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A SOCIOTECHNICAL SYSTEMS ANALYSIS OF VACCINE ACCESSIBILITY FOR YOUNG MOTHERS IN A KENYAN REFERRAL HOSPITAL

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Abstract
Public health vaccination programmes evaluate access through coverage metrics, treating the clinic as a neutral delivery point. This paper argues that in/accessibility for young mothers is systemic, produced by the configuration of the sociotechnical system constituting the maternal and child health clinic. This paper draws on a systems science perspective grounded on assemblage ethnography guided by Actor-Network Theory, conducted at Jaramogi Oginga Odinga Teaching and Referral Hospital in Kisumu, Kenya in 2026. The paper maps human and non-human system components and analyses how interactions generate in/equities for young mothers aged 18 to 24. Seven component categories are identified: spatial configurations, documentary artefacts, cold-chain infrastructure, procedural instruments, informational materials, cultural protective objects, and post-vaccination pharmaceuticals. Each is an active system element whose feedback dynamics determine whether vaccination is genuinely or merely formally available. The weighing scale processes anthropometric data through a Z-score mechanism with no human override. The clinic booklet depends on literacy, a property the system design ignores. Post-vaccination care depends on purchasing capacity that informal settlement mothers do not uniformly possess. A pharmacy closure redirected vaccinated infants through a general outpatient area, a design failure with epidemiological consequences. Equity failures are structural, produced by assemblage configuration rather than individual actors. Redesign, specifically relocating pharmacy services, integrating antipyretics into the free package, sharing anthropometric data with mothers, and producing materials in the community language, addresses these failures directly. The paper demonstrates that systems science offers a practical diagnostic and redesign framework for healthcare delivery constraints in low-resource settings.

Keywords: Sociotechnical systems; actor-network theory; vaccine accessibility; maternal and child health; systems ethnography.

1. Introduction

Health systems researchers have long recognised that the gap between designed protocol and lived practice is not a deviation to be corrected but a constitutive feature of how care systems operate. Yet most accounts of that gap focus on human actors: underpaid health workers, overburdened supervisors, patients who do not comply. What tends to get left out is the material world in which those actors are embedded and which actively shapes what they can do.

This paper takes that material world seriously. It reports on ethnographic fieldwork carried out at the Maternal and Child Health (MCH) vaccination clinic at JOOTRH in Kisumu, Kenya, from January to March 2026. The fieldwork included twelve in-depth interviews with young mothers aged 17 to 24, ten key informant interviews with clinic staff, structured observation sessions, and the production of hand-drawn

facility maps. The data were collected as part of a doctoral study applying assemblage ethnography and ANT to questions of vaccine access for young mothers in a public referral hospital setting.

The paper sits at the intersection of two intellectual traditions that have more in common than their disciplinary boundaries suggest: ANT as developed by Latour, Callon, and Law, and the general systems science tradition associated with Bertalanffy, Checkland, and more recently the complexity turn in social science. Both traditions resist reductionism. Both insist that outcomes emerge from relations rather than from the properties of isolated components. Both attend to feedback, non-linearity, and the ways in which structure constrains possibility. What ANT adds to systems thinking is an insistence on symmetry: that the non-human components of a system are not merely infrastructure but active participants whose configurations shape what is possible for human actors within the system.

The argument of this paper is straightforward. Vaccine delivery at JOOTRH is a sociotechnical system. Its outputs, including who gets vaccinated on schedule and who does not, who experiences the encounter as dignified and who does not, are emergent properties of how its components are assembled. Understanding those outputs requires mapping the assemblage, not just the protocol.

2. Theoretical Framework: ANT, Systems Science, and the Concept of Assemblage

ANT begins from a methodological commitment that Latour (2005) calls the principle of generalised symmetry: humans and non-humans should be analysed with the same conceptual vocabulary. This is not a claim that refrigerators have intentions or that posters feel. It is a claim that the analytical tools used to describe human agency should not be applied asymmetrically, exempting objects from causal consideration while attributing all agency to persons. In a vaccination clinic, what the weighing scale demands, what the cold-chain refrigerator makes possible, and what the documentation booklet requires are as much a part of explaining outcomes as what the nurse says to the mother.

The concept of translation (Callon, 1984) names the process by which actors, human and non-human, are enrolled into stable networks. A vaccination protocol is not simply a set of instructions. It is a translation: a process by which national immunisation policy, vaccine science, refrigeration technology, training procedures, and individual clinical encounters are brought into alignment. When translation holds, the network is stable and vaccination happens as planned. When it fails, the network becomes visible as a network, and its constructed character is exposed.

Latour's (1992) concept of delegation offers a complementary tool. When experts are absent, their authority can be delegated to objects. A temperature management poster on the wall of a cold-store room is not decoration. It is the Ministry of Health, present and instructing even when no ministry official is in the building. A bottle of paracetamol sent home with a mother is a nurse's clinical authority, materialised and made portable. Delegation extends the reach of the system beyond its physical boundaries.

