GREEN FUTURE TECH
LIMITED / HONG KONG SAR

GFT RESEARCH / WARP AND SIGNAL

Utilisation Decides

OEE, line balancing and lean flow in garment manufacturing

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RESEARCH EDITION

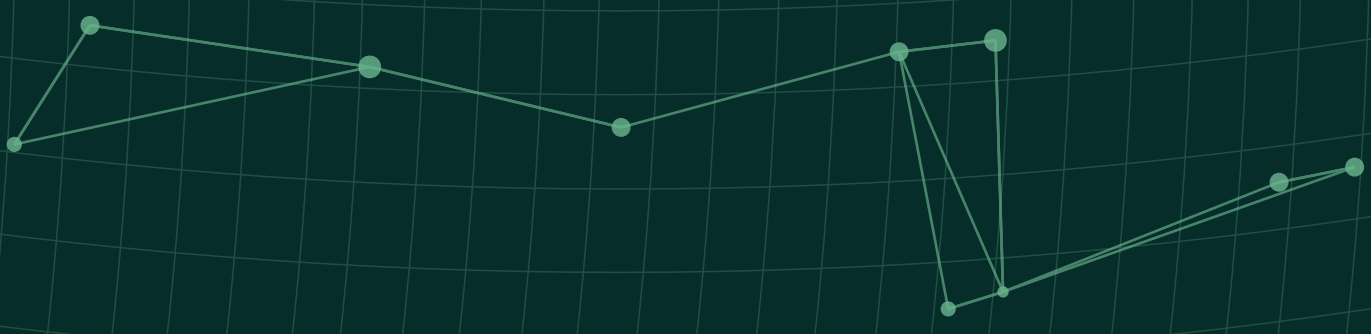
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THE GFT THESIS

Value is made where it is measured.

GFT engineers sustainable factories that capture their own data from the first shift, so raw-material economies can keep the value they grow.



Read the evidence before acting on the recommendation.

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Build the factory and its evidence as one system.

Garment factories do not earn a return on installed machines. They earn it on good garments delivered by the whole line. Utilisation Decides argues that OEE, line balancing and lean flow must be managed as one operating system. OEE locates losses in availability, performance and quality. Balancing converts measured work content into feasible station assignments. Lean flow stops local busyness becoming excess work in progress. In Cameroon, the stakes are visible in reported incumbent capacity utilisation of 10.83 to 48.9 per cent (R12), but the answer is not to chase a universal OEE benchmark. [R12] It is to define the time base, capture losses at source and raise the output of the constraint without sacrificing quality or decent work. The paper distinguishes machine effectiveness from SMV-based sewing-line efficiency and shows why skill, learning, absenteeism, power interruptions and style changes alter the balance. Evidence from ILO programmes and apparel case studies demonstrates large but context-specific gains from balancing, pull and monitoring (S09; S12; S31; S37). GFT's position is practical: begin with clean manual logs, standard work and a feasible balance; stabilise quality and changeovers; then add digital monitoring when it improves the decision. The closing roadmap specifies owners, stage gates and measures: good output, earned standard minutes, constraint throughput, work in progress, throughput time, first-pass yield, downtime by cause, energy per good garment and worker outcomes.

01 Utilisation is an economic variable before it is a technical score: reported incumbent utilisation of 10.83 to 48.9 per cent shows why installed capacity cannot be treated as saleable output. [R12]

02 OEE creates value only as a declared loss tree, because availability, performance and quality point to different actions and published OEE definitions are not uniform. [S01] [S03] [S04] [S05]

03 SMV-based line efficiency, balance efficiency and OEE are different measures; combining their definitions produces false comparisons across styles, lines and factories. [S04] [S13] [S15]

04 The constraint, not maximum local busyness, governs good throughput, and high utilisation in variable systems can increase waiting nonlinearly. [S23] [S28] [S30]

05 Feasible balancing must include precedence, machine and skill constraints; simulation and digital tools can test allocations, but only a line trial can validate them. [S09] [S11] [S15] [S16] [S17]

06 Pull and smaller transfer batches can reduce WIP and throughput time, but case-specific reductions are mechanisms to test rather than targets to copy. [S21] [S22] [S24] [S31]

07 Skill, learning, turnover, supervision, ergonomics and working time are capacity variables, not peripheral human-resources topics. [S17] [S18] [S33] [S38] [S39] [S40] [S41]

08 Power interruptions must enter the availability model and the investment case, with outage, restart and backup effects measured separately from machine failure. [S02] [S35] [S36]

09 Energy per good garment can fall through higher volume alone, so utilisation benefits must be separated from genuine energy-efficiency gains. [S34] [S43] [S44]

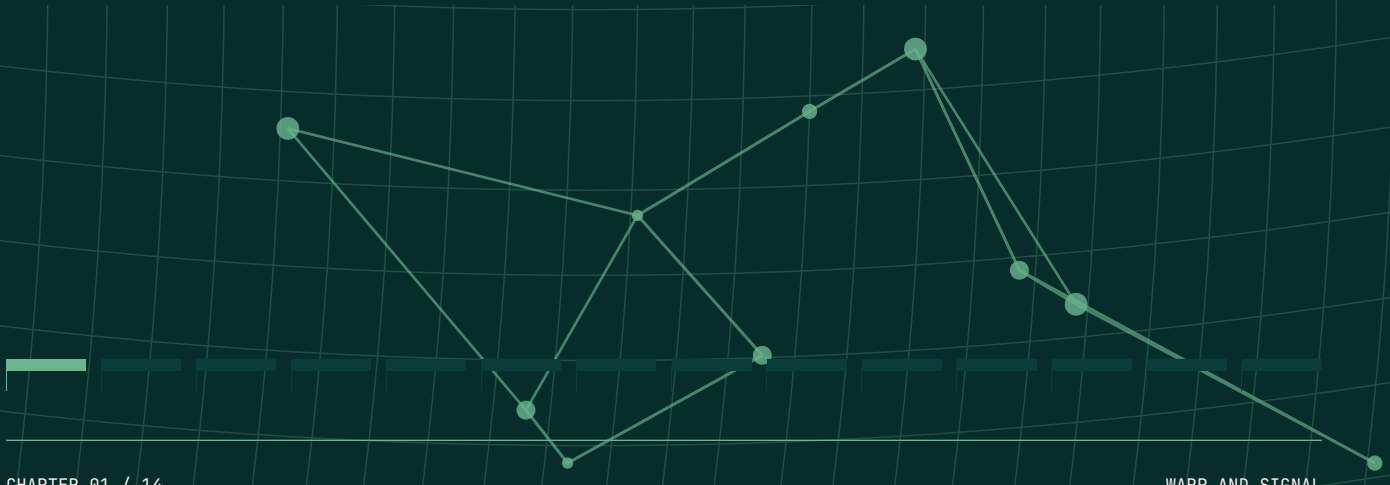
10 GFT should release spending through evidence gates: clean baseline, stable standard work, feasible balance, controlled flow, capable people and power, then decision-linked digital monitoring. [S09] [S12] [S20] [S26]

01

PART I: MEASURE THE FACTORY THAT ACTUALLY EXISTS / THE OPERATING PROBLEM

Utilisation decides whether installed capacity becomes good garments

A garment factory creates value when the whole line converts available time and skill into accepted output. Installed machines and busy stations are evidence of resources, not proof of delivery.



CHAPTER 01
DECISION TEST

A garment factory creates value when the whole line converts available time and skill into accepted output. Installed machines and busy stations are evidence of resources, not proof of delivery.

Utilisation belongs at the centre of the business case because the factory must convert its resources into garments that meet requirements and can fulfil orders. GFT's position is to manage that conversion through connected measures of productive time, labour content and flow. A sponsor should fund an increase in usable system output, subject to quality, working conditions and demand, rather than an increase in machine activity alone. The operating argument in this chapter establishes that decision boundary. It does not offer a universal efficiency target or a forecast for a particular factory.

1.1

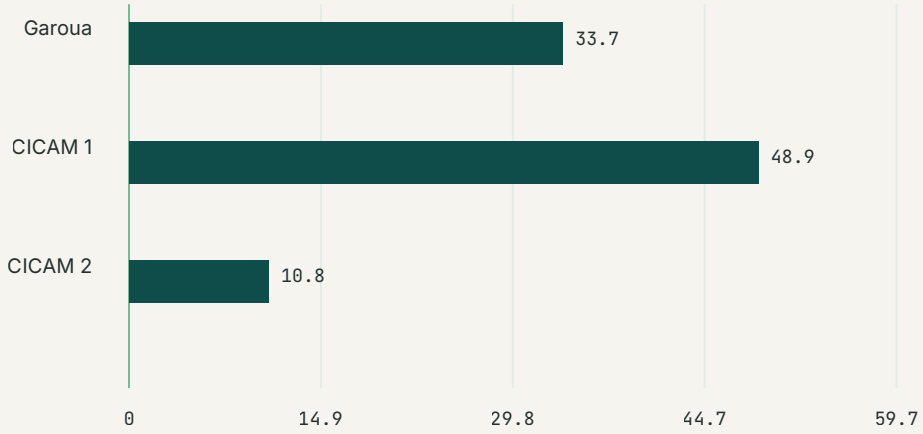
Nameplate capacity is not saleable output

The inherited evidence register records a July 2023 report of capacity utilisation at CICAM facilities: Garoua at 33.7 percent, CICAM 1 at 48.9 percent and CICAM 2 at 10.83 percent. These are historical third-party observations, not measurements made by GFT. The register retains the reported values but does not reproduce the underlying capacity definitions or complete source URL. They establish a reason to investigate the conversion of installed assets into output; they cannot establish present operating performance or diagnose a particular loss. [R12]

The comparison in **Exhibit 1**, p. 15 therefore preserves the reported labels and percentages. It deliberately avoids ranking management teams or valuing the unused capacity. Before using these observations in an investment model, the analyst would need to establish which products, processes, available hours and capacity standards the original report covered. The inherited record's limitations remain part of the evidence, even when the chart is precise. [R12]

EXHIBIT 01 / PERCENT OF REPORTED CAPACITY

Historical utilisation reports distinguish installed assets from output



SOURCED [R12] Inherited register: July 2023 account, Garoua 33.7, CICAM 1 48.9, CICAM 2 10.83. Original denominators and full article URL are not recorded. Historical observations, not current GFT measures.

For an appraisal, GFT recommends separating the supplier's design rate from the rate demonstrated with the intended garment, operators and supporting services. Record what the supplier assumes about fabric, attachments, machine condition and operator

competence. Record whether the rate describes a sewing operation or an entire line. The acceptance test should finish at an identified quality boundary. A test that counts stitched components cannot directly prove the capacity to dispatch finished garments.

The sponsor should then ask what prevents the demonstrated rate from being repeated over the planning period. GFT proposes a capacity bridge that starts with the scheduled production window, identifies time lost, records the rate achieved while running and finally removes output that fails the chosen acceptance test. Keep the commercial question alongside this bridge: is there an authorised order for the resulting product? Technical production and commercial absorption require separate evidence. A finished item awaiting a buyer is not an additional confirmed sale.

Consider the illustrative loss bridge in **Exhibit 2**, p. 16. The assumed reference volume is 1,000 units within a defined planned period. Assumed availability of 90 percent leaves 900 unit equivalents, assumed performance of 80 percent leaves 720 and assumed quality of 95 percent leaves 684. The losses reconcile as 100, 180 and 36 unit equivalents respectively. The multiplicative structure follows the OEE framework; all operating inputs here are assumptions, not Cameroon observations or GFT results. [S04]

EXHIBIT 02 / ILLUSTRATIVE UNIT EQUIVALENTS PER PLANNED PERIOD

Sequential losses leave fewer good-unit equivalents than the plan



ILLUSTRATIVE [S04] Illustrative assumptions: reference volume 1000, availability 0.90, performance 0.80, quality 0.95. Arithmetic: 1000 minus 100 minus 180 minus 36 equals 684; equivalently 1000 × 0.90 × 0.80 × 0.95. Source supports the OEE structure, not these assumed inputs. Loss allocation follows this stated sequence.

The illustrative bridge is an accounting device for a defined process, not a simulation of dependent sewing stations. It should not be multiplied by a separately estimated line-utilisation factor covering the same losses. That would count the same missing output again. Nor should the numerical loss assigned to quality be interpreted as the

total cost of poor quality. Inspection, repair and delayed delivery require their own cost boundaries. GFT recommends naming each loss once before attaching money to it.

