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Production Scheduling for Waste Prevention in Recovered-Material Manufacturing: A Lagos Denim Workshop Study Protocol

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Abstract- ***In small-batch production from recovered material, a workshop can hold enough cloth by weight and still lack a piece that fits a required panel. Production scheduling determines when that incompatibility becomes visible and which responses remain open. This protocol describes a paired-batch feasibility study in a Lagos denim workshop that tests one scheduling change: moving the detailed fit check and the reservation of compatible pieces from the usual pre-cut review, after pattern freeze, to a scheduled review before pattern freeze. Fit criteria, reservation procedure, release gate, sequencing rule, capacity checks, rescue options, substitute-material budget and quality thresholds are identical in both arms, so the comparison estimates the effect of moving the check and reservation together. The central trade-off is explicit: earlier checking may prevent late pattern changes, recutting and emergency buying, but it requires inspection time and can hold material in reservation for longer. The primary sustainability outcome is the dry mass of unusable textile residue generated per batch and per planned garment, recorded in a closed material ledger with mutually exclusive fate categories. Secondary outcomes are new denim purchased and consumed, person-minutes by task, first-pass quality and complete on-time delivery against the original commitment. The protocol specifies the observation boundary, weighing procedure, concealed allocation within matched pairs, run-in objectives, progression criteria and a descriptive pair-level analysis without significance testing. Published reporting on AZACH, a Lagos label that sorts discarded denim item by item, and on Lagos denim practitioners provides context but not outcome data. No results are reported. Findings will be interpreted as workshop-level evidence on waste prevention, consistent with but distinct from the national recycling indicator for Sustainable Development Goal Target 12.5.***

Index Terms- ***Nigeria, order release, production scheduling, reclaimed denim, recovered material, study protocol, upcycling, waste prevention***

I. INTRODUCTION

A pile of denim can be heavy enough to make a pair of shorts and still be useless for the front panels. In a workshop that makes garments from recovered material, the decisive question is often not whether there is enough cloth but when the workshop finds out that the cloth it holds will not yield the pieces a design needs. That timing is a production scheduling decision. If the incompatibility appears only after the pattern has been frozen and the job is waiting to be cut, the remaining options are narrow and costly: redraw a panel, buy or source another piece, or move a different job ahead. If it appears earlier, more options may remain open, but someone has to spend time inspecting and reserving material that might otherwise have been left until it was needed.

The question matters in Nigeria because second-hand clothing is a large and durable feature of the textile economy. African clothing industries have declined since the economic liberalisation of the early 1980s while used-clothing imports have grown (Brooks & Simon, 2012), and Nigeria has maintained a legal ban on importing second-hand clothing that has not stopped a large trade through markets such as Katangowa in Lagos (Al Jazeera, 2012; Brooks, 2015). Alongside resale, Lagos designers now treat discarded denim and cutting-room scraps as raw material for new garments (Ukomadu, 2022; Whipple, 2022). Upcycling of this kind converts used cloth into skilled local work, but it brings an operational problem that conventional garment production rarely faces: the workshop does not know in advance whether the cloth it holds will yield the pieces a design needs.

Each late response has a material and a schedule cost. Redrawing a panel adds seams, pressing and possibly a fit failure. Sourcing another piece adds search time and may add new denim. Resequencing can protect one order and delay another. Nigerian small-business guidance describes a sequence in which a label sketches a product, maps the inputs and sources them before cutting and sewing (FATE Foundation & GIZ SEDIN, 2022, pp. 17–19), which corresponds to a design-led sequence with material checks after the design is fixed. Research on fashion upcycling suggests why this sequence may be ill-suited to recovered material: leftover shapes and the fabric already available can determine which designs are practical (Aus et al., 2021; Han et al., 2017).

Existing research leaves the timing question largely unaddressed. Studies of fashion upcycling have concentrated on design processes and on the business and system barriers to scaling up (Han et al., 2017; Singh et al., 2019; Sung et al., 2020). Production planning research has long recognised that recovered inputs of unknown condition complicate planning (Guide, 2000), and work on remanufacturing has asked whether inspecting and grading inputs before planning is worth its cost (Ferguson et al., 2009; Yanıkoğlu & Denizel, 2021). Workload control research has developed rules for deciding when a job should be released to the shop floor (Thürer et al., 2011). These literatures have not been brought together to test whether moving material checks earlier in the schedule changes what a small upcycling workshop wastes and consumes.

A. Research questions

The primary research question is:

RQ1 In small-batch production using recovered material, does checking and reserving compatible pieces before pattern freeze reduce unusable waste and new denim consumed while maintaining on-time delivery and product quality?

Two secondary questions support the interpretation of RQ1:

RQ2 Which recorded attributes of a recovered piece (usable area after defects, grain, stretch, shade or existing seams) most often make it unsuitable for a required panel?

RQ3 Under which recorded conditions of starting stock coverage, pattern complexity and available capacity does the timing of the check make a material or schedule difference?

B. What the comparison estimates

The study compares two arms that differ in one respect only: when the detailed fit check and the reservation of compatible pieces take place. In the earlier-check arm, both activities happen at a scheduled early review before pattern freeze. In the standard-timing arm, both happen at the usual pre-cut review after pattern freeze. Everything else is held constant, including the fit criteria, reservation procedure, release gate, sequencing rule, capacity checks, rescue options, approved design changes, substitute-material budget and quality thresholds (Section 6). The comparison therefore estimates the effect of moving the check and the reservation together. It does not estimate the effect of introducing a release rule, nor can it separate the effect of earlier inspection from the effect of earlier reservation.