Star and Griesemer's (1989) concept of boundary objects describes artifacts that maintain a coherent identity across different social worlds while adapting to local conditions at each crossing. A single document that simultaneously serves as a patient identifier, a clinical record, a scheduling tool, and a data point in a national reporting system is a boundary object. It holds different actors together around a shared reference without requiring that they share an interpretation.

Systems science contributes a complementary set of analytical tools. Bertalanffy's (1968) general systems theory established that the behaviour of a system cannot be inferred from the properties of its components

in isolation. Checkland's (1981) soft systems methodology operationalised this insight for human activity systems, attending to how different stakeholders construct the purpose of a system differently. More recently, Meadows (2008) showed that the leverage points for changing a system's behaviour are rarely where intuition suggests: they lie not in the symptoms but in the structure, and particularly in the feedback loops, delays, and constraints that govern how components interact.

Together, these frameworks produce a reading of the vaccination encounter that is neither focused on individual human performance nor reducible to systemic determinism. The assemblage concept, drawn from Deleuze and Guattari (1987) and operationalised for social science by DeLanda (2006), names the productive tension between these levels. An assemblage is a whole whose properties emerge from the relations among its parts but which cannot be reduced to those parts. It is historically contingent: assembled in particular ways for particular reasons, carrying the traces of the decisions made when it was configured, and capable of being reassembled differently.

3. Seven Categories of Non-Human Actants in the JOOTRH Vaccination Assemblage

The fieldwork identified seven analytically distinct categories of non-human actants. Each category is described below in terms of its composition, its observed effects on the vaccination encounter, and its implications for systemic equity.

3.1 Spatial Actants

The MCH clinic at JOOTRH occupies a facility known locally as the Totos Corner, positioned at the western edge of the hospital compound and connected to the main buildings by a covered concourse. This spatial arrangement is not neutral. When the dedicated Totos Corner pharmacy was closed due to staff reductions, mothers requiring post-vaccination paracetamol were redirected across the compound to the main hospital pharmacy, requiring vaccinated infants with temporarily activated immune responses to transit through a general outpatient area shared with acutely ill patients. A pharmacy technician noted this directly during observation. The spatial actant here is structural: it was not designed to harm, but its configuration produces a risk that operates below the threshold of formal policy attention.

The waiting area's smallness created social proximity between young and older mothers, simultaneously enabling informal knowledge-sharing and amplifying social surveillance on young mothers who already reported feeling observed and judged. The architectural positioning of HIV testing services adjacent to PMTCT facilities generated stigma through spatial proximity rather than through anyone's intention to stigmatise. These are emergent properties of spatial configuration: outcomes produced by the arrangement rather than by individual decisions.

3.2 Documentary Actants: The MCH Booklet

The Kenya Ministry of Health Mother and Child Health Handbook (MOH216) was the single most consistently mentioned non-human actant in the dataset. Introduced nationally in 2010 following a pilot in Nyanza Province in 2007 (JICA, n.d.), it functions simultaneously as a patient identifier, a clinical record, a vaccination scheduling tool, and a data node in the national immunisation reporting system. Kawakatsu et al. (2015) found, in a study of 2,051 mothers across four districts in Nyanza Province, that MCH booklet ownership was positively associated with appropriate health-seeking behaviour, but that ownership rates in poorer households depended substantially on the quality of community health worker engagement.

The booklet is a boundary object in Star and Griesemer's (1989) sense. For the registration clerk it is an identification document. For the triage nurse it is a clinical record. For the mother it is a calendar. For the

national reporting system it is a data point. These uses are not in conflict: the booklet maintains a common referential identity while adapting to the requirements of each social world it crosses. But for mothers with limited literacy, its scheduling function depends on the mediation of a literate family member, enrolling an informal social network into what the formal system treats as an individual responsibility.

3.3 Cold-Chain Actants

The vaccine cold chain at JOOTRH centred on a Dulas solar-powered refrigerator, supplemented by insulated cooler boxes and wall-mounted temperature management posters produced by the Kenya Expanded Programme on Immunisation (KEPI). PATH's (2020) assessment found that solar-direct-drive refrigerators of this type substantially reduce temperature excursion events relative to older models. The MCH in-charge managed the refrigerator each morning, distributing vaccines to cooler boxes for the day's sessions.

The cold-chain illustrates Latour's (1992) delegation concept clearly. Temperature management posters on the cold-store wall encoded national protocols into a permanently present document: the Ministry of Health instructing staff in a space where no ministry official was present. The refrigerator's operational reliability was contingent on the in-charge's daily presence. When she was absent for training or administrative duties, a structural vulnerability in the network was exposed.