This distinction changes the first investment discussion. Ask whether the proposed asset removes the restriction on accepted line output, whether upstream supply can sustain that output and whether downstream inspection and packing can absorb it. Request a measured baseline and an acceptance condition for the change. Without those items, a supplier's capacity statement remains a technical input to appraisal rather than an established basis for revenue. Detailed costing belongs later in the paper; the opening discipline is to choose the output that deserves to be costed.

1.2

Local processing raises the premium on operating discipline

The inherited sector record states that about 95 percent of Cameroon's cotton fibre is exported raw and about 5 percent is processed locally. A separate entry records a national objective of 50 percent local processing by 2030. The original publication dates are not recorded in these entries. The baseline is approximate, and the policy figure is a target, not evidence that new processing has been delivered. This chapter uses them to explain the operating question, not to certify a current market balance. [R06] [R07]

GFT's inference from that stated ambition is conditional: an increase in processing should be assessed through functioning production stages, rather than through asset announcements alone. A garment operation needs a defined input specification and an output customer. If an appraisal includes spinning, weaving, finishing and sewing, it should retain the boundaries between them. Fibre throughput and garment count are different units. A local-processing target cannot be translated directly into a sewing-line sales forecast without product yields, routing and demand assumptions.

The practical recommendation is to write a conversion map before choosing a utilisation target. For each proposed stage, identify the material received, the form delivered, the acceptance test and the party authorised to accept it. Identify where the flow leaves the project boundary and where another business must act. This is especially useful for an integrated proposal: internal transfer of intermediate stock should not be mistaken for final customer delivery. The appraisal should show which operating risks sit inside the proposed project and which remain with suppliers or buyers.

Use that map to identify the smallest unit of evidence that would support the next decision. A fabric qualification sample may support a material choice; it cannot prove a stable production rate. A successful line trial may support a capacity estimate for the tested style; it cannot prove that all proposed styles share the same work content. GFT recommends an evidence ladder that keeps these claims separate. The aim is to make a large industrial ambition inspectable through smaller operating propositions.

An illustrative domestic-processing proposal might have enough installed sewing capacity to meet its planned garment volume but lack a confirmed supply of qualified fabric. In that assumed situation, adding sewing stations would not resolve the stated

input constraint. The immediate appraisal questions would concern material qualification, supply timing and contingency routes. A different illustrative proposal might have reliable material and orders but fail at final inspection. Its immediate question would concern the mechanism creating defects. Neither situation justifies a general conclusion that the sector needs fewer or more machines.

GFT recommends treating the feasibility model as a set of operating promises. Each promise should have an owner, a test and a consequence if the test fails. For productive volume, identify who will demonstrate the rate and who will validate accepted output. For staffing, identify the skill mix needed at the tested rate. For services, identify the operating envelope under which the test is valid. A model becomes more useful when an unproven promise remains visible than when uncertainty disappears into a single average utilisation assumption.

For a proposed shared facility, GFT recommends making service allocation explicit as well. Identify which line can use the finishing equipment, who authorises a change in the schedule and what happens when requests conflict. A capacity assumption should not silently allocate the same scarce service to every line at once. The appraisal should retain a schedule that demonstrates compatibility, or flag the service assumption as untested. This gives the operating team a concrete question to resolve before a combined site total is treated as deliverable output. The same discipline applies to shared inspection staff, material handling and specialist maintenance support.

The choice also has a sustainability boundary. GFT proposes tracking inputs against accepted garments while retaining absolute consumption and rejected material. A lower input intensity could result from spreading a fixed consumption over more good output; it should not automatically be described as a technical efficiency gain. Equally, a higher output total should not be presented as an environmental benefit without examining the associated material and energy totals. This chapter sets that analytical caution; the energy and unit-cost methods are developed later in the paper.

The market and policy assessment remains outside this operating chapter. Its contribution is narrower: when a processing opportunity is proposed, demand proof that each production stage can repeatedly meet its specification and that the connected system can deliver the required product. This prevents a national aspiration from silently becoming a factory's production assumption. It also makes the case easier to revise. If demand, product mix or supply conditions change, the analyst can update the affected boundary rather than rebuild an unexplained headline ratio.

1.3

Three measurement lenses answer different questions

OEE distinguishes availability, performance and quality. The opened review associates these respectively with downtime, speed losses and defect or yield losses. Their product expresses the fraction of a declared reference output retained at the chosen boundary. That structure helps locate a missing output, but it does not define every garment factory's measurement protocol. GFT recommends declaring the planned time, ideal rate and treatment of rework before comparing scores. [S04]

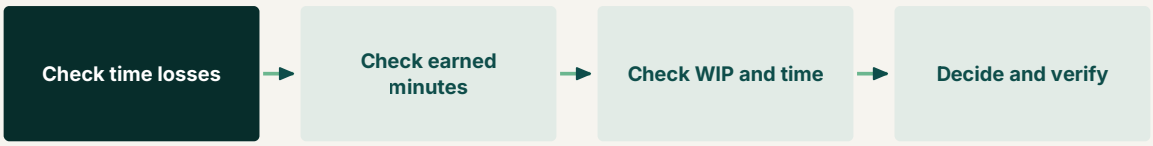
A labour lens asks a different question. The IFC and ILO GEAR assessment explains garment standard minute value as the sum of operation-level standard minutes and calculates efficiency from output minutes relative to available labour minutes. For this paper, GFT proposes counting only accepted output in earned standard minutes and dividing by attended labour minutes. That explicit convention must travel with the result; it should not be assumed to match every external study's completed-piece definition. [S13]

The flow lens asks how long work remains in the system. MIT's lean glossary connects average work in progress, average throughput rate and average throughput time through Little's Law, while warning that its strict application concerns long-term averages in stable systems. For an illustrative steady operation with average WIP of 600 garments and throughput of 100 garments per hour, the corresponding average throughput time is 6 hours. The assumed population includes all work crossing the same entry and exit boundaries. [S22]

The measurement architecture in **Exhibit 3**, p. 19 is GFT's illustrative design. It orders checks on time, labour and flow before a common decision record, rather than collapsing them into a composite score. The evidence sources support the underlying concepts. The proposed connection between those concepts and the management review is an engineering recommendation, not a claim about an installed GFT platform. [S04] [S13] [S22]

EXHIBIT 03 / ILLUSTRATIVE MEASUREMENT DESIGN

Time, labour and flow checks precede the operating decision



ILLUSTRATIVE [S04] [S13] [S22] GFT proposed review sequence: check time losses, labour content and flow, then choose an action. OEE, earned minutes and stable-system WIP relationships remain distinct measures. Arrows indicate review order, not material flow or a combined score. This is not an implemented platform.

WORKED EXAMPLE: THE SAME OUTPUT SUPPORTS DIFFERENT DENOMINATORS

An illustrative line has 20 attended operators, each present for 480 production-window minutes. It produces 300 accepted garments with an assumed standard minute value of 20 minutes per garment. Attended labour is 20 × 480 = 9,600 minutes. Earned work is 300 × 20 = 6,000 standard minutes. Under the stated GFT convention, line efficiency is 6,000 / 9,600 = 62.5 percent. The assumptions demonstrate the labour calculation; they do not establish the line's machine OEE or an attainable factory target. [S13]

Keep this illustrative labour example separate from the earlier reference-volume bridge. Its worker count, time window, garment standard and accepted count describe a different assumed dataset. Combining their outputs would imply a relationship that has not been specified. Before using actual factory records, reconcile the attendance window, accepted-piece count and applicable operation bulletin to the same shift and style.

GFT recommends retaining the raw observations needed to reconstruct each result. A percentage without its denominator should be treated as incomplete. A labour record needs attendance and applicable work content. An OEE record needs scheduled and running time plus the selected reference rate and quality count. A flow record needs a population definition, entry and exit events and a treatment of opening and closing stock. The record should preserve corrections so that the supervisor can explain why a result changed.

Reworked garments require a particularly clear counting rule. GFT proposes retaining the original completion event, the reason for repair and the eventual acceptance event under the same garment or batch identity. Do not add a repaired garment to the physical output total each time it crosses a workstation. Likewise, distinguish a garment awaiting inspection from one already rejected. This is a proposed record structure, not a statement that every operation needs individual-piece tracking. Where only batch records are feasible, state the resolution and reconcile quantities before using them to describe a quality-adjusted production rate.

The lenses can disagree without either calculation being wrong. In an illustrative style change, piece output might fall while earned standard minutes remain unchanged because the new garment contains more work. In another illustrative situation, a machine might meet its running-rate standard while finished output remains limited elsewhere. GFT recommends using such disagreement as a prompt to inspect boundaries and causes. Avoid changing the measurement definition merely to restore a preferred story. A score should make the decision more accountable, not make operational differences disappear.

The following chapters develop these definitions and their controls in detail. Here the decision rule is sufficient: select the measure that answers the question, preserve the observations behind it and examine the effect at the whole-line output boundary. When the purpose is accepted delivery, no isolated machine, labour or flow measure should become the sole acceptance test. The sponsor needs an explanation of how a proposed improvement changes the connected production result and how that change will be verified.

1.4

The whole line outranks the busiest station

The Lean Enterprise Institute's account of the Theory of Constraints starts with the restriction on system throughput and then adjusts the other parts of the system to support it. Its discussion also recognises non-manufacturing constraints, including market demand. The useful implication for this paper is that a local speed gain needs a system explanation: it creates additional accepted delivery only if it addresses the effective restriction or supports the resource that does. [S30]

An illustrative line makes this distinction concrete. Suppose compatible successive operations can sustain 120, 80 and 110 units per hour respectively, with no losses or alternative routes. The middle operation bounds sustained output at 80 units per hour under these assumptions. Raising the first operation to 140 units per hour does not change that bound. If it is fed and run continuously at the higher rate, the queue ahead of the middle operation grows by 60 units per hour. These are constructed rates for explaining the mechanism, not measurements of a sewing line.

The management response in that illustrative situation should depend on the cause of the middle operation's restriction. GFT recommends checking method, machine suitability, qualified staffing, material presentation and acceptance requirements before choosing a remedy. An extra operator would be a poor proposal if the limiting task could not safely be divided or its machine could not be duplicated. A faster attachment would need a trial showing that it preserves the specification. An operational diagnosis should precede the expenditure request.

This does not make idle time automatically desirable. GFT proposes classifying it by purpose and consequence. Waiting caused by missing material calls for investigation. Deliberate reserve capacity that helps recover a disrupted flow needs a different explanation. A station that completes the authorised requirement and then stops should not be rewarded for creating unwanted stock. Equally, reserve capacity should not become a convenient label for chronic missing orders or avoidable downtime. The governing question is what the resource contributes to the agreed delivery obligation.

MIT's capacity lecture warns that waiting time and capacity utilisation have a strongly nonlinear relationship in variable systems. This supports caution about scheduling every resource at its apparent maximum. It does not supply a transferable headroom percentage for a Cameroon sewing line. GFT recommends testing the actual variation in arrivals, operation times and interruptions before setting buffers or promised lead times. [S23]

For an illustrative review, compare matched production windows before and after an upstream speed change. Record accepted output, queue size at the suspected constraint, unfinished stock at the shift boundary and any quality holds. If the upstream counter rises but finished output does not, require an explanation before calling the trial successful. If finished output rises only because old WIP is consumed, extend the observation or explicitly account for that drawdown. A transient release of inventory should not be mistaken for a sustainable increase in production capability.

GFT also recommends keeping the worker's explanation within the evidence record. Ask what prevents the intended task from proceeding and whether the proposed method can be sustained within agreed working conditions. Do not infer a lack of effort from a queue or an idle machine. The purpose of observation is to distinguish an actionable restriction from an appearance. If the loss record cannot distinguish material waiting from machine repair, it cannot fairly assign responsibility or establish which intervention deserves a trial.

GFT recommends stating who may change release quantities during a trial. Otherwise, an apparent improvement in local utilisation could simply reflect a larger supply of unfinished work. Keep the authorised release, actual release and accepted completion in the same review record. If the team deliberately builds a protective buffer, state the operating purpose and the condition for drawing it down. Review its contents for material identity and quality status as well as quantity. A stockpile whose contents cannot be used by the constraint does not demonstrate protection of that constraint, whatever its physical size.