Three milestones are distinguished throughout. Order acceptance is the point at which the workshop records a commitment to a customer, with quantity, specification, original deadline and the design changes the customer will allow. Pattern freeze is the point at which the pattern pieces, their sizes and any planned joins are fixed for cutting. Cut release is the point at which a batch passes the release gate and may be cut. Both arms begin after order acceptance; the intervention operates between order acceptance and pattern freeze.

C. Contributions

The paper makes five contributions. First, it frames the timing of material checks in recovered-material production as a scheduling decision with sustainability consequences, drawing on remanufacturing planning and order release. Second, it specifies a comparison that isolates that timing by holding all other controls constant in both arms. Third, it sets out an auditable fit and reservation procedure, with recorded placements, an allocation rule and defined decision rights. Fourth, it defines a closed material ledger with mutually exclusive fate categories and makes unusable textile residue the primary sustainability outcome. Fifth, it provides an executable pilot design, including eligibility, concealed allocation, run-in objectives, progression criteria and a descriptive analysis plan.

D. Structure of the paper

Section 2 reviews the literature and develops the conceptual framework and propositions. Section 3 summarises the study design. Section 4 presents published Lagos context. Section 5 sets out the fit and reservation procedure shared by both arms, and Section 6 defines the comparison. Sections 7 to 9 cover pilot procedures, measurement and analysis. Section 10 discusses interpretation, limitations and implications, and Section 11 concludes. The appendices contain the workshop records, the cut-release card and an illustrative material balance.

II. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

A. Search approach

To support the narrower gap on timing, waste and delivery, a targeted search was run in November 2026 through a general-purpose web search engine, following results to publisher and repository pages. Search strings combined terms for the material setting (upcycling, upcycled fashion, recovered or reclaimed textile, second-hand garments, remanufacturing), the operational decision (production planning, scheduling, order release, material inspection, grading, timing) and the outcomes (pre-consumer waste, cutting waste, delivery). Items were retained if they were published by September 2024 and addressed garment production from recovered or leftover material, the planning of

variable-quality inputs, or order release in make-to-order settings. Items were excluded if they concerned only fibre-to-fibre recycling, consumer disposal behaviour or marketing.

The retained literature addressed upcycling design methods, the quantity of leftovers in garment factories, barriers to scaling up upcycling businesses, input grading in remanufacturing and workload control. No retained study compared the timing of material inspection and reservation with waste and delivery outcomes in upcycled garment production. Because the search used a general web search engine rather than bibliographic databases, it is reported as a targeted rather than a systematic search.

B. Upcycling as a production problem

Upcycling is commonly defined as the creation of products from used materials, components or products that are of equal or higher quality or value than the originals (Singh et al., 2019; Sung et al., 2020). Much of the fashion literature approaches it as a design practice. Han et al. (2017) compared standard and upcycled fashion design and production and showed that in upcycling the available material shapes the design process rather than following it. Aus et al. (2021) studied the integration of upcycling into conventional garment manufacturing over more than five years and reported that fabric leftovers and textile waste ranged from 25% to 40% of total fabric used, depending on factory size, and that about half of that material could be upcycled into new garments. They also found it useful to classify leftovers by form and to measure them in ways suited to each form. Studies of scaling up upcycling businesses in the UK have taken a systemic view, mapping challenges and success factors across stakeholders and value-chain actors (Singh et al., 2019; Sung et al., 2020).

Work on zero-waste fashion design locates the source of pre-consumer cutting waste in pattern cutting itself: waste can be designed out only when pattern pieces interlock across the full width and length of the cloth (Rissanen & McQuillan, 2023). Zero-waste methods generally assume a known, continuous length of fabric. Recovered denim inverts that assumption. The cloth arrives as irregular pieces whose usable area, grain, stretch and shade must be discovered piece by piece, so the question shifts from how to lay a pattern on a known cloth to whether a set of uncertain pieces can supply the pattern at all, and when that should be established.

C. Variable inputs and the timing of inspection

Production planning for remanufacturing offers a close analogy. Guide (2000) reported that planning and control are more complex in remanufacturing than in conventional manufacturing because returns are stochastic, return and demand rates are imbalanced, and the condition of returned products is unknown until they are inspected. Each feature has a counterpart in upcycled denim: donor garments arrive irregularly, the supply of large clean panels does not track demand for particular designs, and a garment's usable area is unknown until it is opened.

Remanufacturing research has also asked whether it pays to inspect and grade inputs before planning. In a model grounded in data from a mailing-systems remanufacturer, Ferguson et al. (2009) found that a nominal quality-grading system raised profit by an average of about 4% across a wide range of parameters. Yanıkoğlu and Denizel (2021) qualified that result: once the uncertainty inherent in grading is taken into account, the value of grading falls, and a grading cost can erode it substantially or remove it altogether. This is the trade-off at the centre of the present study. Moving the fit check earlier may expose incompatibility while more responses remain open, but the check is itself labour, it may be imperfect, and an early reservation may hold material that another job could have used.

D. Order release as a shared control

Workload control is a production planning and control concept developed for make-to-order job shops. Its central mechanism, order review and release, holds accepted jobs in a pre-shop pool and releases them to the shop floor only when release will not overload capacity or jeopardise due dates (Bergamaschi et al., 1997; Land & Gaalman, 1996; Thürer et al., 2011). Stevenson et al. (2011) describe workload control as one of few planning concepts suited to make-to-order companies and note that it has been argued to be particularly suitable for small and medium-sized enterprises with limited resources. Sequencing among released jobs in this study follows a least-slack principle, which combines a plan made in advance with a defined response to disruption (Herroelen & Leus, 2005).

In this protocol the release gate and sequencing rule are shared controls, applied identically in both arms. They are specified because a comparison of check timing is interpretable only if what happens after the check is the same. The release literature therefore frames the common structure of both workflows rather than the intervention itself.