Vaccine stockouts represent a specific form of network rupture. Drawing on Heidegger's (1962) tool-analysis as mediated through ANT, a functioning cold chain is invisible: it simply enables vaccination to happen. Its constructed character becomes visible only when it fails. Mothers who travelled to the clinic and found specific vaccines unavailable described demoralisation and, in some cases, intent to change facilities. Okeyo and Okeyo (2020) situate these experiences within the geopolitics of vaccine supply, showing that stockouts in Kenya's public health system are not random institutional failures but expressions of the country's position in the global vaccine economy. Wirkas et al. (2007) documented the same pattern in Papua New Guinea, finding cold-chain failures to be the primary driver of vaccination incompleteness in peripheral settings.

3.4 Procedural Actants

The weighing scale and height ruler at the triage station constituted what Timmermans and Berg (2003) would recognise as a standardisation device: instruments that translate individual children's bodies into comparable, classifiable data points assessed against a reference population. Four distinct effects of the weighing scale emerged from the data. First, the requirement to undress the infant in a semi-public space created a moment of social exposure for the mother, making visible her performance of caregiving competence before an institutional audience. Second, for mothers who had dressed infants with traditional protective objects such as waist beads, the undressing requirement created a moment at which cultural practice became institutionally visible, prompting concealment. Third, the Z-score generated from anthropometric measurements distributed subsequent care non-uniformly across attending children: a low score enrolled the nutritionist into the encounter; a normal score did not. The mathematics of the Z-score operated as a non-human triage mechanism. Fourth, mothers were routinely not shown or explained their child's weight reading. One young mother described standing at the scale while the number was recorded without being shared. In Sik's (2016) recognition framework, this constitutes a form of recognition failure: the mother was not acknowledged as a person with a legitimate interest in data being generated about her own child.

3.5 Informational Actants

The walls of the Totos Corner carried an accumulation of health education materials: a hand-drawn vaccination schedule chart, GAVI-funded disease prevention posters, a KEPI immunisation schedule, an HIV stigma and discrimination policy notice, and an Mpox awareness poster. These materials functioned as what Latour (1992) calls delegates: repositories of expert knowledge present in the space even when no expert was physically available. A triage nurse noted that some mothers photographed the vaccination schedule chart with their phones, effectively transforming a static wall-mounted actant into a portable personal information resource and enrolling digital technology as an additional node in the vaccination knowledge network.

Engagement with these materials was not uniform across the attending population. The presence of a clinical officer with Dholuo language competence compensated for the near-total absence of Dholuo-language printed materials, but her availability was contingent. No printed substitute existed for her linguistic mediation. The physical condition of some posters, visibly torn and peeling, communicated something beyond their informational content: duration, under-maintenance, and a particular relationship between the institution and its material environment.

3.6 Cultural Actants

Alongside biomedically sanctioned objects, the clinic encounter consistently involved a parallel set of cultural protective actants. Wanja was applied to infants' eyelids and eyebrows. Beaded strings were tied around waists. Bangles were worn on wrists and necks. Occasionally padlocks and herbal bundles were noted. These were not incidental accessories. They carried active protective functions within a cultural framework that most clinic staff acknowledged but few formally engaged with.

A young mother explained that she applied wanja before visits to public spaces, which she identified as contexts of potential spiritual vulnerability. Geissler and Prince (2010), in their study of therapeutic practice in Luo communities in western Kenya, documented exactly this form of therapeutic pluralism: parents applying traditional and biomedical protections simultaneously, without experiencing the two as contradictory. The cultural actants interacted with the weighing procedure at the point of undressing. The nutritionist observed that mothers tended to conceal beads at the scale rather than remove or disclose them. From an ANT perspective, this is actant management: the mother organising which actants were visible to the biomedical gaze and which were not. Staff generally adopted a non-interventionist stance, recognising that challenging cultural objects would introduce friction that might deter attendance altogether. The decision not to comment was itself a network maintenance strategy.

3.7 Panadol as Post-Vaccination Domestic Actant

Paracetamol suspension, sold commercially as Panadol Baby and Infant, was the most consistently mentioned non-human actant in post-vaccination accounts across all twelve mothers interviewed. Every mother reported receiving a specific, calibrated post-vaccination instruction: administer the medication approximately eight hours after the injection, when the infant's temperature would begin to rise and the injection site might swell. The instruction was not general advice. It described a predicted physiological sequence with a specific temporal window.

In ANT terms, Panadol operated as a script embedded in a material object, in Akrich's (1992) sense. The clinical recommendation specified and amplified the script embedded in the bottle's label. The nurse's authority was delegated to a small pharmaceutical product that would carry the protocol into a domestic

space the nurse could not reach. This is delegation operating across the boundary between institutional and household environments, extending the system's reach through a material object.