The same logic governs the boundary beyond sewing. A trial should state whether trimming, inspection, pressing and packing are included. A sponsor interested in dispatch should examine accepted dispatch-ready output as well as sewing completion. Where the proposed change ends upstream of that boundary, the trial report should say what remains untested. This is the operating meaning of placing the whole line above local busyness: success must survive the next required handover, rather than end at the counter most favourable to the proposal.

1.5

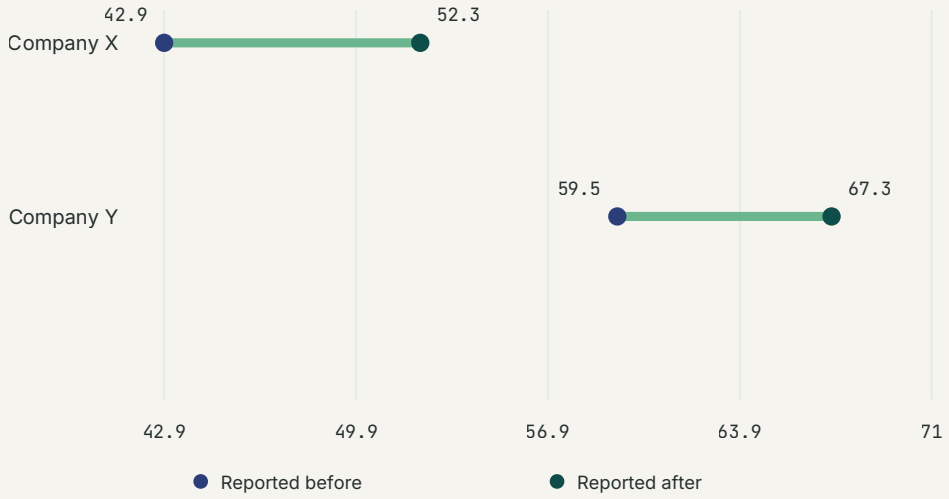
Case gains establish mechanisms, not universal targets

The opened Engineering Reports article, published on 26 July 2025, reports Company X's OEE increasing from 42.91 percent to 52.27 percent with process monitoring devices and digital line balancing. It also reports Company Y moving from 59.47 percent to 67.30 percent. The arithmetic changes are 9.36 and 7.83 percentage points respectively. These are the article's case findings, not GFT results, and they do not establish the effect of either intervention in isolation. [S09]

The paired comparison in **Exhibit 4**, p. 23 uses the same named measure on both rows. It shows the reported starting points and endpoints without applying them to another factory. The article demonstrates a relevant combination of monitoring and balancing. GFT's inference is that the combination deserves a locally designed test, not that a future line should inherit either endpoint as its financial-model assumption. [S09]

EXHIBIT 04 / OEE PERCENT

Reported OEE gains begin from different case baselines



SOURCED [S09] Engineering Reports, 26 July 2025: reported Company X 42.91 to 52.27 and Company Y 59.47 to 67.30. Combined monitoring and digital balancing case results. Neither endpoint is a GFT target or an independently isolated technology effect.

The ILO's article dated 1 June 2022 reports that Edget Garment improved line-balance efficiency from 24 percent to 75 percent and daily line production from 50 to 120 pieces following balancing work. The arithmetic changes are 51 percentage points and 70 pieces per day. This is a different measure and setting from the OEE cases. Neither the ratios nor the absolute levels should be combined into a common productivity benchmark. [S37]

The table in **Exhibit 5**, p. 23 therefore keeps the efficiency and output rows distinct, including their units. The ILO describes examination of cycle time, takt time and operator requirements before a new balance was implemented. That sequence provides a practical reason to test measured work allocation. It does not establish what a greenfield line in Cameroon will deliver, how much it should cost or how long its improvement will take. [S37]

EXHIBIT 05 / ROW-SPECIFIC UNITS

The Edget case reports different efficiency and output measures

Measure	Before	After
Line-balance efficiency (%)	24	75
Daily line output (pieces)	50	120

SOURCED [S37] ILO article, 1 June 2022, reporting Edget Garment in Ethiopia. Line-balance efficiency is not OEE. Daily output is a piece count, not a labour-normalised productivity ratio. The table reproduces case observations without extrapolation.

For GFT, the appraisal task is to convert a published mechanism into a testable local proposition. Specify the suspected loss, the operational change and the output expected to respond. If the proposal combines new data capture, supervisor practice

and task reassignment, record that package explicitly. Do not subsequently attribute all improvement to the software alone. A useful comparison preserves the production context closely enough for the result to inform the next decision, while disclosing changes that prevent a clean interpretation.

GFT recommends a trial record that includes style and method, skill coverage, attendance, input readiness, quality status, available services and the definition of accepted output. Agree what would count as a material adverse result before beginning. This includes deterioration in working conditions, an increase in unresolved defects or a shift of unfinished work into a later period. The record should retain a trial that fails. Its value is the avoided repetition of a poor intervention, not a presentationally attractive success rate.

The result should support a bounded decision. An effective trial can justify retaining a method under the tested conditions and planning a further test where conditions differ. It should not automatically justify expanding every line, replacing the factory's system or rewriting the entire production forecast. GFT recommends attaching the decision scope directly to the evidence: what the test established, what it did not test and what new condition would require a fresh check. This preserves useful case evidence without turning it into a promise.

1.6

GFT's position is to measure first and automate the decision second

GFT proposes carrying the performance-management remit of its Cameroon textile programme into a practical operating record: output, defects and downtime captured from the first production shift, with hourly review where it supports intervention. This is a recommendation for implementation, not a claim that a factory has already adopted the system or achieved a result. The record should connect an observed deviation to a named operating role, a chosen action and a later check at the accepted-output boundary.

Start with definitions that a supervisor and operator can use together. State what counts as completion, when a hold is released, which minutes belong to production and how overlapping stops are handled. Record unresolved causes as unresolved rather than force-fitting them into a convenient category. GFT recommends checking a sample of recorded events against the physical line before interpreting a trend. A missing event is a measurement problem; it should not silently become evidence that the corresponding loss did not occur.

> **GFT NOTE**
>
> Give every displayed measure an operating question, a boundary, an owner and a response. Start with a controlled manual record if it can answer those questions reliably. Automate capture when the additional timeliness or detail changes a decision and the underlying event can be reconciled to physical production. Release further spending against demonstrated decision value and accepted output, with working conditions retained as a constraint.

For the review itself, GFT recommends beginning with the gap between authorised output and accepted output. Ask which restriction explains it and whether the available observations support that explanation. Choose a corrective action proportionate to the evidence. Record who will act and how the next review will establish whether the restriction changed. Avoid declaring closure because a maintenance ticket was signed or a dashboard turned green. Closure belongs to the agreed operating consequence, which may require more observation.

An illustrative decision record could concern recurring material waiting ahead of the constraint. The proposed action might be a defined pre-shift readiness check and a controlled buffer of qualified components. The acceptance condition would concern sustained accepted output and absence of uncontrolled WIP growth, rather than faster material issue alone. If the same record instead shows a quality hold, the response should follow the defect mechanism. The data system earns its place by supporting the distinction and preserving the outcome of the action taken.

Automation should follow a written event contract. GFT proposes stating which physical event a sensor or operator entry represents, when it receives a timestamp and how an error can be corrected. A machine pulse should not become a good-garment count without a demonstrated connection to the relevant operation and acceptance event. Preserve manual reconciliation during the trial. If a network interruption occurs, distinguish missing telemetry from stopped production. The detailed governance and reference architecture sit elsewhere in the paper library; the operating requirement is interpretable evidence.

The paper record should remain usable when a shift changes. GFT proposes a short handover that separates unresolved production restrictions from unresolved measurement questions. A production restriction needs an operational owner; a measurement question needs a check before it becomes part of a performance conclusion. Carry forward the evidence and the next action, rather than only the latest percentage. When the team corrects an earlier count, preserve the correction and its reason. That makes the next shift's review a continuation of the same investigation and allows the sponsor to reconstruct how a claimed operating improvement was established.

Before accepting a claimed improvement, the sponsor should request a concise reconciliation: planned output, accepted output, key losses, unfinished stock movement and any deterioration in quality or working conditions. Compare like production boundaries and disclose changed assumptions. This chapter's illustrative arithmetic is a method demonstration and is not investment, legal or tax advice. A project decision

needs current, project-specific operating and commercial evidence. The remaining chapters develop the loss tree, work measurement, balancing, flow and investment controls needed to supply it.

Capacity becomes a business case when accepted output survives the whole line.

CHAPTER SOURCE NOTES

R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.

S04 MDPI, Applied Sciences. 2020-09-17.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S13 International Finance Corporation and International Labour Organization, Better Work. 2025.

S22 Massachusetts Institute of Technology, MIT OpenCourseWare. 2012.

S30 Lean Enterprise Institute. 2006-09-08.

S23 Massachusetts Institute of Technology, MIT OpenCourseWare. 2004.

S09 Wiley, Engineering Reports. 2025-07-26.

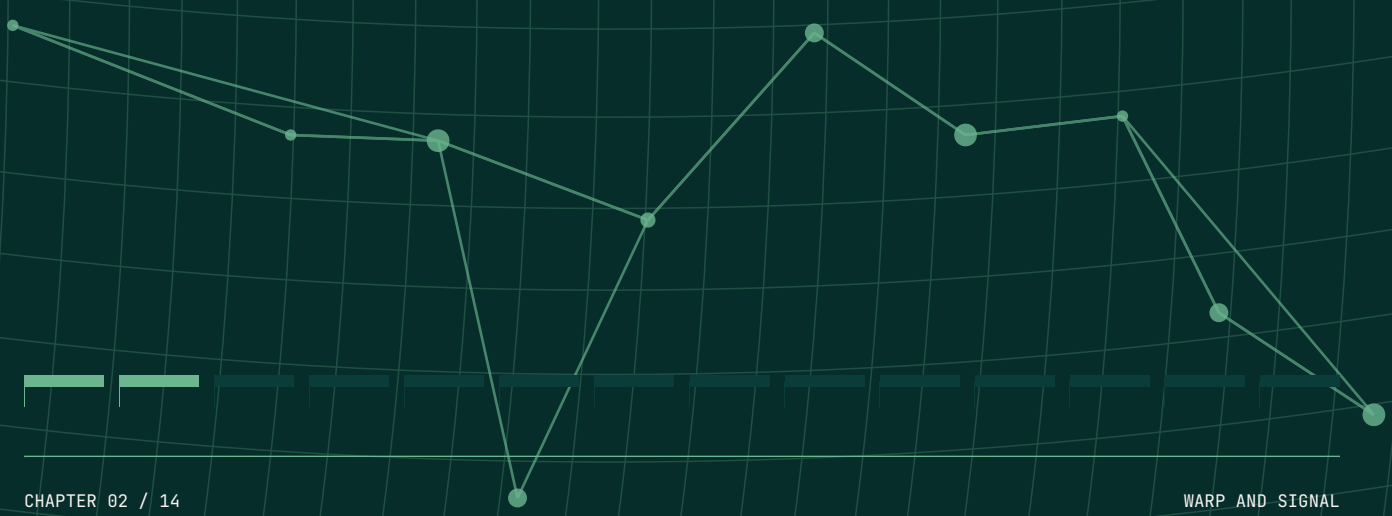
S37 International Labour Organization, SCORE and SIRAYE. 2022-06-01.

02

PART I: MEASURE THE FACTORY THAT ACTUALLY EXISTS / MEASUREMENT BEFORE TARGETS

OEE is useful only when it remains a loss tree

A single OEE score can start a conversation, but only its components and loss codes can tell a supervisor what to fix.



CHAPTER 02
DECISION TEST

A single OEE score can start a conversation, but only its components and loss codes can tell a supervisor what to fix.

OEE is useful when it explains where a declared production opportunity was lost and identifies an action that could recover good output. Its headline score is insufficient. GFT recommends retaining the underlying time records, output counts, component calculations and cause codes as a connected loss tree. The method below is a proposed operating protocol for a garment line, not an account of measured GFT factory results. It combines the familiar availability, performance and quality structure with explicit reconciliation and ownership rules. [S02]

2.1

The formula multiplies three different kinds of loss

The NIST maintenance report presents OEE as availability multiplied by performance rate and quality rate. Its definitions relate downtime to required availability, design cycle time and output to operating time, and quality defects to production input. These are different denominators, so the components cannot be added or averaged to obtain OEE. [S02] For this chapter, the practical question is whether the production records can explain every step from planned opportunity to accepted output.