E. Waste prevention as the sustainability outcome

Target 12.5 of the Sustainable Development Goals calls for substantially reducing waste generation through prevention, reduction, recycling and reuse by 2030 (United Nations General Assembly, 2015). Its global indicator, 12.5.1, is the national recycling rate and tons of material recycled (United Nations General

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Assembly, 2017). The target therefore distinguishes preventing waste from recycling it, while the indicator measures recycling at national scale. A workshop study cannot report against that indicator. It can, however, measure whether a scheduling change reduces the generation of unusable residue within a defined boundary, which corresponds to the prevention element of the target. Routing the same residue to a recovery outlet changes its destination but not its generation, and buying less new denim may reflect drawing on existing stock rather than consuming less. The outcome definitions in Section 8 keep these distinctions separate. Wider claims about carbon savings or avoided upstream production would require additional evidence on what the recovered cloth would otherwise have displaced (Sandin & Peters, 2018).

F. The Nigerian context

Nigerian evidence on upcycling operations is thin. The second-hand clothing trade has been studied mainly in terms of its effects on local industry and its trade networks (Brooks, 2015; Brooks & Simon, 2012). Practitioner-focused work is more recent: the *Denim to Denim* project gathered accounts from Lagos traders, designers and alterationists (Whipple, 2022), and a survey of 180 small-scale garment producers in Lagos State examined their profitability and identified unstable power supply as a constraint on production (Ehinmowo & Simon-Oke, 2022). Quantified, workshop-level data on recovered-cloth yield and cutting-room residue are absent from the sources reviewed. Evidence from neighbouring Ghana indicates how much imported second-hand clothing may be unusable: research by The Or Foundation at Accra's Kantamanto market found that around 40% of the average bale leaves the market as waste (Aklotsoe, 2023). That figure concerns resale rather than cutting and is not a Nigerian measurement, but it underlines that quantity of cloth and quantity of usable cloth are different things.

G. Research gap, conceptual framework and propositions

The literature identifies the ingredients of the problem without connecting them. Upcycling research shows that material shapes design; remanufacturing research shows that input variability complicates planning and that early inspection has a cost; and release research shows how a shared gate protects flow and due dates. What is missing is a controlled test of whether moving the material check earlier in the schedule changes waste, consumption and delivery in recovered-material production. Figure 1 shows the two workflows compared.

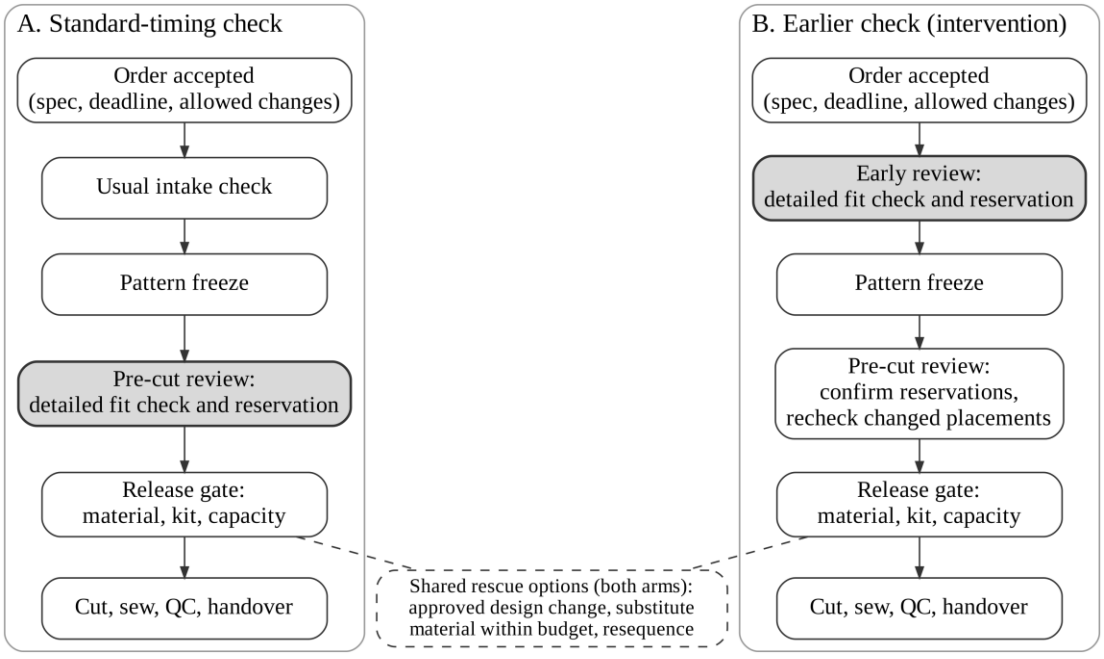


Figure 1. Standard-timing and earlier-check workflows

Note. The shaded step is the only activity that moves between arms. The release gate, sequencing rule and rescue options are identical in both arms. Both arms begin after order acceptance.

Three propositions follow. They state what the literature leads one to expect; they are not findings.

P1 Moving the detailed fit check and reservation before pattern freeze reduces unusable textile residue and new denim consumed, and the reduction is larger for patterns with tightly matched or hard-to-substitute panels.

P2 The earlier check shifts hands-on labour towards inspection and lengthens the time material spends in reservation; whether total person-minutes fall depends on how well the starting stock covers the required panels.

P3 Any effect on complete on-time delivery is greatest when compatible material, rather than sewing capacity, is the binding constraint, and may be negative when early reservations hold stock needed by another batch.

