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# Affordable Assistive Technology in Low-Resource Settings: A Theoretical Account of Frugal Innovation, Local Production and Digital Fabrication for Disability Inclusion in Africa

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## ABSTRACT

*Most of the people who need an assistive product do not have one, and the shortfall is deepest in Africa, where imported devices are costly, hard to repair and often poorly matched to the terrain, climate and daily tasks of the people who use them. This paper asks whether the technologies now entering the field, among them desktop 3D printing, optical scanning and open-source hardware, change the economics of assistive-technology provision in low-resource settings, or merely relocate its difficulties. The paper is a theoretical synthesis built from peer-reviewed journal articles published between 2023 and 2026, each verified against its publisher record, and read through the frugal-innovation and inclusive-innovation literatures and the assistive-technology systems scholarship. It distinguishes three provisioning models, import, local assembly and local production, and argues that digital fabrication shifts the binding constraint on the third model away from capital and production scale and towards design knowledge, quality assurance and service infrastructure. Nine propositions follow from this claim. They concern the conditions under which locally produced devices are affordable over their whole life rather than at the point of sale, safe without a regulatory apparatus that most African states do not yet have, and sustained by repair, follow-up and personnel that current provision systems rarely fund. The paper then sketches an ecosystem model in which universities, maker spaces, organisations of persons with disabilities and health systems take distinct and complementary roles, and sets out the procurement and regulatory reforms that would allow local production to move from pilot to policy. The contribution is a framework that treats affordability as a property of a system rather than of a product, and a research agenda for the engineering and rehabilitation disciplines that follows from that view.*

***Keywords:*** assistive technology; frugal innovation; 3D printing; digital fabrication; local production

# Affordable Assistive Technology in Low-Resource Settings: A Theoretical Account of Frugal Innovation, Local Production and Digital Fabrication for Disability Inclusion in Africa

## 1. INTRODUCTION

The arithmetic of assistive technology is not in dispute. The World Health Organization and UNICEF estimate that more than 2.5 billion people need at least one assistive product, that the figure will reach 3.5 billion by 2050, and that the share of need met ranges from roughly three per cent in some low-income countries to ninety per cent in wealthy ones; about two-thirds of those who have a product paid for it themselves (World Health Organization [WHO] & UNICEF, 2022). What is disputed is what to do about it. One answer, dominant for decades, has been to buy more of the devices that already exist and ship them to the places that lack them. Its limits are now well documented: devices arrive without the personnel to fit them, break without anyone to mend them, and are sized, priced and engineered for the markets they were designed in. A second answer has grown up alongside the first: produce the devices where they are needed, using tools that have recently become cheap enough to put in a district hospital or a university workshop. This paper is about the second answer, and about the conditions under which it is better than the first.

The question matters most in Africa, where the gap between need and provision is widest. Pakouyowou (2026) puts the continental figure at more than 240 million people who need at least one assistive product, with access below three per cent in sub-Saharan Africa, and attributes the gap to a market that has never been deliberately designed. Fewer than one in ten people in low- and middle-income countries who need a hearing aid has one, and the proportion falls to around two per cent across Africa (Swanepoel et al., 2026). The need for mobility devices is growing: the number of people living with a traumatic amputation worldwide rose by about half between 1990 and 2019, even as age-standardised rates fell (Yuan et al., 2023). Among 280 stroke survivors attending two hospitals in Kano, only 41 per cent used any assistive device (Usman et al., 2023); among 189 people with mobility or visual impairments in urban Ghana, device cost was the barrier named most often (Acheampong et al., 2025). Behind each figure sits the same structural fact: the device is imported, the price is set elsewhere, and the local system is asked only to distribute.

Digital fabrication has been offered as a way out of this arrangement since the first widely reported 3D-printed prosthetic hands a decade ago. The early promise was overstated, and clinicians were right to be sceptical of components that could not survive daily use (Raschke, 2023). But the evidence has moved. There are now multi-year follow-ups of locally printed prosthetic sockets in rural Sierra Leone (van der Stelt et al., 2025), a cohort in which socket shapes were generated by software and produced by staff with little prosthetic training (van der Stelt et al., 2026), a hospital workflow in Ethiopia that delivered patient-specific burn orthoses within days (Kim et al., 2026), upper-limb terminal devices co-designed in Uganda and transferred to local printers (Hussaini et al., 2023), an open-source ossicular prosthesis that costs nine euros to make (Knulst et al., 2026) and a trial of ultra-low-cost hearing aids in Malawi (Parmar et al., 2023). None of these studies is large, and several say plainly that they are pilots. Together, though, they describe a production logic different from the one that has governed assistive technology, and the purpose of this paper is to say what that logic is and what it requires.