GFT proposes a local notation before any dashboard is configured. Let T be planned production minutes, D be counted downtime minutes, R be running minutes after subtracting D, c be the approved ideal cycle in minutes per unit, N be total completed units and G be units accepted without rework at the declared checkpoint. These variables describe a single operation and a single product basis. They are not attended labour minutes, stitch counts or a sum of unrelated machine capacities.

> **METHOD**
>
> The chapter's proposed convention is A = R / T, P = c × N / R, Q = G / N, and OEE = A × P × Q = c × G / T. Use fractions in the multiplication and convert to percentages only for presentation. The cancellation assumes identical boundaries, a common unit and a fixed cycle basis across the component calculations. It does not establish that every published OEE calculation uses this convention. [S02] [S03]

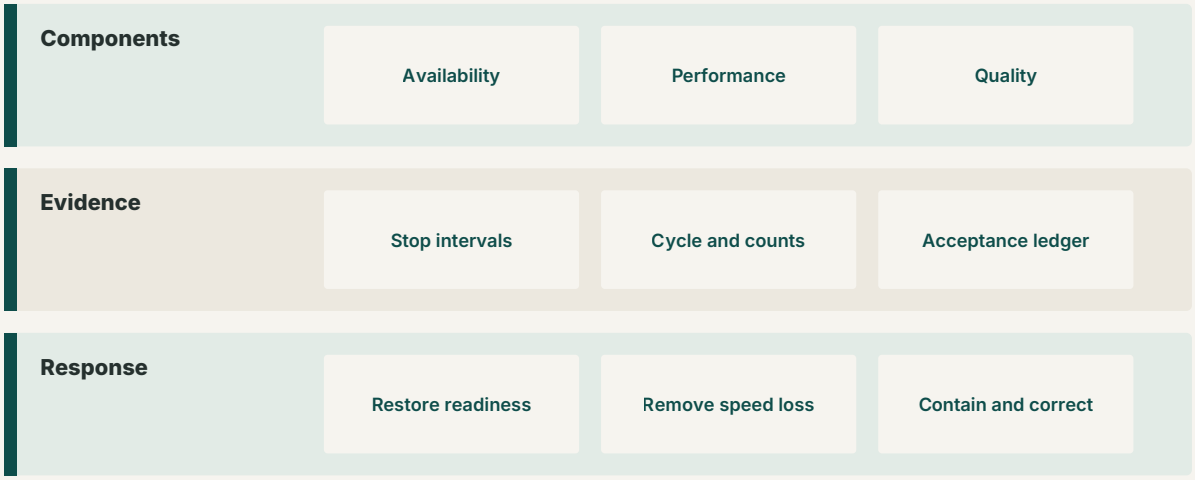
This convention makes an important distinction. The final ratio measures effective output against opportunity, while the components explain the route to that result. A low score alone cannot reveal whether the loss arose because the machine stopped, the operation ran slowly or completed work failed inspection. The loss tree therefore needs both a reconciled total and a credible allocation. Recalculating the total is an arithmetic check; validating the allocation requires observation.

For a proposed garment application, define the output event at an operation that produces a countable result, such as a completed seam operation or an inspected finished garment. Do not call a machine stitch a garment. For parallel machines, identify whether the denominator is machine minutes or elapsed line minutes. When the boundary is the whole line, use an approved line output model. Multiplying machine scores does not create a defensible line score because the same garment can pass through those machines.

The proposed architecture in **Exhibit 6**, p. 29 connects a component to its evidence and decision. It adapts NIST's loss categories into a supervisory method. The layer labels are recommendations, not a claim that GFT has implemented this design. [S02]

EXHIBIT 06 / PROPOSED DIAGNOSTIC STRUCTURE

Each OEE branch needs evidence and a response



ILLUSTRATIVE [S02] Illustrative GFT protocol adapted from the NIST maintenance report's loss categories. Layers connect metric, observation and action; no measured factory values are represented.

Read the architecture from the observation towards the decision as well as from the score downwards. A supervisor who sees a persistent speed residual should first ask whether counts, time and cycle basis agree. Only then should the residual become a work-method investigation. This order avoids presenting a calculation error as an operator problem. It also allows a paper log and a later digital system to use the same definitions.

Retain unavailable or invalid results explicitly. If planned time is absent, the OEE denominator is unresolved. If running time or completed output is absent, some components cannot be divided meaningfully. Report the observed stop and output state with the calculation limitation rather than allowing spreadsheet defaults to invent a result. The purpose is an inspectable account of production, including periods when the component calculation is not defined.

GFT proposes retaining a compact calculation packet for every reporting period. It should contain the approved schedule, the cycle-standard version, the event intervals, the completed-output ledger, the acceptance ledger and the calculation result. A reviewer should be able to reconstruct the score without interviewing its original author. A dashboard screenshot cannot replace this packet because it omits the assumptions that determine the result. Where records disagree, show the discrepancy before approving the period for comparison.

The packet should also distinguish machine time from human work. An operator may inspect, prepare or handle a component while the machine is not cycling. Under the proposed method, that observation prompts a check of the cycle boundary and work

content; it does not automatically become avoidable downtime. A machine signal needs an operational definition before it can describe a manual or mixed activity. This preserves the distinction between observing electrical activity and measuring effective production.

2.2

Availability losses extend beyond breakdowns

NIST's maintenance review includes equipment breakdown, setup and adjustment slowdowns, brief idling, reduced capacity, quality-related losses and start or restart losses in its discussion of total productive maintenance. The categories extend beyond equipment failure. [S02] GFT's proposed availability branch therefore separates the fact that production stopped from the question of which function could prevent that stop recurring.

For the proposed sewing-line log, use observable states before inferred causes. Record whether the station lacked power, lacked released material, awaited an attachment, underwent adjustment, awaited inspection clearance or suffered a mechanical fault. Keep an unresolved state available. Asking an operator to choose a definitive root cause during every interruption would turn uncertain observations into apparently certain maintenance statistics. A supervisor can refine a cause after investigation while preserving the original entry.

Allocate elapsed time only once within the declared station boundary. In an illustrative overlap, suppose material is unavailable for 20 minutes and a power interruption affects the same station during 8 of those minutes. The union is 20 lost minutes, not 28. Keep both conditions as tags, use a documented primary-state rule for the additive time ledger, and retain the overlap for investigation. The primary label is an accounting convention; it does not prove which intervention would recover production.

Separate restoration from administrative closure. GFT proposes that the stop ends when the station is capable of production under the declared rule, while the event remains open for cause investigation if necessary. A technician's arrival, completion of a repair and acceptance of a restart piece are different events. A time log should preserve their sequence where they affect the operating decision. Otherwise response delay can disappear inside repair time and restart losses can disappear inside a closed work order.

The responsibility table in **Exhibit 7**, p. 31 is an illustrative starting point. Its assignments follow the observed problem rather than the machine's location. Local management should adapt them to actual authority and escalation arrangements; the table does not establish a staffing requirement or a contractual allocation of fault.

EXHIBIT 07 / PROPOSED RESPONSE ASSIGNMENT

The observed loss determines the first response

Observed loss	First response	Check before closure
Mechanical stop	Maintenance	Stable restart
Setup delay	Industrial engineering	Approved first piece
No released input	Materials planning	Feed restored
Power interruption	Facilities	Safe supply restored
Slow cycle	Supervision	Method and cycle basis
Rejected output	Quality	Containment and cause

ILLUSTRATIVE [S02] Illustrative GFT response model informed by NIST loss categories. Roles describe responsibilities, not known GFT personnel. Ownership must be confirmed locally.

Closing an event should require evidence that the proposed response changed the relevant condition. For a material interruption, delivery of the correct released component is more useful evidence than a message saying that the store was contacted. For a mechanical interruption, a brief production check should accompany the repair record. A recurrence should link to the earlier event so that repeated temporary restoration remains visible as an unresolved cause.

Keep scheduled exclusions outside the tree only under a declared planning policy. GFT recommends freezing that policy before the reporting period and showing excluded time beside the OEE result. Reclassifying a difficult production interval afterwards changes the opportunity against which the factory is judged. The following chapter develops the broader time base; the requirement here is that every exclusion can be explained and reproduced from the original schedule.

At shift handover, GFT proposes transferring open events with their observed state, current response, outstanding verification and next decision owner. An interruption crossing the handover should remain a connected event even if its elapsed minutes are allocated between reporting periods. Starting a fresh event without a link would hide its total duration; leaving all time in the earlier shift would distort the later shift. The event identity and the period allocation serve different purposes and should both survive aggregation.

Use separate fields for immediate restoration and prevention of recurrence. Production can restart while a material-routing problem still awaits redesign. Conversely, an investigation can identify a credible cause while production remains stopped awaiting a part. Neither condition should be compressed into a single closed status. GFT recommends that the review ask whether production capability returned, whether the cause is established, and whether the preventive action has been checked under comparable work.

2.3

Performance losses include slow work and micro-stops

Research by Sonmez and colleagues explicitly identifies uncertainty in OEE components when production speeds and stoppage durations are captured manually or semi-automatically. Its abstract also discusses ignored minor stops, idling and speed losses. [S07] GFT's practical implication is to treat performance as a measured residual that needs investigation, rather than automatic proof of insufficient effort.

Under the proposed convention, running time still contains brief interruptions that the protocol leaves below the separately timed stop threshold. Performance compares the ideal time represented by completed work with that running interval. The threshold therefore changes the division between availability and performance. It should be selected for reliable observation and useful response, recorded in the protocol and kept stable through the comparison. It is not a device for improving either component.

Consider an illustrative operation with 450 planned minutes, 45 minutes of recorded downtime, 300 completed units and an assumed ideal cycle of 1 minute per unit. Running time is 405 minutes and ideal production time is 300 minutes. Performance is 300 / 405, approximately 74.07 per cent. Its residual is 105 minutes. That residual could contain brief stops, slow handling, count error or an unsuitable cycle assumption; the arithmetic alone cannot divide it among those explanations.

In the same illustrative case, assume observation identifies 15 minutes of brief stops within that residual. Moving those minutes into downtime gives running time of 390 minutes. Availability changes from 90.00 to approximately 86.67 per cent, while performance changes from approximately 74.07 to 76.92 per cent. Their product remains 300 / 450, approximately 66.67 per cent. A changed component score has not recovered any output. Preserve both the old and revised classification when definitions change.

Do not subtract the same brief stop twice. If it has already reduced the running-time denominator, it must not also be deducted as a separate performance-minute loss. Conversely, if it remains in running time, the performance residual already includes its effect. The event register may tag the interruption in either treatment, but the reconciliation must identify which branch carries its duration. The source log should be richer than the additive loss account without making the account non-additive.

GFT recommends an observation check before modifying the ideal cycle. Confirm the product, operation, machine, attachment, method and output unit. A cycle based on a different seam length or different handling requirement is a different comparison. An apparent result above the approved maximum should trigger a count, clock and standard review. Silently capping the result would hide the discrepancy; quietly loosening the standard would reward it. The next chapter treats the relationship with standard minutes in detail.

For the proposed capture method, make the threshold observable with the tools actually available. A rule requiring precise timing that a paper log cannot support will create apparent precision rather than better decisions. Trial the rule against direct observation and ask whether different observers classify the same event consistently.

If they do not, simplify the state definitions or improve capture before attaching consequences to the component score. The measurement-uncertainty research supports exposing these limitations rather than concealing them in a point estimate. [S07]

Treat missing short-stop causes differently from missing short-stop time. If output, cycle basis and running time are trustworthy, the performance residual can be calculated even while its causes remain unknown. If the clock or count is unreliable, the residual itself is uncertain. GFT recommends marking these situations separately: the first needs diagnostic observation, while the second needs record repair. Combining them in an uncoded loss bucket would obscure which kind of work could make the account more useful.

Use short observation samples to test the residual's composition, with their limits recorded. A sample of stable running does not establish how often interruptions occur across a shift. A sample taken during a difficult change does not describe normal method speed. GFT proposes retaining the observation conditions alongside the estimate and reporting an unresolved balance where the sample cannot explain all lost time. False precision in cause allocation is less useful than an honest residual with a named follow-up.