III. STUDY DESIGN

A. Overview

The study is a single-workshop, two-arm, paired-batch feasibility pilot with a preceding run-in. Batches of one product family, panelled denim shorts, are formed into matched pairs and, where practical, allocated to arms by concealed random allocation within each pair. Panelled shorts are chosen because paired panels must agree in size, grain and appearance, which makes the matching problem explicit. Jackets and other families are not pooled, because a long sleeve or an unsplit back panel creates a different allocation problem. Reporting follows the principles of the CONSORT extension for pilot and feasibility trials, which also offers guidance for non-randomised pilot studies (Eldridge et al., 2016).

B. Role of published evidence

Published sources are used to establish context and to specify variables, not as outcome data. Practitioner and media sources are used only for what they describe directly, and each is paired with its principal limit. All cited sources were published no later than September 2024. Table 1 summarises the empirical sources used for context.

Table 1. *Published sources used for context and their limits*

Source	What it provides	Principal limit
Ukomadu (2022); DW (2023)	AZACH's founding, use of second-hand clothing for streetwear, item-by-item sorting of discarded denim at a Lagos market.	News reporting; no cutting records, piece origins, labour times or order history.
Whipple (2022)	Profiles of Lagos traders, designers and alterationists in the *Denim to Denim* project.	Small purposive set of participants; describes variables, not their frequency.
Ehinmowo & Simon-Oke (2022)	Revenue, profit and drivers of profitability among 180 small-scale garment producers in Lagos State.	Conventional garment makers, not upcycling; financial survey data, not production records.
Adikwu (2022); The Index Project (2023)	Comparator Nigerian practices: thrift-market denim with patchwork; Dakala cloth made from offcuts.	Different processes; not comparable labour or workflow evidence.

Note. Planning and measurement concepts from the academic literature are reviewed in Section 2 and are not listed here.

C. Units of analysis

The batch is the unit of assignment and analysis. Garments are outputs within their batch, and orders are linked to batches by identifier because a batch can serve more than one order. Garments are not treated as independent observations, and a delayed batch is not treated as several separate experiments.

IV. PUBLISHED LAGOS CONTEXT

A. Reclaimed denim in Lagos

The 2022 *Denim to Denim* project profiled nine participants across Nigeria and the UK, six of whom were Nigeria-based practitioners or students (Whipple, 2022, pp. 9–21, 24–25). At Tejuosho Market, trader Patrick Nwanade worked with tailors on customised products and discussed colour and wear as commercial issues. Folakemi Shonubi of Bash House of Denim reported difficulty finding high-quality denim and wanted to use studio scraps. In Yaba, alterationist Samson Orji described a pedal-powered single-needle machine that could be motorised where electricity was available. These accounts identify variables worth logging (colour, wear, quality of supply and equipment constraints) but not their frequency across Lagos. Table 2 sets out why

the main sources of recovered denim are recorded separately in the ledger.

Table 2. *Why sources of recovered denim are recorded separately*

Source type	What to check before allocation	What could affect the schedule
Second-hand jeans	Wear at knees, crotch and pocket corners; existing seams; usable area after opening the garment.	Washing and unpicking may be needed before an accurate fit check.
Cutting offcuts	Usable shape, size, grain and shade; separate narrow strips from large pieces.	A reliable source can still supply mostly pieces too small for main panels.
Unused deadstock	Actual clean width and length, fibre or stretch where known, fading and storage damage.	A large section may resolve a panel shortage; its availability and purchase time are separate records.

Note. The source categories are not interchangeable, even when all are sold or donated as reclaimed denim.

Ehinmowo and Simon-Oke (2022) used multistage sampling to survey 180 small-scale garment producers in Lagos State. They reported average annual revenue of ₦601,234 against net profit of ₦59,514, found that customer patronage, experience and household size were positively associated with profitability, and recommended policies to stabilise power supply so that garment makers could raise production. These are conventional garment makers, not upcycling workshops, and the data are financial rather than operational. Their relevance is that small Lagos garment businesses work on thin margins and with unreliable infrastructure, so any procedure tested must be cheap to operate and simple to adopt, and the protocol must create the records it needs rather than assume they exist.

B. AZACH as published context

AZACH is a Lagos label founded by Uche Aladimma, an engineering graduate. Reuters reported in November 2022 that he had launched the brand in February of that year to counter fast fashion by using second-hand clothes to make durable streetwear (Ukomadu, 2022). The same report described Aladimma sorting discarded denim at an open market in Lagos and deciding, item by item, whether a piece such as a faded jacket should become an apron, a tote bag or something else. A year later, DW reported that the brand was focused on making fashionable and durable streetwear from recycled denim (DW, 2023).

This reporting establishes two things relevant to the protocol. First, inspection and allocation of recovered denim is a distinct activity that takes place piece by piece, before cutting. Second, in this reported practice the piece shapes the product, which is consistent with research showing that available material drives design in upcycling (Han et al., 2017). The reporting does not establish how allocation works when a customer has already ordered a particular design, which is the situation the protocol addresses. Nor does it show who cut, how many pieces were rejected, how long sorting took or whether orders were delivered on time. AZACH is not a participant in the study. Table 3 summarises what the reporting can and cannot support.

Table 3. *What the AZACH reporting supports, and what it does not*

Published evidence	Use in this protocol	Not established
Second-hand clothing used as the raw material for streetwear	Focus on recovered denim and on one product family at a time.	Product mix, pattern dimensions or the number of usable donor garments per item.
Item-by-item sorting of market denim reported	Treat inspection and allocation as a distinct, timed task.	How long sorting takes, or what share of purchased denim is later rejected.
Product chosen to suit each recovered piece	Contrast material-led choice with commitments made to a fixed design.	Whether allocation happens before or after a customer order is accepted.

Note. This is published context based on news reporting. It is not a factory audit, a product teardown or a review of the label's order ledger.