The argument runs as follows. Assistive products reach people through one of three provisioning models: import of finished devices, local assembly of imported components, or local production from locally available materials and digital designs. Each model has a binding constraint, the resource whose scarcity sets the ceiling on what can be delivered. For import the constraint is capital, in the form of foreign exchange, tariffs and the scale needed to make a production run economic; for assembly it is capital together with the trained personnel who configure and fit imported components. Digital fabrication does not remove constraints; it moves them. Under local production the ceiling is set by design knowledge, by the capacity to assure quality without a mature regulator, and by the service infrastructure of fitting, follow-up and repair that no printer can supply. This relocation is the paper's central claim, and the propositions in Section 4 are its consequences. The paper also argues, with the inclusive-innovation scholarship, that affordability belongs to the system that delivers, maintains and replaces a device rather than to the object itself, and that much of what is

called affordable assistive technology is only cheap at the moment of purchase.

Three objectives follow: to develop the import–assembly–production framework and specify the binding constraint of each model; to derive propositions about the conditions under which local production delivers devices that are affordable, safe and sustained; and to describe the roles of universities, maker spaces, organisations of persons with disabilities and health systems in an African assistive-technology ecosystem, together with the regulatory and procurement changes that would let such an ecosystem form.

## 2. LITERATURE REVIEW

### 2.1 CONCEPTUAL REVIEW

Four concepts carry the argument and each needs fixing before use. The first is assistive technology itself, which the global policy literature treats as a system rather than a category of objects. Borg et al. (2023), analysing surveys from twenty countries, found that access to assistive products was associated first with the geographic coverage of services within a country and then with policy and personnel, with the availability of products necessary but not the primary driver. That ordering implies that a cheaper device delivered through the same thin service network changes little, and it is why this paper treats provisioning rather than manufacturing as its unit of analysis.

The second concept is the provisioning model. The distinction drawn here between import, local assembly and local production is not found in this form in the existing literature, which tends to contrast "donated" with "locally made" or "conventional" with "3D-printed", and so conflates the technology of fabrication with the location of production and the source of the design. The three-model framework separates them. Under import, design, fabrication and often fitting expertise are all external. Under assembly, components and designs are external but the final device is configured locally; the conventional prosthetic workflow in which an imported foot and pylon are attached to a locally laminated socket is the paradigm case. Under local production, design files and materials are available locally and the device is made in full where it will be used. The models are not stages on a path; a country can and usually will run all three at once for different product categories.

The third concept is digital fabrication, meaning the chain of optical scanning, computer-aided design and additive manufacturing that turns a measurement of a body into an object without manual moulding. Oldfrey et al. (2024), in a scoping review that screened 3,487 records and retained 130 articles on lower-limb and 117 on upper-limb prostheses, found production workflows and materials highly variable, long-term and larger-scale studies lacking and research on training requirements likewise lacking. Bhatt et al. (2023) survey the additive processes now used for lower-limb prostheses and their sockets, and Dagge et al. (2025) add that load-bearing sockets are a different engineering problem from the low-load devices on which additive manufacturing has typically focused, with their own structural standard, ISO 10328, and with clinician and technician trust in the regulation of digital processes among the barriers to adoption. Claims about "3D printing" in the abstract are therefore rarely useful, and the paper is specific about which workflow each study used.

Frugal innovation, the fourth concept, is defined here as the design of products and services that meet a need at a fraction of the usual cost by removing what is not essential and reconfiguring what is. A bibliometric review of 420 articles (Escudero-Cipriani et al., 2024) shows how quickly the construct has spread through the business literature, where its claimed contributions are reduced environmental impact and social inclusion through firm practice rather than outcomes for particular users; in health, the case for it is now made on environmental as well as financial grounds (Brown et al., 2023). The more useful strand for this paper asks what frugality does for development. Hossain et al. (2023), from 22 interviews across 13 South Asian frugal enterprises, found that frugal innovations tended to contribute more to the Sustainable Development Goals than conventional products but that some goals left little room for any such contribution, a caution against assuming that cheapness and inclusion travel together.