> **GFT NOTE**
>
> Keep the performance residual visible until the evidence explains it. Ask the line team to distinguish method, material, machine condition, counting and standard-setting questions before assigning a corrective action. Approve a definition change through the same review as a production change, and compare periods again on a common basis. A cleaner classification is valuable, but it must not be presented as recovered output.

2.4

Quality losses belong inside effective output

The apparel study by Koç and Eryürük describes quality as the share of defect-free units and discusses the contribution of fabric and stitching faults to rework and scrap. [S09] GFT proposes counting first-pass accepted output at a declared checkpoint for the loss tree. This preserves the difference between completing an operation and producing an acceptable result. Final disposition and recovered rework should remain visible in a companion quality ledger.

Define a completed unit before defining its acceptance. A unit can carry several defects while still being a single rejected completion. Counting defects as rejected units would confuse defect frequency with yield. Similarly, counting an item again every time it returns for repair would inflate total completions. The proposed rule is a unique first completion for the primary cohort, linked repair events for subsequent work and a final disposition that cannot erase the original first-pass failure.

The following illustrative worked example uses assumed inputs to reconcile the full tree. Its accepted units are first-pass good units at the operation checkpoint. All units have the same assumed cycle basis, the completed cohort has a known disposition, and there is no opening or closing inspection backlog. These restrictions make the arithmetic transparent; a live factory must account for departures from them.

WORKED EXAMPLE: THE LOSS ACCOUNT MUST CLOSE

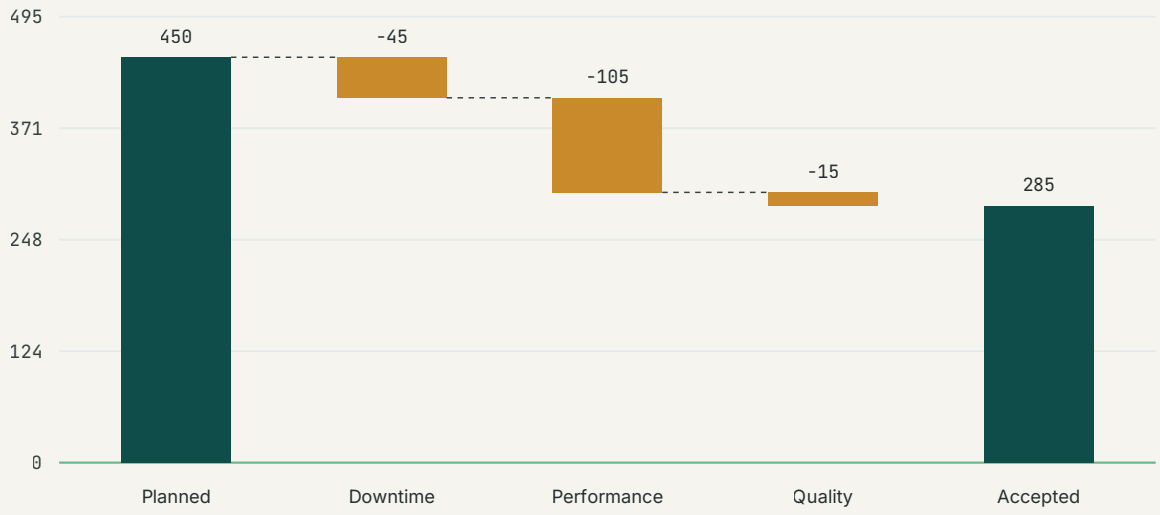
Assume, illustratively, planned production time of 450 minutes, downtime of 45 minutes, an ideal cycle of 1 minute per completed unit, 300 unique completed units and 285 accepted first-pass units. Availability is 405 / 450 = 90.00 per cent. Performance is 300 / 405, approximately 74.07 per cent. Quality is 285 / 300 = 95.00 per cent. Multiplying unrounded fractions gives OEE of 285 / 450, approximately 63.33 per cent, using the component structure in the NIST report. [S02]

The illustrative loss account starts with 450 planned minutes and deducts 45 downtime minutes, 105 performance-equivalent minutes and 15 quality-equivalent minutes. It closes at 285 accepted-output-equivalent minutes. The quality deduction is the assumed cycle multiplied by rejected first completions, not an observation that repairs took 15 minutes. Actual repair labour and elapsed repair time need separate records. No output, cost saving or GFT operating result is claimed.

The waterfall in **Exhibit 8**, p. 34 expresses that illustrative account on a common equivalent-time basis. Only the downtime segment is necessarily a directly timed interval. The other deductions translate output shortfalls into ideal-cycle minutes so that the tree reconciles without mixing physical minutes, pieces and defects.

EXHIBIT 08 / ILLUSTRATIVE IDEAL-CYCLE-EQUIVALENT MINUTES

A declared loss account closes at accepted output



ILLUSTRATIVE [S02] Illustrative assumed inputs: T=450 min, D=45 min, c=1 min/unit, N=300 units, G=285 first-pass units. R=405; performance loss=405-300=105; quality equivalent=1*(300-285)=15; accepted equivalent=285. Formula structure from S02. Assumed data are not factory observations.

For pending inspections, GFT recommends reporting a provisional output cohort with its unresolved quantity rather than treating uninspected units as accepted. When results arrive, update the cohort and retain the revision date. A shift-of-production view and a shift-of-inspection view answer different questions. Their reconciliation should explain why the acceptance record changed, especially when repairs or inspections cross a reporting boundary.

Acceptance criteria also need a stable version. GFT proposes recording the product specification and inspection rule used for the cohort, together with any authorised concession. A relaxed rule can raise accepted output without changing production capability. A stricter rule can lower apparent quality while revealing defects previously missed. Neither should be hidden inside an unexplained trend. Retain the original classification and disclose the rule change so that operating improvement and changed acceptance remain distinguishable.

Apply the same discipline to material downgraded for another use. The primary process should retain its original acceptance outcome, with the alternative disposition recorded separately. Otherwise a commercial recovery can erase the signal that the operation failed its intended requirement. This is a proposed measurement convention, not a valuation rule. Determining whether recovery has economic value requires actual saleability, costs and product restrictions, which the OEE quality component cannot establish by itself.

The proposed first-pass rule is deliberately conservative about recovered work. A repaired unit may become saleable, but the time and intervention consumed remain operationally relevant. Report recovered output separately and avoid charging the same repair twice in a combined economic account. If a repair uses the measured station during planned production, its time must enter that station's operating account consistently with the chosen completion rule. Quality detail and inspection deployment belong to the dedicated quality chapters and paper.

2.5

OEE values are not automatically comparable

The NIST standards-meeting report explicitly records multiple OEE definitions, interpretations and calculations. [S03] The ISO catalogue describes manufacturing KPIs through formulas, elements, time behaviour and units. [S01] Together these sources support disclosing the measurement protocol before comparing scores. They do not establish that a vendor dashboard and a factory spreadsheet become equivalent merely because both display the label OEE.

The protocol table in **Exhibit 9**, p. 36 is GFT's proposed disclosure minimum. It deliberately uses a table rather than numerical scoring: the questions are categorical and a plausible-looking coordinate would add no evidence. A comparison is usable when the records answer the same questions or can be recalculated onto a common basis.

EXHIBIT 09 / PROPOSED DISCLOSURE FIELDS

Comparison requires a shared measurement contract

Field	Disclose	Comparison risk
Boundary	Asset and checkpoint	Different operations
Time	Plan and exclusions	Shrinking denominator
Cycle	Unit, style, version	Changing standard
Waiting	Input and power rule	Hidden external loss
Brief stops	Capture threshold	Component migration
Quality	Rework and pending rule	Inflated good output

ILLUSTRATIVE [S01] [S03] [S07] Illustrative GFT comparison protocol informed by ISO's KPI description requirements, NIST's definition warning and measurement-uncertainty research. Fields are recommendations, not a claim of formal ISO conformity.

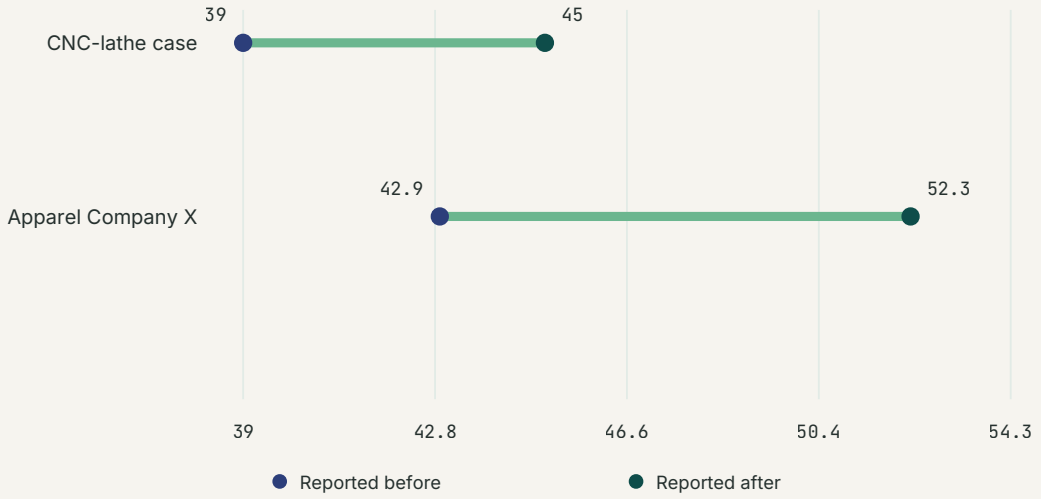
Aggregation also needs the underlying opportunity. For an illustrative pair of comparable shifts, assume accepted ideal-time equivalents of 225 and 90 minutes against planned times of 450 and 150 minutes. Their individual OEE results are 50 and 60 per cent. The pooled result is (225 + 90) / (450 + 150), or 52.5 per cent, rather than the unweighted average of 55 per cent. Both shifts must still share the same measurement meaning for that pooled result to be useful.

For mixed styles, GFT proposes calculating accepted ideal-time equivalents within each homogeneous operation and style segment, then retaining the segment denominators when aggregating. Piece counts should not conceal changes in work content. A revised cycle standard should have an effective date and a reason. Compare performance under a stable standard, or recalculate the earlier period where records permit. Without that bridge, report a break in the series rather than treating the difference as improvement.

Published cases are useful as bounded observations. NIST MEP reports OEE increasing from 39 to 45 per cent in a CNC-lathe maintenance case, while the apparel study reports Company X moving from 42.91 to 52.27 per cent with process monitoring and digital line balancing. These are different settings, measures and interventions. The paired endpoints in **Exhibit 10**, p. 37 preserve each report without ranking their effectiveness or proposing a common target. [S08] [S09]

EXHIBIT 10 / REPORTED OEE, PER CENT

Reported gains remain within their case boundaries



SOURCED [S08] [S09] S08: CNC-lathe TPM case, published 4 October 2022, page updated 11 April 2026. S09: apparel Company X, published 26 July 2025. Endpoints reproduce reports; methods and exposure differ. S09's displayed baseline components multiply to about 42.24%, not its reported 42.91%; see adjacent qualification. No pooled effect or GFT result is inferred.

The apparel source itself requires caution: its displayed baseline component rates for Company X are 73.04, 64.64 and 89.46 per cent. GFT's multiplication of those published inputs gives approximately 42.24 per cent, rather than the reported 42.91 per cent. The exhibit retains the reported headline; the discrepancy remains unresolved. It is not a rounding adjustment made by this chapter, and the published headline should not calibrate a factory model without reconciliation. [S09]

For a local improvement claim, GFT recommends preserving a comparable baseline, the intervention record and the post-change observation conditions. Disclose changed products, schedules, standards and inspection rules. Show component movements alongside accepted output and the relevant loss events. This establishes what the comparison permits without pretending that a before-and-after chart alone proves causation. A maintenance action and a simultaneous release-policy change cannot be separated by the headline score.

Before accepting a supplier's OEE comparison, GFT proposes asking for a worked reconciliation using a disclosed observation period. Request the included schedule, the stopped intervals, the cycle basis, the completion count and the acceptance count. If these cannot reproduce the displayed result, the score should remain unqualified for comparison. The request is a definition check, not a demand for confidential production detail: an anonymised or illustrative record can demonstrate how the calculation works without establishing an achieved factory result.