The cost dimension of this actant constitutes a structural critique. Panadol was not dispensed free of charge at JOOTRH. Mothers were instructed to purchase it. Staff were aware that some mothers went without, purchasing cheaper generic alternatives from community pharmacies or foregoing post-vaccination medication entirely. Patel et al. (2018) documented this pattern across sub-Saharan African MCH facilities, identifying cost barriers to post-vaccination antipyretics as a consistent systemic feature. In Sik's (2016) recognition framework, the mothers who could not afford Panadol received detailed, caring clinical instruction and were then sent to procure the means of acting on it at a price that the protocol assumed they could pay. The recognition was real. The structural condition undermined it.

4. Reading the Assemblage as a System

The seven actant categories described above are not independent. They form a coupled system in which the output of one component conditions the functioning of another. When the refrigerator holds temperature, vaccines are viable. When vaccines are viable and the MCH booklet is complete and legible, the documentation network functions. When the documentation network functions and the weighing scale generates data that triggers appropriate referrals, the procedural network functions. When the procedural network functions and the mother can afford post-vaccination medication, the post-vaccination care chain closes. Vaccination, as an outcome, is produced when all of these elements hold simultaneously.

This is a coupled system with multiple failure modes, and the consequences of failure are not uniformly distributed. Young, low-income, first-time mothers are more likely to experience the system's failure points. They are less likely to have the literacy required to use the MCH booklet independently. They are less likely to have the purchasing capacity to buy post-vaccination medication. They are more likely to be deterred by the spatial distance between the vaccination room and the main pharmacy. They are less likely to have the social capital that helps experienced mothers navigate the informal norms of the clinic encounter. These are not individual deficits. They are the predictable consequences of an assemblage configured without their specific circumstances in mind.

Meadows (2008) argued that changing the behaviour of a system requires identifying the leverage points that govern its structure rather than attending only to symptomatic outputs. In this assemblage, the structural leverage points are identifiable. The closure of the dedicated Totos Corner pharmacy created a spatial failure mode that could be reversed. The absence of a free paracetamol dispensing protocol created a post-vaccination care gap that could be closed. The absence of Dholuo-language printed materials created an informational failure mode compensated by a single individual whose availability was contingent. The weighing procedure's design created a recognition failure that could be addressed through a minor procedural modification. None of these are expensive interventions. Each targets a structural configuration of the system rather than the performance of individuals within it.

Checkland's (1981) soft systems methodology is useful here for a different reason. The stakeholders in this system do not share a common reading of its purpose. For a national health planning official, the system's purpose is the achievement of WHO coverage targets. For the MCH in-charge, its purpose is delivering safe, effective vaccination to attending children. For the young mother, its purpose is protecting her infant while managing the practical and social demands of the clinic encounter. These are not the same purpose, and the assemblage was not configured to hold all of them simultaneously. The documentation infrastructure serves national reporting more reliably than it serves the mother's information needs. The

procedural sequence optimises throughput more effectively than it optimises the quality of the individual encounter. These are design choices embedded in the material configuration of the system, and they can be chosen differently.

The systems science concept of emergence is worth foregrounding here. The inequities this paper documents were not the intended output of the vaccination system. No individual actor in the clinic designed the system to disadvantage young mothers. But the inequities are real, consistent, and predictable from the system's configuration. They are emergent properties of the assemblage: properties that exist at the level of the system and cannot be attributed to any of its components individually. This is precisely why individual-level interventions, whether through training, motivation, or compliance monitoring, are unlikely to address them. Emergent properties require systemic responses.

5. Conclusion

This paper has argued for reading the vaccination encounter as a sociotechnical system whose outputs are emergent properties of its material configuration. The ANT frameworks of translation, delegation, boundary objects, and inscription name the mechanisms through which human and non-human actors are brought into alignment or fall out of it. The systems science frameworks of emergence, structural constraint, and leverage points name the properties of the system that explain why individual-level interventions have limited traction on systemic inequities.

The practical implications of this reading are specific and achievable. Re-establishing a pharmacy dispensing point within the Totos Corner, or substantially reducing the distance between vaccination services and medication access, would close a structural gap in the post-vaccination care chain. Including paracetamol suspension in the standard free vaccination package would address the recognition failure that currently accompanies the otherwise careful post-vaccination counselling mothers receive. Producing vaccination schedule materials in Dholuo would reduce dependence on a single bilingual staff member whose availability cannot be guaranteed. Modifying the weighing procedure to include a brief, direct communication of the child's weight to the attending mother would cost nothing and would meaningfully improve the quality of the encounter.

None of these recommendations requires changing individual actors. Each requires changing the assemblage. That is the contribution that systems science and ANT together make to understanding health equity: they shift the analytical focus from the performance of people in the system to the structure of the system itself, and in doing so, they identify the interventions most likely to produce durable change.

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