### 2.2 THEORETICAL REVIEW

The theoretical resources for this paper come from three places. The first is frugal and inclusive innovation theory. Onsongo et al. (2023), studying Philips Community Life Centres in sub-Saharan Africa, showed that a multinational could run several versions of the same frugal business model in different markets, and that what varied was not the value proposition or the cost structure but the financing arrangement. The finding transfers directly to assistive technology, where the device may be the same across countries while who pays for it, and how, determines whether anyone receives it. Kale et al.

(2023), studying three diagnostic devices developed for the Indian market, found the state's role critical, early-stage finance and later stakeholder collaboration facilitating, and affordability best understood as a reduction in the cost of care over time, through earlier diagnosis, rather than a low purchase price; that reframing is adopted here as a premise. Adomako et al. (2024), in a time-lagged study of 301 Ghanaian manufacturers, found that environmental threats drove frugal product innovation through firms' capacity to innovate with partners, with incomplete legal institutions shaping the strength of the effect: adversity breeds ingenuity only where there is someone to be ingenious with. Bhattacharjya et al. (2023) complete the picture from the community side, showing in an Indian case that informal actors could contribute when trust-building mechanisms were in place, that an intermediary attached to but separate from a university could steer collaboration, and that universities had to change their norms to take part.

The second resource is the assistive-technology systems literature, which supplies the dependent variable. Anderson et al. (2026), drawing on document review and expert interviews across six sub-Saharan countries, found that effective leadership rested on government ownership, inclusive coordination bodies such as technical working groups and clear governance, with funding limits, weak coordination between ministries and thin capacity the recurring obstacles. Smith et al. (2024) mapped the Kenyan ecosystem as a network and found it distributed, with ministries and organisations of persons with disabilities at the centre, but with the strength of ties concentrated on awareness and communication, fewer organisations actively collaborating, and innovation-training organisations not yet well integrated. An ecosystem, it follows, can be dense and still lack the links that matter for production.

The third resource is the access literature in rehabilitation, which supplies the mechanisms of failure. Kombe et al. (2025) applied the three-delays model, developed for maternal mortality, to prosthetic and orthotic services in low- and middle-income countries and found the delays interconnected and cascading: fear of the financial implications delayed the decision to seek care, transport delayed reaching it, and the availability of respectful care shaped what was received. Oldfrey et al. (2023), collating field data from Kenya, Uganda, Sierra Leone and Indonesia, identified three repair models, informal community repair, local initiatives and specialist workshop repair, and concluded that community-based repair was of paramount importance to keeping devices working and yet was often overlooked in the planning and design of provision. Between them these studies describe the service infrastructure that the paper treats as a binding constraint under local production.

## 2.3 EMPIRICAL REVIEW

The empirical record on digitally fabricated assistive technology in low-resource settings is short enough to be read in full. The most sustained programme is in Sierra Leone, where van der Stelt et al. (2025) followed nine recipients of locally manufactured transtibial prostheses with 3D-printed sockets for two and a half years. Six sockets failed, at intervals between roughly one and two years, yet median daily use at the end of the study was around twelve hours: people wore the devices, and the devices broke. In the follow-on cohort, van der Stelt et al. (2026) had socket shapes generated by software and produced by local co-workers with limited prosthetic experience; of 34 participants, 27 completed ten weeks of follow-up, with gains in lower-extremity function and condition-specific quality of life but no change in generic health status. The authors read this as evidence that design software can substitute for part of the scarce prosthetist's expertise, a reading the paper returns to.