C. Other Nigerian practices

Vogue Business documented Pith Africa's use of denim sourced from Lagos thrift markets and described work with local artisans, including deconstruction and patchwork (Adikwu, 2022). NKWO, led by Nkwo Onwuka, illustrates a different route: its Dakala cloth was developed from offcuts and began with leftover pieces of denim, producing a new fabric with the look of handloom-woven cloth (The Index Project, 2023). Making usable textile before garments are cut converts an irregular-piece problem

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into a more conventional continuous-cloth problem at the cost of upstream labour. It is a different process from patching directly into panels and is noted here as a strategic alternative, not a comparator.

V. FIT AND RESERVATION PROCEDURE (BOTH ARMS)

The procedure in this section is identical in both arms. Only its timing differs (Section 6).

A. Fit criteria

A recovered piece is compatible with a panel only if the panel can be placed within the piece's usable area with the required seam allowances, on the required grain, clear of excluded defects, and with stretch and shade within the limits set in the approved brief. The usable area is the continuous region that remains after excluding worn or abraded zones, existing seams that the design cannot accept and distortion. Panel-level criteria are written down for each pattern before any batch is assigned, so that both arms apply the same test. A panel is classed as hard to substitute if its shape, location or appearance makes an unapproved change unacceptable; this classification is also fixed before assignment.

B. Recording placements

Each accepted placement is recorded with the piece ID, the panel ID and the exact position on the piece, marked on a layout sketch or photograph with chalk or pins. Rejected placements are recorded with a cause code (Appendix A). A piece can carry more than one placement only if the recorded positions do not overlap; the reviewer checks this on the layout before confirming any second reservation. Figure 2(a) illustrates a donor piece with one accepted and two rejected placements.

C. Allocation rule

Placements are reserved in order of flexibility: hard-to-substitute panels first, then other main panels, then pockets, loops and small parts. When a panel cannot be placed, the reviewer checks whether reassigning an earlier reservation would free a compatible piece before declaring a shortage. Figure 2(b) shows why. Panel A fits pieces 1 and 2; panels B and C each fit pieces 1 and 3. If A is assigned to piece 1 first, B takes piece 3 and C appears short. Reassigning A to piece 2 frees pieces 1 and 3 for B and C, and all three panels are covered from the same stock. A shortage is recorded only after this check.

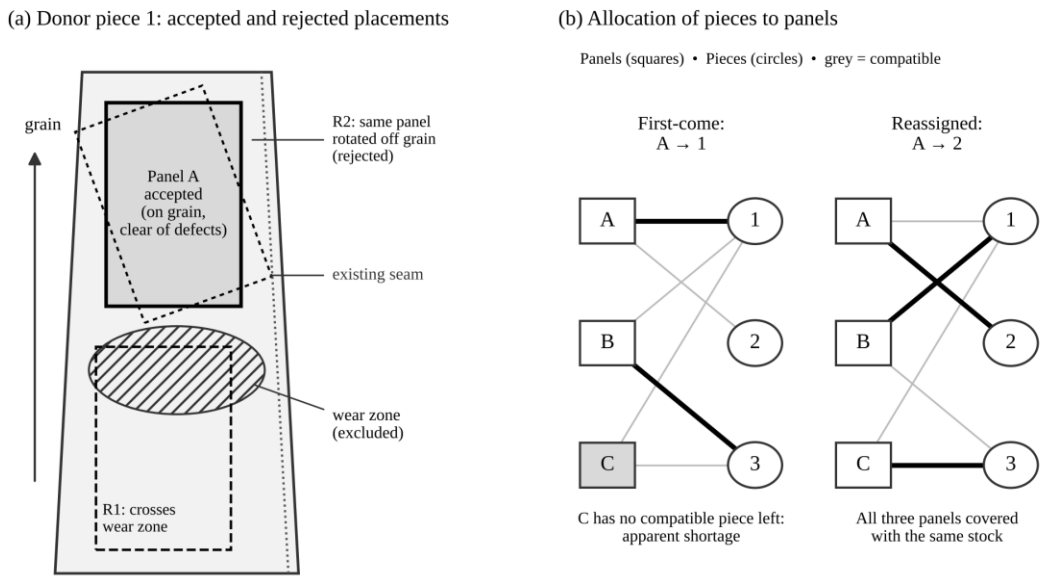


Figure 2. Illustrative fit decision and allocation

Note. (a) A single donor piece showing an accepted placement for panel A, a placement rejected because it crosses the excluded wear zone (R1), and a placement rejected because the panel is rotated off grain (R2). (b) A compatibility example in which a first-come assignment produces an apparent shortage that reassignment resolves. Both panels are schematic and do not represent recorded data.

D. Decision rights and reservation status

Table 4 sets out who makes each decision. A reservation is tentative when first made and becomes confirmed when the reviewer has checked the placement and any overlaps. A tentative reservation expires if it is not confirmed within the expiry period fixed at the end of the run-in, and in any case at the pre-cut review if not confirmed by then. Expired

reservations return the piece to available stock, and the expiry is logged.

Table 4. *Decision rights in the fit and reservation procedure*

Decision	Made by	Recorded
Propose a placement	Cutter or person conducting the review.	Piece ID, panel ID, position, time.
Confirm a placement or resolve an unresolved fit	Designer (or owner-designer where one person holds both roles).	Confirmation time, any overlap check, reason if rejected.
Approve a new seam, join or shade variation	Designer; customer as well where the order specifies approval.	Change, approver, approval time, whether it moves the planned freeze or cutting date.
Authorise use of substitute material	Owner, within the batch's pre-set substitute-material budget.	Mass, source, cost, reason.
Release, hold or refer a batch at the release gate	Owner or production lead.	Decision, reason code, time.

Note. Roles are confirmed with the workshop during the run-in and do not change between arms.