2.6

A low machine score can originate outside the machine

NIST's standards discussion recommends considering raw materials, supply chains, scheduling and other operational factors when designing manufacturing diagnostics. [S03] GFT applies that system perspective to the proposed loss tree. A machine can be capable of running while its production boundary records lost opportunity because suitable input never arrived. That distinction matters for action, even when the arithmetic properly includes the waiting interval.

Use an illustrative starvation scenario to separate measurement location from intervention location. Assume a station has 450 planned minutes but lacks released cut panels for 90 minutes. It then runs for 360 minutes at an assumed cycle of 1 minute per unit, completing 360 accepted units. Availability is 80 per cent, performance and quality are each 100 per cent, and OEE is 80 per cent. On these assumptions, a mechanical repair has no identified loss to remove; material release is the first investigation.

The same illustrative numbers could describe a station that was mechanically stopped for 90 minutes and otherwise ran perfectly. The component scores would be identical. The cause records distinguish the situations, and the investigation tests whether the proposed action can recover the affected interval. An OEE alert should therefore link to the event account, not directly generate a maintenance instruction from the score.

GFT recommends a practical diagnostic sequence. Verify the boundary and records, identify the largest credible loss, inspect the relevant production condition, assign an owner with authority over that condition, and define the observation that would demonstrate recovery. If the condition is unresolved or outside local authority, escalate it explicitly. Do not alter the metric to make the problem appear controllable by the person receiving the dashboard.

Prioritisation should also consider system effect. A station's lost opportunity does not automatically equal lost finished garments. For the proposed method, ask whether the interval constrained downstream accepted output or was absorbed by available stock and later recovery. Keep the station loss visible either way. This chapter does not calculate the line's constraint or optimal buffer; the subsequent balancing and flow chapters provide those decision methods. Here the essential safeguard is to avoid valuing every local minute as an identical shipment loss.

Design the review so that admitting uncertainty improves the record. GFT recommends showing uncoded time, unresolved inspections, corrected counts and cycle-standard exceptions alongside the components. A supervisor should be able to challenge a record before it becomes a target or personnel judgement. Preserve the original entry and the reason for correction. These controls turn the data trace into something the production team can inspect, rather than a separate narrative imposed after the shift.

Select corrective actions against the identified mechanism. For the proposed review, state which loss category should change, which underlying event should become less frequent or shorter, and which accepted-output observation should confirm the

effect. Also name a condition that would invalidate the claim, such as a changed product basis or unresolved inspection backlog. If the component improves while the underlying event persists, investigate reclassification before celebrating recovery. This makes the review useful even when an initial intervention fails.

For the GFT OEE and sewing-line simulator, the proposed interface should expose the same assumptions as the paper method. Show planned time, exclusions, downtime, cycle basis, completed output, first-pass acceptance and unresolved quantities before displaying the calculated score. Let a user inspect how a changed stop threshold redistributes components while holding output fixed. Let an input-starvation scenario carry a materials response. These are design recommendations; this chapter does not claim a tested or deployed simulator.

The managerial test is consequently practical: can the team move from a low component to a verified condition, a responsible response and a comparable output check? If it cannot, the score is still a signal requiring investigation. If it can, the loss tree has become an operating instrument. It preserves the production warp and the measurement weft together: the work creates the record, and the record points back to a change in the work.

A useful score keeps the path back to the loss.

CHAPTER SOURCE NOTES

S02 National Institute of Standards and Technology. 2018-04.

S03 National Institute of Standards and Technology. 2020-03.

S07 Springer, International Journal of Advanced Manufacturing Technology. 2017-10-12.

S09 Wiley, Engineering Reports. 2025-07-26.

S01 International Organization for Standardization. 2014-01.

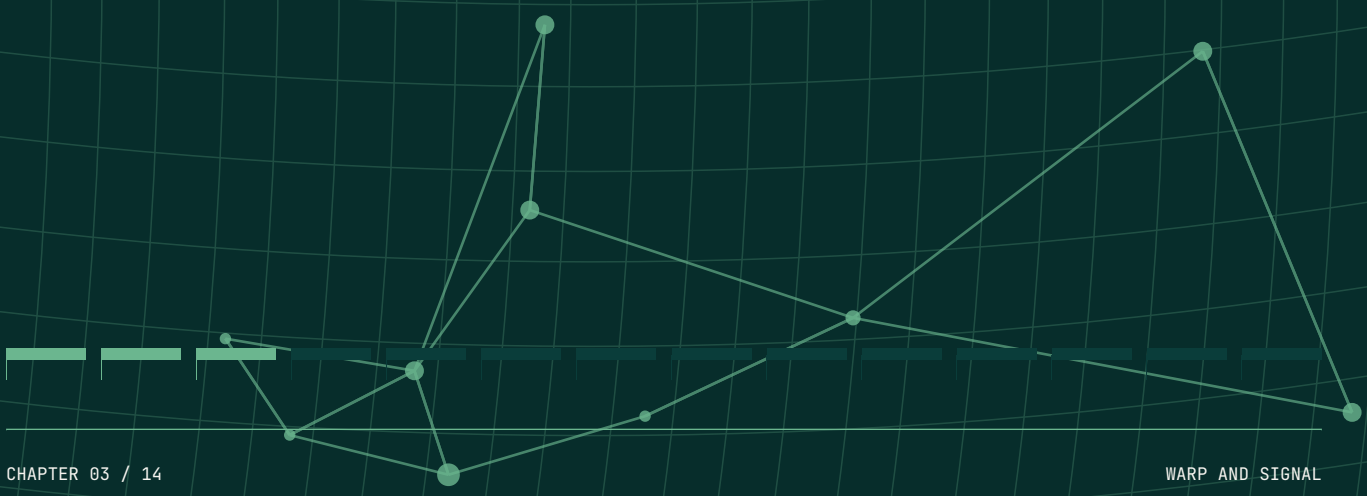
S08 NIST Manufacturing Extension Partnership. 2022-10-04.

03

PART I: MEASURE THE FACTORY THAT ACTUALLY EXISTS / AVAILABILITY IS CONSTRUCTED

The time base determines what utilisation means

A factory cannot interpret downtime until it has separated legal hours, planned production, external interruptions and losses inside the line.



CHAPTER 03
DECISION TEST

A factory cannot interpret downtime until it has separated legal hours, planned production, external interruptions and losses inside the line.

A garment factory cannot interpret an availability percentage or an Overall Equipment Effectiveness (OEE) score until it declares the clock from which its denominator is cut. [S01] Availability is the ratio of actual operating time to planned production time, yet two factories experiencing identical physical stoppages can report radically different availability scores simply by shifting the boundary between scheduled shift hours, planned exclusions and unplanned downtime. [S03] When a plant reclassifies power outages, material starvation, style changeovers or extended maintenance windows as "unscheduled time" rather than availability loss, the dashboard score rises while physical output stands still. [S05] In Cameroon, where reported capacity utilisation at incumbent textile plants ranged from 10.83 percent at CICAM 2 to 33.7 percent at Garoua and 48.9 percent at CICAM 1 in the July 2023 account, and where national policy seeks to lift local cotton processing from roughly 5 percent of fibre output to 50 percent by 2030, an elastic time base is a commercial hazard. [R06] [R07] [R12] Green Future Tech Limited (GFT) treats the time base as the first engineering assumption of any garment programme: before a sewing line selects target speeds or digital sensors, it must anchor available hours in statutory labour rules, separate calendar time into nested operational intervals, price external grid interruptions separately from internal breakdowns, bound changeover duration from last good piece to first approved piece, set an explicit recording threshold for short stops and bind every downtime code to a single accountable owner. [S01] [S02] [S33]

3.1

Available hours begin with lawful and humane scheduling

Capacity planning in labour-intensive sewing operations begins with the legal and physiological limits of the human workforce rather than the mechanical duty cycle of a lockstitch head. [S14] While a spinning frame may run continuously across twenty-four illustrative hours a day, a garment assembly line is an interdependent human-machine system requiring sustained visual focus, manual dexterity and postural stability. [S02] [S14] Treating the calendar week as an unconstrained reservoir of machine hours produces paper capacity models that fail through fatigue, absenteeism, rework and regulatory non-compliance. [S41]

3.2 STATUTORY LIMITS AND OVERTIME RULES BOUND THE WEEKLY DENOMINATOR

In Cameroon, the primary boundary on regular production time is established by Law No. 92/007 of 14 August 1992, the national Labour Code, which states that statutory hours of work in all public and private non-agricultural establishments may not exceed 40 hours per week. [S33] The inherited sector evidence register likewise records a standard 40-hour working week, a 48-hour maximum working week including authorised overtime, and an overtime wage premium starting at 1.2 times the regular hourly rate, alongside an informal employment share of roughly 90 percent and a statutory minimum wage (SMIG) raised from XAF 41,875 per month in 2023 to XAF 43,969 per month from 23 February 2024. [R14] [R16] This operational analysis is not legal or tax advice, and sponsors must obtain local legal counsel when structuring shift rosters and overtime authorisations. [S33] For the industrial engineer, the bound-

ary is clear: a single-shift garment plant must anchor its baseline capacity model on 40 regular hours per week (2,080 regular hours across a 52-week illustrative year before holidays), not on fifty-five or sixty weekly hours. [R16] [S33]

Embedding permanent overtime into the nominal capacity denominator inflates marginal unit labour cost by at least the 1.2 times statutory multiplier and removes the time buffer needed to absorb delayed fabric containers or utility outages. [R16] [S35] [S41] If the regular schedule already consumes the 48-hour weekly ceiling, the plant has no lawful reserve left to recover lost output without adding a second crew. [R16] [S33]

3.3 EXTENDED HOURS ERODE HOURLY EFFECTIVENESS AND MASK PLANNING DEFECTS

Even within legally authorised limits, extending the working day does not yield a linear increase in good garments. [S41] Research synthesised by the International Labour Organization (ILO) and International Finance Corporation (IFC) Better Work programme demonstrates that the extension of working hours does not in general yield proportionate increases in total output, and can even lead to an absolute reduction in total output over the long run. [S41] During the ninth and tenth hours of an illustrative extended shift, operator pace falls as muscular and visual fatigue increases stitch placement errors, needle breaks and thread breakages, creating rework that consumes regular production hours the next morning. [S04] [S09] [S41]

Chronic overtime also corrupts the diagnostic signal of the time base. [S03] When supervisors know that an evening extension is routinely approved whenever a line falls behind target, they face weak pressure to eliminate the morning stoppages that caused the shortfall. [S41] Holding the baseline schedule to the statutory 40-hour week forces losses into the open: if a line planned for 480 attended minutes across five eight-hour days fails to deliver its target output within regular hours, the variance is recorded as an availability, performance or quality loss demanding an engineering remedy. [R16] [S04] [S33]

3.4 SHIFT ARCHITECTURE SEPARATES CALENDAR PRESENCE FROM ATTENDED PRODUCTION

Constructing a clean time base requires codifying how weekly statutory hours are partitioned into daily shifts, meal breaks and rest allowances. [S01] In an illustrative single-shift plant operating five days per week for 8.0 paid hours per day inside an 8.5-hour presence window with an unpaid 30-minute meal break, the 1,440-minute calendar day splits into 930 unscheduled minutes, 30 meal-break minutes and 480 scheduled shift minutes. [S01] Deducting a 10-minute morning huddle and 20 minutes of scheduled operator rest and machine cleaning leaves 450 illustrative minutes of planned production time. [S01] [S26]

Keeping those boundaries aligned is essential because Standard Minute Value (SMV) labour efficiency compares earned standard minutes against attended labour minutes, whereas OEE availability compares operating time against planned production time. [S04] [S13] If industrial engineering calculates takt time on 480 minutes while the floor runs for 450 illustrative minutes after huddles and cleaning, the line will finish every shift 6.25 percent short of target even at 100 percent standard pace. [S01] [S13]

3.5

Planned production time must be distinguished from calendar time

ISO 22400-2 specifies that manufacturing KPIs must be presented by means of their formula, corresponding elements, time behaviour, unit or dimension and other boundary characteristics. [S01] Yet academic review of the ISO standard identifies two radically different versions of the OEE indicator with no explicit demonstration of their equivalence, while a National Institute of Standards and Technology (NIST) subcommittee report confirms that multiple definitions, interpretations and calculations of OEE coexist across industry. [S03] [S05] The primary source of divergence is the availability denominator: which non-operating intervals are deducted before planned production time is declared, and which remain inside the denominator as availability losses. [S04] [S05]