In Ethiopia, Kim et al. (2026) ran a hospital-based workflow of scanning, computer-aided design and fused-filament printing for four children with burns and delivered fitted orthoses within days of the clinical request; scanning took under half an hour, design five to eight hours and printing between 29 and 78 hours, with no print failures. In Uganda, Hussaini et al. (2023) co-designed two upper-limb terminal devices, a passive hand in flexible filament and an impact-resistant prehensor, both attaching to a standard socket thread, and reported that local researchers with comparable printers were beginning to fabricate them in preparation for field testing. Knulst et al. (2026) validated an open-source titanium sheet-metal ossicular prosthesis costing nine euros, with sound transmission comparable to commercial devices. On hearing aids, Parmar et al. (2023) found no significant difference in outcomes between an ultra-low-cost device and refurbished programmable aids among sixteen adults in Blantyre over a month; Swanepoel et al. (2026) place such devices within a wider strategy of task-sharing, preset over-the-counter aids and community-based provision that must be embedded in universal health coverage to scale.

Replicability is what separates a demonstration from a provisioning model, and two studies speak to it. Romani et al. (2026) printed four batches of a two-piece forearm crutch with virgin and recycled filament on small and large printers, tested them to the ISO 11334 static-load standard and found comparable strength, consistent failure behaviour and limited cost variation; replicability, they argue, has to be designed in rather than hoped for. Thorsen et al. (2023) showed that two people with cerebral palsy could co-manufacture a custom spoon handle guided remotely by videoconference, a small result that matters because it moves the user from recipient to maker. From the clinician side, Benham et al. (2026) report that rehabilitation clients, care partners and clinicians saw 3D printing as a complement to conventional provision that could bypass slow or costly commercial sourcing, but wanted better education, more durable devices and structured follow-up before relying on it.

The African provisioning context is described by a smaller set of studies. Acheampong et al. (2025) found that two-thirds of urban Ghanaian respondents used assistive technology, that uptake was lower among women, and that cost led the list of barriers. In a later study of 385 Ghanaians with mobility, hearing or visual impairments, Acheampong et al. (2026) found affordability, ease of use and customisation to be the strongest influences on willingness to adopt AI-enabled devices, with device cost, poor connectivity and low digital literacy the main obstacles. Lister et al. (2024) assessed sixty users of the standard manual wheelchair issued in a South African municipality and found most (78 per cent) comfortable and generally satisfied, in a programme where gaps in referral, assessment, training, follow-up and maintenance had been reported only anecdotally. Ogondiek (2026), analysing Tanzania's disability and education policy documents, found outdated frameworks, no enforceable mandates, weak financing and dependence on imports, and recommended incentives for local production. On regulation, Nasir et al. (2023) reviewed 39 documents on medical-device oversight in African countries and found pre-market testing limited, reliance on foreign certification common and post-market monitoring weak. Gurusamy et al. (2026) show that even where regulators are mature, researchers making customised 3D-printed devices lack a complete understanding of the need for regulation and of the rules that apply to them. The technology, in short, is spreading faster than the capacity to govern it, and fastest where that capacity was thinnest to begin with.

## 3. MATERIALS AND METHODS

This is a conceptual paper. Its design is a theoretical synthesis in which constructs are drawn from existing literatures, combined into a framework, and used to derive propositions that are falsifiable in principle though not tested here. No human participants were involved, no primary data were collected and no ethics approval was required. The only dataset is the reference list, which is openly available.

The literature was assembled in four steps. First, candidate articles were identified through structured searches of the Crossref and OpenAlex bibliographic indices and of PubMed, using combinations of terms for assistive technology, prosthetics, orthotics, hearing aids, wheelchairs, 3D printing, additive manufacturing, digital fabrication, open-source hardware, frugal innovation, inclusive innovation, repair, regulation and procurement, restricted to publication dates from 1 January 2023 onward. Second, titles and abstracts were screened against three inclusion criteria: a peer-reviewed journal article, published between 2023 and 2026, relevant either to the provisioning of assistive technology in low-resource settings or to the theory of frugal and inclusive innovation. Preprints, conference papers, book chapters and reports were excluded, with one exception treated as a policy instrument rather than evidence: the WHO and UNICEF Global Report on Assistive Technology, whose statistics frame the problem. Third, every retained article was verified against its publisher's Crossref record, or where that service was unavailable against the OpenAlex mirror of the same record, to confirm authorship, title, container, volume, issue, pagination and digital object identifier, and each record was checked for retraction, correction or expression-of-concern notices; none was found. Fourth, abstracts were read for every article, and full text where openly available, before any finding was attributed. Roughly ninety records were screened and 36 journal articles retained, together with the one policy document.