E. Release gate, sequencing and rescue options

Before cutting, every batch in both arms passes the same release gate. The material check confirms that every hard-to-substitute panel has a confirmed placement or an approved join. The kit check confirms that all parts needed at cutting are present and reserved and that later-stage trims have verified availability. The capacity check confirms workable slots for cutting, sewing, inspection and handover, net of existing bookings. A batch that fails a check is held, and the reason is logged. Among released batches, the one with least slack against its original commitment is sequenced first; a batch may be moved forward for convenience only if the displaced batch keeps adequate slack.

When compatible material is short, the same three rescue options are available in both arms (Table 5). The substitute-material budget for each batch is fixed before assignment as a maximum mass of new denim, so neither arm can resolve shortages with more new material than the other.

Table 5. *Rescue options available in both arms*

Option	Condition for use	What is recorded
Approved design change	An extra seam or different pairing fits the brief, passes a test seam and is approved under Table 4.	Change, approval, redrawing and pressing time, any fit or quality failure.
Substitute material	A compatible donor or new-denim piece can be obtained within the batch budget before the last safe cutting slot.	Search and travel time, purchase mass and cost, receipt, usable size.
Resequence	Another batch is genuinely ready and can use the slot without taking a reserved piece or endangering a firmer commitment.	Slot reassigned, dates affected, when the held batch re-enters the queue.

Note. The options, their conditions and the budget are identical in both arms.

VI. THE COMPARISON

A. What changes between arms

Table 6 sets out each decision point. Only the rows marked as different change between arms.

Table 6. *Decision points in each arm*

Decision point	Earlier check (intervention)	Standard-timing check
Order accepted	Record quantity, specification, original deadline and allowed changes.	Same.
Before pattern freeze (differs)	Conduct the detailed fit check and reserve compliant placements at the scheduled early review.	Conduct the usual intake check only. Defer the detailed fit check and reservation.
Pre-cut review (differs)	Confirm reservations and recheck any changed placements.	Conduct the initial detailed fit check and reserve compliant placements.
Release to cutting	Same material, kit and capacity checks. Record a hold, approval or release.	Same.

Note. Fit criteria, reservation procedure, decision rights, release gate, sequencing rule, rescue options, substitute-material budget and quality thresholds are identical in both arms.

B. The early review window

The early review in the intervention arm takes place within a defined window that opens at order acceptance and closes a fixed lead time before the planned pattern freeze. The lead time is set during the run-in so that, in most batches, an incompatibility found at the early review leaves enough time to source substitute material or obtain a design approval before freeze. The run-in records how long each of these actions actually takes. If the run-in shows that no workable window exists for the workshop's typical order, the comparison does not proceed in its current form.

C. Recording changes and deviations

In both arms, every approved design change is logged with its approval time and with whether it moves the planned freeze date, the planned cutting date or neither. Deviations from the assigned workflow, such as an early check performed in a standard-timing batch, are recorded with the reason. Batches remain in their assigned arm for analysis even if the workflow changes, so that deviations are visible rather than hidden.

VII. PILOT PROCEDURES

A. Setting and eligibility

One consenting Lagos workshop is recruited. It must routinely make panelled denim shorts from recovered material, accept customer orders with stated deadlines, and be able to link orders to cutting sheets or start a simple log. A batch is eligible if it belongs to the panelled-shorts family, uses recovered denim for at least its hard-to-substitute panels, has an original deadline recorded at order acceptance and has not yet reached pattern freeze when it is registered for the study.

B. Run-in

A run-in period precedes the comparison. Its records are reported as feasibility data and are not included in the comparison. The run-in is used to:

– measure how long a detailed fit check and reservation take per batch;

– check whether two reviewers, assessing the same sample of pieces independently, agree on compatibility, and resolve recurring disagreements by refining the written criteria;

– measure how long sourcing substitute material and obtaining design approvals take, and set the early review lead time accordingly;

– establish a realistic reconciliation tolerance for the material balance;

– set the tentative-reservation expiry period and confirm decision rights;

– measure the recording burden per batch and adjust forms that prove impractical.

C. Pairing and allocation

Eligible batches are paired on planned volume, size mix, pattern complexity, available capacity, starting stock compatibility and deadline. Starting stock compatibility is assessed before assignment with the same written rubric for both batches, and unresolved assessments remain visible in the record. Where the workshop can support it, the arm for each pair is decided by concealed random allocation. Before the comparison begins, a person not involved in production prepares a list of allocations, one per planned pair, and seals each in an opaque numbered envelope. An envelope is opened only after both batches in a pair have been registered and their baseline characteristics recorded. The order in which the two batches run is recorded separately.

If random allocation proves impractical, batches are assigned by matching against transparent criteria recorded in advance, and the results are interpreted as observed differences rather than estimated effects. In either case, transfers of stock between batches and disruptions caused by shared workers are recorded, and every assigned batch stays in the record.

D. Recruitment window and number of pairs

A recruitment window and a minimum number of usable pairs are fixed at the end of the run-in from the workshop's actual order book. Because this is a feasibility pilot, the number of pairs is not set by a power calculation, consistent with guidance that pilot studies should state their objectives and progression criteria rather than claim confirmatory power (Eldridge et al., 2016).

E. Progression criteria

Table 7 lists the criteria for proceeding to a larger study. Thresholds are agreed with the workshop at the end of the run-in and recorded in a dated protocol amendment before the first comparison pair is registered. They are not changed after that point.