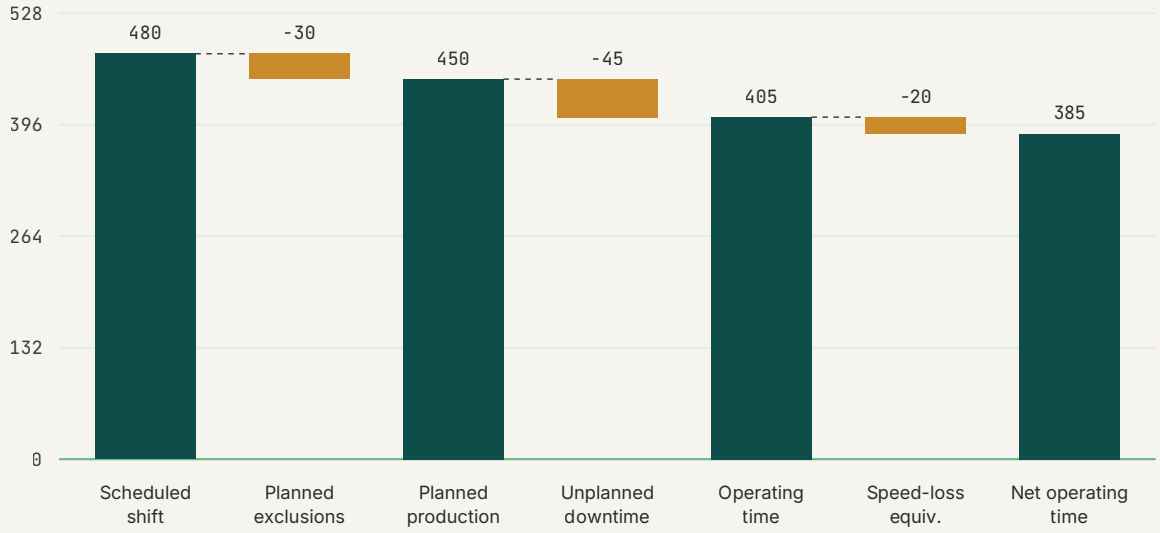
3.6 FIVE NESTED TIME INTERVALS GOVERN THE AVAILABILITY DENOMINATOR

To eliminate ambiguity between Total Effective Equipment Performance and shift OEE, GFT partitions the clock into five nested intervals, illustrated in **Exhibit 11**, p. 44: [S01] [S04]

- **Calendar time:** Total elapsed duration of the period (1,440 illustrative minutes per day). [S01]
- **Scheduled shift time:** Calendar time minus off-shift hours, weekends, holidays and unrostered stand-downs (480 illustrative minutes per shift). [S01] [S33]
- **Planned production time:** Scheduled shift time minus pre-declared, fixed-duration non-production intervals such as scheduled preventive maintenance, statutory rest breaks and shift-start huddles (450 illustrative minutes). [S01] [S04]
- **Actual operating time:** Planned production time minus all unplanned downtime losses, including breakdowns, adjustments, needle and thread stops above threshold, changeovers, material starvation and utility outages (405 illustrative minutes after 45 minutes of downtime). [S02] [S04]
- **Net operating time:** Operating time minus the time equivalent of speed losses and minor stoppages (385 illustrative minutes after 20 minutes of speed loss) before quality losses are deducted. [S02] [S04]

EXHIBIT 11 / MINUTES PER SHIFT

The OEE clock narrows from scheduled time to effective production



DERIVED [S01] [S04] Derived with illustrative shift inputs using the ISO 22400-2 time-element hierarchy (S01) and OEE loss structure (S04): 480 scheduled shift minutes less 30 minutes of planned non-production yields 450 minutes of planned production time; deducting 45 minutes of unplanned downtime yields 405 operating minutes (90.0% availability); deducting 20 minutes of speed-loss equivalent yields 385 net operating minutes before quality losses.

As **Exhibit 11**, p. 44 illustrates, each subtraction answers a different management question. [S01] [S04] Under those illustrative inputs, availability is calculated across the 450-minute planned production base: deducting 45 minutes of unplanned downtime leaves 405 operating minutes (90.0 percent availability), and subtracting 20 minutes of speed-loss equivalent yields 385 net operating minutes (95.06 percent performance) before quality losses. [S04] What **Exhibit 11**, p. 44 cannot establish on its own is whether the 30 illustrative minutes of planned exclusions were genuinely optimal; reclassifying routine changeovers or material waiting as "planned exclusions" inflates reported availability while actual operating minutes fall. [S03] [S05]

3.7 UNREPORTED EXCLUSIONS INFLATE AVAILABILITY WHILE SHRINKING REAL CAPACITY

Semiconductor and discrete manufacturing research demonstrates that OEE is distorted when equipment-independent conditions, such as lack of input items, are dropped from the clock or misattributed to the workstation. [S06] Pausing the OEE clock whenever a sewing line waits for cut panels or electricity measures machine reliability during isolated fragments of the day while fixed overheads, medium-voltage demand charges and operator wages accrue across the full shift. [R16] [S03] [S06] [S34] GFT therefore separates *commercial stand-downs* (no order scheduled and no crew rostered) from *operational interruptions* (a crew is rostered and paid, but halted by material, power, maintenance or changeover events). [S01] [S06]

> **WARNING**
>
> Excluding material starvation, quality holds, changeover overruns or grid outages from planned production time creates a false illusion of high availability while fixed labour and capital costs continue to accrue. Any hour for which operators are rostered and paid to produce must remain inside the planned production denominator; only pre-scheduled, fixed-duration breaks and unrostered shifts may be deducted above the line. [S01] [S06]

3.8 CROSS-FACTORY COMPARISONS FAIL WITHOUT A DECLARED CALENDAR PROTOCOL

External benchmarking across garment factories is hazardous unless the underlying time protocol is audited first. [S03] [S05] In the apparel literature, Company X reported a baseline OEE of 42.91 percent (73.04 percent availability, 64.64 percent performance and 89.46 percent quality) before rising to 52.27 percent with process monitoring and digital line balancing, while Company Y recorded a baseline OEE of 58.81 percent (83.39 percent availability, 71.66 percent performance and 98.42 percent quality). [S09] In a NIST Manufacturing Extension Partnership (MEP) case, OEE rose from 39 percent to 45 percent as lost capacity fell from 61 percent to 55 percent under Total Productive Maintenance (TPM). [S08] Comparing Company X's 73.04 percent availability, the NIST case's 39 percent OEE and CICAM's July 2023 capacity utilisation of 10.83 to 48.9 percent as one scale would misread all three, because corporate utilisation compares annual volume against nameplate capacity whereas shift OEE measures operating minutes against a specific planned shift denominator. [R12] [S08] [S09]

3.9

Power interruption is an availability loss with an external cause

In Cameroon and across much of sub-Saharan Africa, grid reliability is a primary determinant of manufacturing capacity utilisation. [S35] [S36] The IFC's Country Private Sector Diagnostic for Cameroon states directly that energy supply is limited and unreliable. [S35] If a garment factory's OEE protocol omits grid outages from its downtime log or lumps them into a generic "facility downtime" bucket alongside broken needles, management cannot price the capacity destroyed by utility interruptions or evaluate backup power investments. [S02] [S35]

3.10 GRID INSTABILITY IMPOSES DIRECT STOPPAGES AND HIDDEN RESTART PENALTIES

A World Bank Policy Research Working Paper analysing firm-level manufacturing data across 84 developing countries between 2006 and 2019 finds that power outages negatively and significantly affect firm-level revenue-based total factor productivity, with a 9 percent lower unconditional average productivity for outage-exposed firms compared with non-exposed firms. [S36] While that 9 percent gap is a multi-country average across 84 economies rather than a Cameroon-specific garment coefficient, World Bank Enterprise Survey indicators show how directly the mechanism applies in Cameroon. [S36] [S0301] As shown in **Exhibit 12**, p. 46, 93.3 percent of surveyed Cameroonian firms reported experiencing electrical outages in 2024 (following 92.5

percent in 2016 and 92.4 percent in 2009), and affected Cameroonian firms reported losing an average of 2.0 percent of annual sales to electrical outages in 2024 (compared with 5.0 percent in 2016 and 1.48 percent in 2009). [S0301] [S0302]

EXHIBIT 12 / PERCENT

Outages belong in the capacity model

-9.0%	93.3%	2.0%
TFP penalty in outage-exposed firms	**Cameroon firms experiencing outages**	**Sales lost by affected Cameroon firms**
Average revenue-based TFP gap across 84 countries, 2006 to 2019 (S36)	Surveyed Cameroon firms reporting outages in 2024 (S0301)	Reported sales value lost to outages in Cameroon in 2024 (S0302)

SOURCED [S36] [S0301] [S0302] Sourced from World Bank research and Enterprise Survey indicators: unconditional average revenue-based total factor productivity (TFP) gap for outage-exposed manufacturers across 84 developing countries, 2006 to 2019 (S36); share of surveyed Cameroon firms experiencing electrical outages in 2024 (S0301); and average value lost due to electrical outages as a share of sales for affected Cameroon firms in 2024 (S0302). Cross-country and sector-aggregate figures are context, not a single-factory garment forecast.

The indicators in **Exhibit 12**, p. 46 establish that power interruptions in Cameroon are a routine operating condition affecting more than nine out of ten surveyed enterprises, though they cannot by themselves predict the exact minutes a specific sewing line will lose without local logging. [S36] [S0301] [S0302] On a garment floor, an electrical interruption inflicts three distinct time losses within the TPM six-loss structure, which explicitly includes startup and restart losses alongside equipment breakdowns and quality losses: [S02]

1. **Direct blackout or transfer dead-time:** The elapsed minutes between the loss of utility voltage and the restoration of stable power from the public grid or standby generation. [S02] [S35]
2. **Process restart and thermal recovery time:** Even when backup generation restores voltage within two illustrative minutes, electrically heated steam boilers, fusing presses and automated cutting spreaders require recovery time to return to operating pressure and temperature. [S02]
3. **Abrupt-stop quality and rethreading loss:** When power cuts mid-seam across forty illustrative workstations simultaneously, servo motors halt without completing their thread-trim cycle and fusing belts can scorch trapped panels, generating rework and rethreading delays upon restart. [S02] [S04]

3.11 SEPARATE LOSS CODES DISTINGUISH UTILITY FAILURE FROM MECHANICAL BREAKDOWN

If a line supervisor records a 25-minute grid drop and subsequent boiler recovery under "machine downtime", the maintenance team's repair records are polluted by events that mechanics cannot prevent. [S02] Conversely, if the supervisor subtracts those 25 illustrative minutes from planned production time so that line availability still reads 95 percent, the executive team never sees the cumulative capacity cost of weak grid power. [S03] [S35] GFT resolves this conflict by keeping utility interruptions inside planned production time while isolating them in dedicated external-cause codes (`PWR-GRID` for unmitigated blackout minutes, `PWR-XFER` for generator transfer and `PWR-RSTR` for boiler and equipment restart), allowing the plant to track both *total line availability* and *internal mechanical availability*. [S01] [S02] [S06]

3.12 TARIFF STRUCTURE AND BACKUP GENERATION CONNECT DOWNTIME TO ENERGY ECONOMICS

Separating power-loss codes also provides the empirical inputs needed to size backup generation and manage electricity tariffs, connecting shop-floor OEE to the weak-grid engineering covered in paper wp07. [S34] [S35] In Cameroon, Decision No. 00000427 of the electricity sector regulator (ARSEL) dated 12 December 2022 establishes that medium-voltage (MT) electricity tariffs consist of two additive terms: a fixed monthly charge per kilowatt of subscribed demand and a variable charge per kilowatt-hour consumed across time-differentiated schedules. [S34] Meanwhile, guidance from the United Nations Industrial Development Organization (UNIDO) demonstrates that when a factory carries a large fixed energy base load, lower production volume causes energy intensity per unit to rise purely through the denominator effect, even when process equipment efficiency has not changed. [S44] Recording exact outage durations, transfer times and backup-generation running hours in the line's time base gives facilities engineers the duty-cycle ledger required to price backup power and tariff exposure accurately. [S34] [S35] [S44]