The analytical procedure followed the logic of conceptual theory-building. The three provisioning models were derived by asking what varied across the empirical studies: the origin of the design, the location of fabrication and the source of materials. The binding-constraint construct was taken from the frugal-innovation literature's attention to what is scarce and applied to each model in turn. Propositions were written wherever the framework implied a relationship that the evidence supported, contradicted or could not yet speak to, and the last category is flagged in Section 4.2. The basis of

judgement is coherence with the verified evidence and with the theories reviewed in Section 2, together with the author's reading of African provisioning conditions, which is a reading rather than a measurement and is presented as such.

An artificial-intelligence writing assistant was used, under the author's direction, to support literature retrieval, bibliographic verification, drafting and formatting. Every source was verified against its publisher record, every attribution was checked against the source's abstract or full text, and the author is responsible for the argument, the propositions and any errors. No generative tool was used to create data, results or references.

## 4. RESULTS AND DISCUSSION

### 4.1 RESULTS

The framework has two parts: a typology of provisioning models with the binding constraint of each, and a set of propositions about the conditions under which the third model delivers. Table 1 presents the typology.

**Table. 1. Three provisioning models for assistive technology and the constraint that binds each**

| Model | Origin of design | Location of fabrication | Source of materials | Binding constraint | Illustrative evidence |
|---|---|---|---|---|---|
| Import | External | External | External | Capital: foreign exchange, tariffs, purchase price; scale economies lie abroad | Cost as leading barrier in Ghana (Acheampong et al., 2025); import dependence in Tanzanian policy (Ogondiek, 2026); trade and tariff reform as lever (Pakouyowou, 2026) |
| Local assembly | External | Local configuration of imported components | Mostly external | Capital and personnel: component supply chains and trained fitters | Conventional socket lamination with imported feet; three-delays barriers to prosthetic services (Kombe et al., 2025); standard wheelchair provision in South Africa (Lister et al., 2024) |
| Local production | Local or open-source, locally adapted | Local | Local or locally stocked (filament, sheet metal) | Design knowledge, quality assurance and service infrastructure (fitting, training, follow-up, repair) | Sierra Leone sockets (van der Stelt et al., 2025, 2026); Ethiopian burn orthoses (Kim et al., 2026); Uganda terminal devices, co-designed locally and transferred to local printers (Hussaini et al., 2023); nine-euro ossicular prosthesis (Knulst et al., 2026); replicable crutches (Romani et al., 2026) |

The typology makes one claim that is easy to miss. Local production does not relax the capital constraint so much as convert it. The capital that matters under import is working capital for purchase; under production it is the fixed capital of a printer, a scanner and a stock of filament, which is small, and the human capital of design and quality assurance, which is not. The Sierra Leone programme illustrates the conversion: the device was cheap to make, six of nine sockets showed damage within roughly one to

two years (van der Stelt et al., 2025), and the follow-on study's reliance on design software (van der Stelt et al., 2026) answers exactly the design-knowledge constraint the framework predicts. The Ethiopian workflow illustrates the other half: printing alone took between 29 and 78 hours, but the workflow sat inside a hospital with clinicians to prescribe, fit and review (Kim et al., 2026), which is to say inside a service infrastructure that already existed.

Table 2 sets out nine propositions, each stated as a relationship with its mechanism and the evidence that bears on it.