Table 7. *Progression criteria*

Criterion	Measure	Threshold
Usable pairs	Pairs with both batches completed or closed at the cut-off and with outcome data available.	Fixed at end of run-in.
Adherence in each arm	Share of batches in each arm in which the check and reservation took place at the assigned point.	Fixed at end of run-in; reported separately by arm.
Recording burden	Recording minutes per batch; owner and worker feedback.	Fixed at end of run-in.
Material balance	Share of batches whose ledger closes within the run-in tolerance.	Fixed at end of run-in.
Traceability	Share of placements and residue entries traceable to a piece ID and a verified origin or destination.	Fixed at end of run-in.

Note. Thresholds are locked before the comparison and reported with the results.

F. Ethics and consent

The owner's agreement and the informed consent of participating workers are obtained before any times are collected. Worker and customer identifiers are anonymised. Participants are told that timing is a study of the process, not a way to rank workers or change pay, and that they may withdraw without consequence. Approval from an appropriate research ethics committee is obtained before data collection.

VIII. MEASUREMENT

A. Observation boundary and closing date

The main ledger for each batch begins when recovered material is issued to the batch, after intake preparation, and ends at the batch closing date. Intake preparation, dismantling of donor garments and donor pieces rejected before issue are recorded in a linked intake account, not in the main ledger, and the same rule applies in both arms. The closing date for each batch is fixed in advance as a set number of working days after the last scheduled handover; the number is the same for every batch and is set at the end of the run-in. Material still in work or held for a decision on the closing date is reported as such.

B. Weighing procedure

All textile masses are recorded on a consistent dry-mass basis: material is weighed after washing and drying, with trims and hardware removed or weighed separately. A bench scale with 1 g resolution is used, checked at the start of each working day against a reference mass, and containers are tared before each reading. Each entry records the piece or residue ID, the mass, the time and the person weighing. A second person, not the cutter who generated the entry, verifies the ledger at batch close. Any difference between the two sides of the material balance (Section 8.4) is reported for every batch, whether or not it falls within the run-in tolerance.

C. Material fate categories

Every gram issued to a batch is assigned to one of the mutually exclusive categories in Table 8. Unknown destinations are recorded as unknown, not allocated to a category by assumption.

Table 8. *Mutually exclusive material fate categories*

Category	Definition
Incorporated	Textile in accepted garments.
Reusable remnant held	Pieces retained in labelled stock that meet the workshop's pre-defined minimum size for reuse.
Documented usable transfer	Usable pieces transferred to another batch or another user, with the recipient recorded.
Residue to recovery	Unusable residue sent to a documented recovery outlet, such as a stuffing or fibre-recovery buyer.
Residue to disposal	Unusable residue discarded.
Destination unknown	Material whose fate cannot be verified at the closing date.
In work or held for decision	Material still in production, or rejected pieces awaiting a decision, at the closing date.

Note. Unusable residue for the primary outcome is the sum of residue to recovery and residue to disposal.

D. Material balance

At batch close, the ledger is reconciled on a dry-mass basis: fabric issued plus transfers in must equal the sum of the seven fate categories in Table 8. A balanced ledger can still contain material whose origin is unverified, so origin evidence is recorded separately for every piece, and mass of unknown origin is reported. Appendix C gives an illustrative balance.

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E. Outcomes

Table 9 defines the outcomes. Material outcomes are always reported alongside quantity and quality, so that an incomplete batch cannot appear efficient because it generated less residue.

Table 9. *Outcome definitions*

Outcome	What is recorded and reported
Primary: unusable textile residue	Total dry grams of unusable residue generated per batch (residue to recovery plus residue to disposal), and grams per planned garment. Grams per accepted garment are also reported where accepted output is non-zero.
Material fate and reuse	Grams in each Table 8 category, reported separately. Work in progress and unresolved stock at the closing date are shown explicitly.
New material demand	New denim purchased for the batch and new denim actually consumed, reported separately. Material drawn from existing stock is linked to the batch. Origin evidence and mass of unknown origin are reported separately.
Scheduling and service	Timestamps for order acceptance, incompatibility detection, pattern freeze, release, waiting (with reason), resequencing, rework and completion. Complete on-time output against the original commitment. Approved deadline changes are recorded separately and do not replace the original deadline.
Trade-offs	Person-minutes by task (inspection, reservation, sourcing, preparation, cutting, sewing, pressing, quality check, rework), time material spends in reservation, and first-pass quality.

F. Missing data

Missing values are recorded as missing, never as zero. A recorded zero means that the quantity was observed and was nil. When a deadline or handover timestamp is missing, the delivery outcome is labelled unverified, and the report shows how classifying unverified orders as all late or all on time would change the counts.

IX. ANALYSIS PLAN

A. Pair-level display

The analysis is descriptive. Each pair is displayed with its starting conditions, its earlier-minus-standard differences on each outcome and any deviations, using the row structure in Table 10. Stage-level person-minutes are shown beside the total, so that a shorter cut offset by a longer inspection is visible as shifted rather than saved work.

Table 10. *Paired results template*

Pair ID	Planned / accepted qty	Starting panel coverage	Residue (g)	New denim consumed (g)	Inspection and rework (min)	On-time status	Deviation or missing-data reason

Note. One row per arm within each pair, followed by a difference row (earlier minus standard). The template contains no data.

B. Summaries

For the primary outcome, the median and range of the paired differences in residue are reported. The same summary is given for new denim consumed and total person-minutes. For delivery, the number of orders due in each arm and the number delivered complete and on time against the original commitment are reported together, with percentage-point differences given only after those counts. Cancellations initiated by the customer are reported separately; cancellations caused by the workshop count as not on time. Unfinished batches at the closing date remain in the denominator. Significance testing is not used, because a very small feasibility study cannot support it; the observed spread of paired differences is used instead to plan a larger study.

For RQ2, the frequency of each rejection cause code is tabulated by source type. For RQ3, pairs are grouped descriptively by starting stock coverage, pattern

complexity and whether material or sewing capacity was the recorded cause of waiting.

