ZFW-Adv. Econ. Geogr.
- Murphy, J.T., Carmody, P., 2019. Generative urbanization in Africa? A sociotechnical systems view of Tanzania's urban transition. *Urban Geogr.* 40, 128–157.
- Natarajan, N., Newsham, A., Rigg, J., Suhardiman, D., 2022. A sustainable livelihoods framework for the 21st century. *World Dev.* 155, 105898.
- Patel, K., 2013. A successful slum upgrade in Durban: a case of formal change and informal continuity. *Habitat Int.* 40, 211–217.
- Rakodi, C., Lloyd-Jones, T., 2002. *Urban Livelihoods: a People-Centred Approach to Poverty Reduction*. Earthscan/DFID, London.
- Reckwitz, A., 2002. Toward a theory of social practices: a development in culturalist theorizing. *Eur. J. Soc. Theory* 5, 243–263.
- Rip, A., Kemp, R., 1998. Technological change. *Hum. Choice Clim. Change* 2, 327–399.

- Rosenbloom, D., 2020. Engaging with multi-system interactions in sustainability transitions: a comment on the transitions research agenda. *Environ. Innov. Soc. Transit.* 34, 336–340.
- Rouse, J.R., 2006. Seeking common ground for people: livelihoods, governance and waste. *Habitat Int.* 30, 741–753.
- Saharan, T., Pfeffer, K., Baud, I., Scott, D., 2019. Comparing governance and bargaining of livelihoods in informal settlements in Chennai and eThekweni. *Cities*, 102287.
- Schot, J., Kanger, L., Verbong, G., 2016. The roles of users in shaping transitions to new energy systems. *Nat. Energy* 1, 1–7.
- Scoones, I. 1998. **Sustainable rural livelihoods: a framework for analysis.**
- Shove, E., Pantzar, M., Watson, M., 2012. *The Dynamics of Social Practice: Everyday Life and How It Changes.* Sage.
- Shove, E., Watson, M., Spurling, N., 2015. Conceptualizing connections: energy demand, infrastructures and social practices. *Eur. J. Soc. Theory* 18, 274–287.
- Smit, S., Musango, J.K., 2015. Towards connecting green economy with informal economy in South Africa: a review and way forward. *Ecol. Econ.* 116, 154–159.
- Swilling, M., 2014. Contesting inclusive urbanism in a divided city: the limits to the neoliberalisation of Cape Town's energy system. *Urban Stud.* 51, 3180–3197.
- Swilling, M., Musango, J., Wakeford, J., 2016. Developmental states and sustainability transitions: prospects of a just transition in South Africa. *J. Environ. Policy Plan.* 18, 650–672.
- The World Bank 2019. **Combined Project Information Documents/Integrated Safeguards Datasheet (PID/ISDS).**
- UN Habitat, 2016. **UN-Habitat Support to Sustainable Urban Development in Kenya: Addressing Urban Informality.** Nairobi.
- UN, 2020. **Progress Towards the Sustainable Development Goals.** United Nations.
- Van Horen, B., 2000. Informal settlement upgrading: bridging the gap between the de facto and the de jure. *J. Plan. Educ. Res. Afr. Lit.* 19, 389–400.
- Van Welie, M.J., Cherunya, P.C., Truffer, B., Murphy, J.T., 2018. Analysing transition pathways in developing cities: the case of Nairobi's splintered sanitation regime. *Technol. Forecast. Soc. Change* 137, 259–271.
- Warde, A., 2005. Consumption and theories of practice. *J. Consum. Cult.* 5, 131–153.
- Worldbank 2011. **Project Appraisal Document on a Proposed Credit in the Amount of SDR 65.0 Million (US \$ 100 Million Equivalent) to the Republic of Kenya for the Informal Settlement Improvement Project.**
- Yeboah, V., Asibey, M.O., Abdulai, A.-S.J., 2021. Slum upgrading approaches from a social diversity perspective in the global south: lessons from the Brazil, Kenya and Thailand cases. *Cities* 113, 103164.