**Table. 2. Propositions on the conditions for affordable, safe and sustained local production of assistive technology**

| No. | Proposition | Mechanism | Supporting or qualifying literature |
|---|---|---|---|
| P1 | Digital fabrication shifts the binding constraint on provisioning from capital and scale to design knowledge, quality assurance and service infrastructure. | Fixed capital per unit falls; the scarce input becomes the capacity to produce a correct, safe and fitted device. | van der Stelt et al. (2025, 2026); Kim et al. (2026); Dagge et al. (2025); Oldfrey et al. (2024) |
| P2 | Locally produced devices are affordable only when life-cycle cost, including repair and replacement, falls below that of the imported alternative; purchase price alone is a misleading measure. | Devices with short service lives transfer cost from the point of sale to the user's time and the system's follow-up burden. | Kale et al. (2023); van der Stelt et al. (2025); Oldfrey et al. (2023) |
| P3 | Design knowledge is the constraint most amenable to substitution by software and open-source repositories, but the substitution is partial and leaves fitting, prescription and review with scarce personnel. | Parametric and AI-assisted design encodes part of expert judgement; the clinical encounter does not reduce to shape. | van der Stelt et al. (2026); Hussaini et al. (2023); Romani et al. (2026) |
| P4 | In the absence of a functioning national regulator, device safety under local production depends on adherence to open international test standards and on documented, replicable processes rather than on certification. | Standards such as ISO 10328 and ISO 11334 can be applied by a university or workshop; certification cannot. | Dagge et al. (2025); Romani et al. (2026); Nasir et al. (2023); Gurusamy et al. (2026) |
| P5 | Local production is sustained where community-based repair is recognised, resourced and connected to specialist repair, and remains fragile where the repair that already keeps devices working is left informal and unplanned. | Repair is the main route by which devices stay in use in low-resource settings; digital designs make parts reproducible only if someone is organised to reproduce them. | Oldfrey et al. (2023); Romani et al. (2026) |
| P6 | The returns to local production are highest for product categories with high customisation needs and low load-bearing demands, and lowest where structural safety dominates. | Customisation is where digital fabrication has a comparative advantage; load-bearing is where material and validation gaps are greatest. | Kim et al. (2026); Thorsen et al. (2023); Stauffer et al. (2026); Bhatt et al. (2023) |
| P7 | An ecosystem for local production requires an intermediary between universities, makers, health services and disability organisations; universities alone do not provide it. | Academic norms and incentives are poorly matched to production and service; an intermediary can hold the relationships universities cannot. | Bhattacharjya et al. (2023); Smith et al. (2024); Anderson et al. (2026) |
| P8 | Public procurement that specifies outcomes and service rather than branded devices is the policy instrument most | Demand-side certainty allows local producers to invest in quality systems; device-specification tenders lock in | Pakouyowou (2026); Onsongo et al. (2023); Borg et al. (2023); Ogondiek (2026) |

| | | | |
|---|---|---|---|
| | likely to make local production viable at scale. | import. | |
| P9 | Frugal device innovation improves access only when combined with a frugal service model; the two must be designed together. | Service reach, not product availability, is the strongest predictor of access; a cheap device delivered through an unchanged service network changes little. | Borg et al. (2023); Swanepoel et al. (2026); Parmar et al. (2023); Kombe et al. (2025) |

P1 and P2 concern the economics of the shift; P3 and P4 the two constraints, design and quality, that technology can partly address; P5 and P6 what technology cannot address, the service infrastructure and the limits of the materials; and P7 to P9 the ecosystem and policy instruments that would allow local production to be more than a pilot.

The ecosystem implied by P7 to P9 has four parts. Universities supply design capacity, testing to open standards and technician training, but on the evidence of Bhattacharjya et al. (2023) and Smith et al. (2024) not the connective tissue of production. Maker spaces and small enterprises supply fabrication and, when linked to community repairers, the community-based repair that Oldfrey et al. (2023) found to be of paramount importance. Organisations of persons with disabilities supply the specification of need and the testing of fit and acceptability, the kind of input the Ghanaian preference data on affordability, usability and customisation (Acheampong et al., 2026) exemplify. Health systems supply prescription, fitting, follow-up and the financing channel without which, as Onsongo et al. (2023) found for primary care, the same device reaches no one. The intermediary of P7 holds these together; in the African cases reviewed it is a technical working group under government leadership (Anderson et al., 2026) or a programme embedded in a hospital (Kim et al., 2026; van der Stelt et al., 2026).

## 4.2 DISCUSSION

Which of the propositions can the evidence already test? P1 is supported wherever a programme has run long enough to report what went wrong. The Sierra Leone cohort is the clearest case: the sockets were made, worn and damaged, and the follow-on study's innovation lay in design software, not in fabrication (van der Stelt et al., 2025, 2026). The Ethiopian workflow supports P1 from the other direction, since the principal constraint it reports, printer time apart, is design time of five to eight hours per device (Kim et al., 2026), and the scoping review by Oldfrey et al. (2024) supports it at the level of the field, where the gaps are in long-term and larger-scale studies, training requirements and standardised workflows, none of them a capital shortage. The hearing-aid literature points the same way: the barriers it reports are workforce shortages, cost and trade barriers, centralisation and stigma, and the model with evidence behind it is community-health-worker-facilitated provision with structured counselling and mobile-health support (Swanepoel et al., 2026).