C. Decision rules and adverse results

Acceptance limits for quality, schedule and extra labour are agreed with the workshop before the first comparison pair, alongside the progression thresholds. Table 11 sets out how the results will be used. Adverse and mixed results are reported in full, including less residue with longer waits, or less purchasing with unchanged consumption of new denim.

Table 11. *Pre-agreed use of the results*

Decision	Evidence that would support it
Keep the earlier check	Lower unusable residue, with quality, schedule and extra labour within the agreed acceptance limits.
Use it selectively	A benefit concentrated in a defined kind of batch, such as tightly matched panels or poor starting coverage.
Revise or stop	No consistent reduction in residue, labour shifted into inspection beyond the agreed limit, or longer waits and missed commitments that outweigh the material change.

Note. Acceptance limits are fixed before the comparison and reported with the results.

D. Extension by simulation

If the pilot produces an adequate timestamped history, receipts, inspections, reservations, cutting, sewing, quality checks and handover can be replayed in time order. A later discrete-event model could vary stock coverage and pattern mix beyond what one workshop experiences. Such a model should be validated against a separate period before policies are tested and reported against the STRESS guidelines (Monks et al., 2019); missing inputs should not be filled from national or regional totals.

X. DISCUSSION

A. Interpreting the results

Three interpretations are distinguished in advance.

– Waste prevention is shown if the earlier check reduces unusable residue generated per planned garment within the measured boundary, with accepted output and first-pass quality maintained. A shift of the same residue from disposal to recovery is a change of destination, not prevention.

– Burden shifting is shown if residue falls but the labour, waiting or reservation time needed to achieve it rises beyond the agreed limits, or if residue is moved from the main ledger into the intake account, held stock or unknown destinations.

– Improved scheduling is shown if the earlier check reduces late pattern changes, resequencing or waiting and increases complete on-time output against the original commitment, whether or not residue changes.

These outcomes are not mutually exclusive. The earlier check could improve scheduling without preventing waste, or prevent waste at a schedule cost. Reporting all three together is what allows a reader to judge the trade-off.

B. Keeping sustainability claims proportionate

A reduction in unusable residue is evidence about waste prevention within one workshop's boundary. It is relevant to the prevention element of Target 12.5 (United Nations General Assembly, 2015) but is not a measure of the national recycling indicator (United Nations General Assembly, 2017). Lower purchasing of new denim is not the same as lower consumption, because a batch can draw on existing stock. Claims about carbon savings or avoided upstream production would need evidence on what the recovered cloth displaced (Sandin & Peters, 2018), and the protocol does not collect it.

C. Theoretical implications

The protocol extends two lines of research. For remanufacturing planning, it carries the question of when to inspect variable inputs into a craft setting where inspection is done by eye and hand, where one donor garment yields several parts of different value, and where the cost of inspection falls on the same small team that cuts and sews (Ferguson et al., 2009; Guide, 2000; Yanıkoğlu & Denizel, 2021). For order release, it treats the release gate as a shared structure and asks whether the timing of material information upstream of the gate changes what passes through it (Thürer et al., 2011). For upcycling research, it adds an operations-level test to design- and business-level studies (Han et al., 2017; Singh et al., 2019; Sung et al., 2020).

D. Practical implications

Whatever the result, the procedure gives a workshop a way to see where its cloth goes. The cut-release card (Appendix B) and the material ledger (Appendix A) can be used without the comparison. If the main delay turns out to be a shared sewing machine rather than the cloth, that bottleneck should be addressed before the cutter is asked to inspect earlier. For support organisations, the protocol offers a low-cost way to generate workshop-level data on recovered-cloth yield and residue, which the sources reviewed here do not provide. Support for small garment producers, whose thin margins are

documented by Ehinmowo and Simon-Oke (2022), would be better targeted with such data.

E. Limitations

The study involves one workshop and one product family, and its results cannot stand in for Lagos or Nigeria. Staff cannot be blinded to the arm, so outcomes are tied to records that can be checked against a physical or documentary source. Workers may become more skilled at either workflow as the pilot proceeds, and stock may change between pairs; matching, concealed allocation and recording of running order reduce but do not remove these risks. The observation period ends at a fixed closing date, before some reusable remnants are used, so their eventual fate is unknown and they are reported as held. The comparison estimates the effect of moving inspection and reservation together and cannot separate the two. The literature search was targeted rather than systematic, and the published Lagos context comes partly from news reporting.

F. What a completed study would need to show

A strong empirical follow-up would present batch-level results for every pair, including pairs in which the earlier check made little difference or added work. It would include at least one traceable example from donor material through inspection, pattern decision, cutting and final material accounting, with the schedule consequence and the finished output shown alongside the residue result. It would state what the evidence supports and what requires testing across further workshops, product families and seasons.

XI. CONCLUSION

In recovered-material production, the time at which a workshop learns that its cloth will not fit is a scheduling decision with material consequences. This protocol isolates that decision by moving one activity, the detailed fit check and reservation, from after pattern freeze to before it, while holding every other control constant. Cloth should be weighed for the material account, but the pattern should be checked against the cloth before the pattern is frozen if doing so prevents more residue, recutting and emergency buying than it costs in inspection time and reserved stock. The pilot is designed to show whether that condition holds, for which batches, and at what cost to the schedule.

DECLARATIONS

Ethics statement. This article is a study protocol and analyses published sources only; no human participants were involved in its preparation. AZACH is discussed as published context and is not a research participant. The field study requires the workshop owner's agreement, informed consent from participating workers and approval from an appropriate research ethics committee before data collection (Section 7.6).

Data availability. No new data were generated. All sources are publicly available and are listed in the References. All cited sources were published no later than September 2024.

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