P2 is the proposition most at odds with how the field reports itself. Studies routinely report unit cost and rarely cost per year of use. A printed socket that lasts eighteen months and is replaced twice is not obviously cheaper than a laminated one that lasts four years, once the user's travel, the technician's time and the system's follow-up are counted. Kale et al. (2023) make the general point for diagnostics, that affordability lies in lowering the cost of care over time rather than in a low product price, and the point is sharper for assistive products because the user bears most of the cost of failure. The literature cannot yet test P2 because almost no study reports life-cycle costs. That is itself a finding.

P3 is where this paper departs from the more optimistic readings of its own evidence. The follow-on Sierra Leone study is presented, reasonably, as showing that software can stand in for a prosthetist's judgement of socket shape (van der Stelt et al., 2026). But the study also lost seven of 34 participants before ten weeks, reported no change in generic health status, and took place in a programme with years of accumulated clinical presence. Software substitutes for the part of expertise that can be written down; the decision to prescribe, the assessment of the residual limb, the recognition of a poor fit and the conversation in which a user says what is wrong remain with people who are scarce. Hussaini et al. (2023) are instructive because their devices were co-designed in Uganda, printed in the United Kingdom, then transferred to local printers: design knowledge travelled, but through a relationship rather than a file.

P4 raises a question the regulatory literature has not resolved. If African device regulation relies on foreign certification and is weak on post-market surveillance (Nasir et al., 2023), and if researchers even in well-regulated jurisdictions lack a complete understanding of the rules for customised printed

devices (Gurusamy et al., 2026), then waiting for certification is not a strategy. The alternative proposed here, adherence to open structural standards with documented process control, is what Romani et al. (2026) did for crutches and what Dagge et al. (2025) describe for sockets. It is not equivalent to regulation: a standard tests a sample and does not inspect a workshop or recall a batch. But it is the form of assurance a university or hospital can actually provide. The risk, which should be stated, is that a documented process becomes a substitute for a regulator rather than a step towards one.

P5 and P6 mark the limits of the technology. Repair is where the evidence is strongest and the policy attention weakest. Oldfrey et al. (2023) found community-based repair to be of paramount importance to keeping devices in use across four countries and found it often overlooked in the planning and design of provision; in the South African wheelchair programme studied by Lister et al. (2024), gaps in follow-up and maintenance were known only from anecdotal report, which is itself a measure of how little the stage is studied. Digital fabrication makes spare parts reproducible in principle, and Romani et al. (2026) report that limited cost variation across batches supports repairability and a longer product life, but a file on a server repairs nothing. P6 concerns the product mix. The literature's strongest results are for customised, low-load devices: orthoses, terminal devices, handles, an ossicular prosthesis (Kim et al., 2026; Hussaini et al., 2023; Thorsen et al., 2023; Knulst et al., 2026). Its most equivocal results are for load-bearing sockets, where several additive processes are in use (Bhatt et al., 2023) and where material performance, regulation and clinical validation remain limiting (Stauffer et al., 2026; Dagge et al., 2025). Local production should therefore start where the technology is strong rather than where the need is most visible.

P7 to P9 concern the system and are the propositions the evidence can least directly test, because no African country has yet run the experiment. The Kenyan network analysis (Smith et al., 2024) shows an ecosystem with the right nodes and the wrong edges; the six-country study (Anderson et al., 2026) shows that where coordination works it is because a government-led body holds the relationships. The quadruple-helix evidence from India (Bhattacharjya et al., 2023) and the firm-level evidence from Ghana (Adomako et al., 2024) agree that frugal innovation is a collaborative rather than a solitary achievement and that institutions, including incomplete ones, shape whether collaboration happens. P8 draws on Pakouyowou (2026), who argues that the African market for assistive technology has to be built deliberately through tariff reform, technology transfer and demand financing, and on Onsongo et al. (2023), whose finding that the financing model is what varies across markets implies that procurement is where governments have the most purchase. P9 restates the ordering found by Borg et al. (2023) as a design principle: the Malawi trial (Parmar et al., 2023) mattered less for its device than for showing that a month with an ultra-low-cost aid could match refurbished programmable ones, and it is the community-based service model that the later review proposes to scale (Swanepoel et al., 2026).

Three studies would settle most of what is open. A life-cycle costing of printed against conventional devices in one African service, counting user time and repair, would test P2. A comparison of outcomes between a programme that resources community repair and one that does not would test P5. A procurement experiment in which one jurisdiction tenders for outcomes and another for devices would test P8. None requires a new technology. All require the kind of long-term, larger-scale follow-up that the scoping review found lacking (Oldfrey et al., 2024), which remains the most honest summary of where the evidence stands.

## 5. CONCLUSION AND RECOMMENDATION

The paper set out to say whether emerging fabrication technologies change the economics of assistive-technology provision in Africa. The answer offered is that they change its constraints rather than its costs. Under import, what is scarce is money; under local production, what is scarce is the knowledge to design a safe device, the capacity to assure its quality without a regulator, and the service infrastructure that fits, follows up and repairs it. A printer in a district hospital relocates the problem of provision from the customs post to the workshop bench, and that relocation is worth having, because the resources needed at the bench are ones that African universities, hospitals and disability organisations can build, where foreign exchange is not. But it is a relocation, and a programme that treats it as a solution will reproduce the pattern the evidence already shows, of devices that are made, worn and then broken with no one to mend them.

Several recommendations follow for named actors. Ministries of health and of social affairs should treat local production as a service programme rather than a procurement line, fund the personnel and follow-up

that make devices last, and begin with the product categories where the technology is strong: orthoses, terminal devices, custom aids to daily living and low-load components. National regulators, which in most African countries are not yet equipped to certify customised devices, should recognise documented adherence to open international standards as an interim pathway and publish, rather than wait for, guidance on point-of-care manufacturing. Procurement agencies should tender for outcomes and service, including repair, rather than for branded devices, so that a local producer has a demand it can invest against. Universities should build testing capacity to open standards and train technicians, and accept that an intermediary, whether a technical working group or a hospital-based programme, will be needed to turn designs into provision. Maker spaces and small enterprises should be contracted into formal provision as repair and fabrication partners rather than tolerated as an informal sector. Organisations of persons with disabilities should be funded to specify need, test fit and acceptability and hold producers to account. Donors should shift from device donation, whose failures the repair literature documents, to investment in the local service infrastructure that would make any device, imported or printed, last.

For researchers in engineering and rehabilitation, the agenda is plain. Report life-cycle cost, not unit cost. Follow users for years, not weeks. Publish failure rates and the conditions of failure. Test replicability across workshops, not just performance in one. And study repair as a service with its own economics, because the evidence says it is where provision succeeds or fails.

## 6. CONTRIBUTION TO EXISTING KNOWLEDGE

The paper makes three contributions. The first is the import–assembly–production framework, which separates the origin of a design, the location of fabrication and the source of materials, and so replaces the literature's loose contrasts between donated and local or conventional and printed devices with a typology that identifies what is actually scarce under each arrangement. The binding-constraint construct gives the typology its edge: the claim that digital fabrication moves the constraint from capital and scale to design knowledge, quality assurance and service infrastructure is, to the author's knowledge, stated here for the first time as a proposition that evidence can test.

The second contribution is the set of nine propositions in Table 2, which translate the framework into relationships that can be supported, qualified or refuted. The discussion has been explicit about which propositions the existing evidence bears on and which await studies not yet done, and it identifies life-cycle costing, resourced community repair and outcome-based procurement as the three experiments that would do most to settle whether local production can be a policy rather than a pilot.

The third contribution is to the theory of frugal and inclusive innovation as applied to disability. By holding that affordability belongs to a system rather than to a product, the paper joins the inclusive-innovation literature's reframing of cost to the assistive-technology systems literature's finding that service reach, not product availability, predicts access. The resulting ecosystem model, with universities, maker spaces, disability organisations and health systems in distinct roles held together by an intermediary, is offered as a template for African assistive-technology policy and as a corrective to accounts in which a cheaper device is taken to be the same thing as a more accessible one.

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