3.13

Changeover consumes capacity even when nothing is broken

A sewing line with reliable electricity and functioning machines still loses a large share of its planned production time whenever it switches garment styles, fabric weights or colourways. [S02] [S25] In NIST's TPM taxonomy, setup and adjustment slowdowns form the second of the six major equipment losses. [S02] As apparel buyers demand smaller order quantities and frequent style drops, treating changeover as "free time outside the OEE clock" causes saleable output to fall while reported operating efficiency appears unchanged. [S03] [S25]

3.14 STYLE TRANSITIONS RUN FROM THE LAST GOOD PIECE TO THE FIRST APPROVED PIECE

Defining changeover time as the brief interval when a mechanic swaps a presser foot or folder on one machine understates the true line loss. [S25] Across thirty or forty illustrative workstations, a changeover propagates from the first preparation station to final inspection. [S14] [S25] Lean methodology bounds changeover from completion of the last good piece of the outgoing style to completion of the first approved, defect-free piece of the incoming style at target rhythm, including line run-out, mechanical

and thread changes, and first-piece quality approval. [S02] [S25] Keeping that entire window inside planned production time makes setup loss visible inside availability and post-restart performance. [S02] [S04]

3.15 SEPARATING EXTERNAL PREPARATION FROM INTERNAL SETUP COMPRESSES STOPPED TIME

Retaining changeover inside the availability denominator creates a direct incentive to compress it using Single Minute Exchange of Die (SMED), which the Lean Enterprise Institute defines through the conceptual target of reducing changeover times to a single digit (under 10 minutes) by separating internal setup steps performed while stopped from external setup steps completed while the outgoing style is still running. [S25] In a cork-stopper manufacturing case study, applying SMED reduced total changeover time by 43 percent; while non-apparel in scope, this result evidences the mechanism of externalising setup preparation. [S25] [S45] On a sewing line, SMED means pre-calibrating spare heads, folders and bobbins on a mechanic's cart, staging cut bundles and operation-bulletin cards beside each station before run-out, and converting workstations in a rolling wave behind the final outgoing bundle. [S13] [S25] [S26]

3.16 POST-CHANGEOVER RAMP AND ADJUSTMENT BELONG IN THE LOSS ACCOUNTING

Even after the first piece of a new style passes inspection, a sewing line rarely jumps instantaneously to 100 percent of its steady-state standard pace. [S02] NIST's TPM framework explicitly names startup and restart losses alongside setup and adjustment slowdowns as distinct components of the six big losses. [S02] In apparel manufacturing, empirical data from Company X's sewing-floor monitoring confirm how heavily adjustment burdens weigh on downtime: across the monitored period, machine adjustment accounted for 3,694 minutes of recorded downtime, second only to technical malfunction at 4,923 minutes. [S09] GFT's time-base protocol therefore tracks both stopped changeover minutes (`CHG-STP`) and post-changeover hourly earned-minute ramp variance against standardised changeover sheets. [S02] [S13] [S26]

3.17

Small stops need explicit capture rules

While catastrophic breakdowns, power blackouts and full-line style changeovers are impossible to ignore, a sewing floor loses an equally damaging fraction of its capacity through hundreds of brief interruptions lasting between thirty seconds and five minutes, such as rethreading a snapped upper thread, replacing a burred needle or clearing a bobbin snarl. [S02] [S09] Because each individual event is short, manual paper logs routinely omit them, distorting how OEE availability and performance are reported. [S07]

3.18 RECORDING THRESHOLDS PREVENT SHORT INTERRUPTIONS FROM VANISHING INTO SPEED LOSS

In OEE theory, availability measures downtime losses from breakdowns and setups, whereas performance measures speed losses from reduced operating speed and minor stoppages. [S02] [S04] If a stop is not recorded in the downtime log, those lost minutes remain inside actual operating time, making availability look artificially high

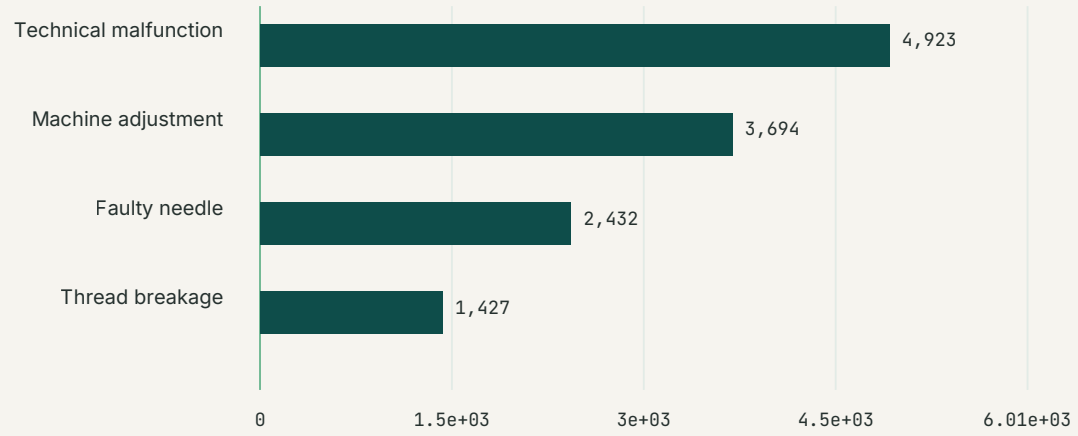
and performance look artificially low. [S04] [S09] Research in the *International Journal of Advanced Manufacturing Technology* highlights that components of OEE contain significant uncertainty under manual or semi-automatic measurement systems because observers record stoppage durations and speeds with variable precision. [S07] To eliminate observer bias, GFT's manual log protocol declares an explicit *minimum stop-recording threshold* of 2.0 illustrative minutes for discrete timestamped downtime entries, paired with mandatory tally marks for every needle change and thread break regardless of duration. [S07] [S09]

3.19 SEWING-FLOOR FAULT LOGS REVEAL ASYMMETRIC DOWNTIME ACROSS FAILURE MODES

When a garment factory enforces disciplined fault capture across its sewing lines, the resulting distribution of downtime provides a clear priority list for maintenance and industrial engineering. [S09] In the apparel OEE study of Company X, researchers deployed Process Monitoring Devices (PMDs) across sewing workstations to record the exact minutes lost to major operational faults. [S09] As shown in **Exhibit 13**, p. 49, technical malfunction consumed 4,923 minutes of downtime, machine adjustment consumed 3,694 minutes, faulty needles accounted for 2,432 minutes and thread breakage accounted for 1,427 minutes, totalling 12,476 minutes across those four categories. [S09]

EXHIBIT 13 / RECORDED DOWNTIME MINUTES

Sewing faults create unequal downtime burdens



SOURCED [S09] Sourced from Company X sewing-line monitoring in S09. Values show cumulative recorded downtime minutes by fault category during the baseline monitoring period (total 12,476 minutes across these four fault categories). Single-company empirical observation, not a universal industry benchmark.

The distribution in **Exhibit 13**, p. 49 shows that mechanical breakdowns (4,923 minutes, or 39.46 percent of the 12,476-minute total) and machine adjustments (3,694 minutes, or 29.61 percent) generated 69.07 percent of recorded fault time, while faulty needles (2,432 minutes, or 19.49 percent) and thread breakage (1,427 minutes, or 11.44 percent) still consumed 3,859 minutes (30.93 percent). [S09] Each bar points to a distinct countermeasure: preventive maintenance for malfunctions, SMED gauges for adjustments, needle-cooling and change policies for needle faults,

and cone tension checks for thread breaks. [S02] [S09] [S25] While bounded by Company X's internal monitoring scope (excluding grid outages or cutting delays), **Exhibit 13**, p. 49 proves the diagnostic value of categorised minute capture. [S06] [S09]

3.20 MANUAL TIMESTAMP DISCIPLINE PRECEDES EDGE-SENSOR AUTOMATION

While Company X used Process Monitoring Devices and paper wp18 details edge hardware, waiting for sensor deployment before fixing the time base reverses the proper engineering sequence. [S07] [S09] Without defined planned-time boundaries, stop thresholds and cause codes, motor sensors cannot distinguish a broken hook from bundle starvation or normal fabric-alignment pauses. [S07] [S14] GFT therefore starts every line with a manual supervisor log and workstation colour cards from the first shift, automating capture only after the definitions govern daily decisions. [S07] [S12]

METHOD

Time-base and availability reconciliation equations

For any declared shift or weekly reporting period, let all time elements be measured in minutes at a single workstation or at the governing line constraint: [S01] [S04]

1. **Scheduled shift time (T_{sched}):** $T_{\text{sched}} = T_{\text{cal}} - T_{\text{unsched}}$, where T_{cal} is calendar time and T_{unsched} comprises off-shift hours, weekends, public holidays and unrostered no-order stand-downs. [S01] [S33]
2. **Planned production time (T_{plan}):** $T_{\text{plan}} = T_{\text{sched}} - T_{\text{excl}}$, where T_{excl} comprises only pre-declared, fixed-duration non-production intervals within paid shift hours. [S01] [S04]
3. **Actual operating time (T_{op}):** $T_{\text{op}} = T_{\text{plan}} - \sum_{k} D_{k} = T_{\text{plan}} - (D_{\text{mech}} + D_{\text{adj}} + D_{\text{chg}} + D_{\text{mat}} + D_{\text{pwr}} + D_{\text{qual}} + D_{\text{abs}})$, summing all recorded downtime categories inside planned production time. [S02] [S04] [S06]
4. **Protocol-compliant availability (A_{tot}) versus internal mechanical availability (A_{mech}):**

$$A_{\text{tot}} = \frac{T_{\text{op}}}{T_{\text{plan}}}, \qquad A_{\text{mech}} = \frac{T_{\text{plan}} - \left(D_{\text{mech}} + D_{\text{adj}}\right)}{T_{\text{plan}}}$$ Reporting both ratios preserves total capacity truth via A_{tot} while isolating maintenance execution via A_{mech}, provided that $\sum D_{k} + T_{\text{op}} \equiv T_{\text{plan}}$ is verified at every shift close. [S01] [S02] [S06]

3.21

Downtime coding must point to an owner

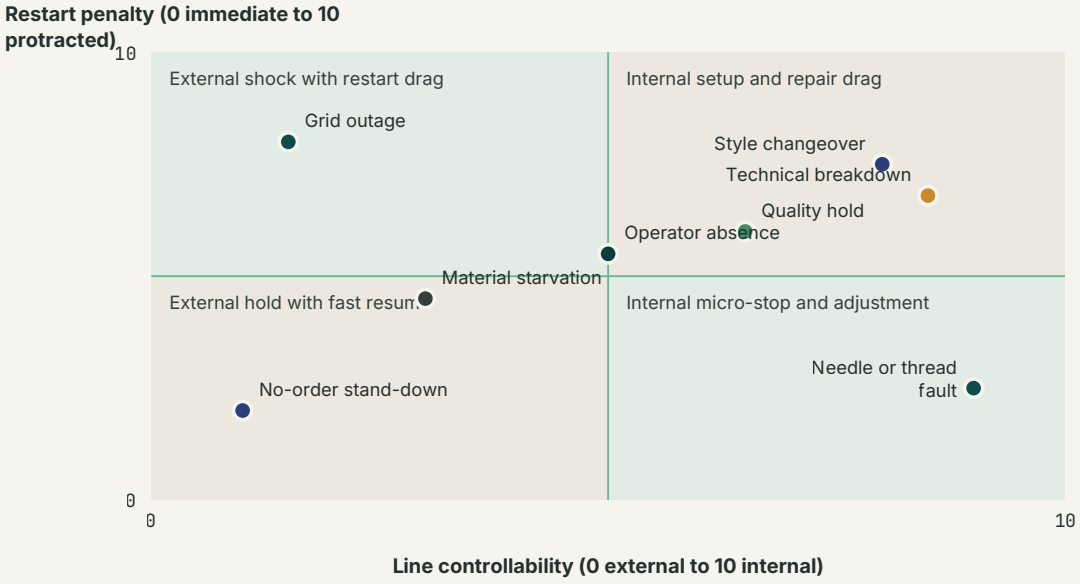
Capturing downtime minutes accurately improves factory economics only when each code triggers a specific corrective workflow. [S02] [S12] When a daily production report lists a single aggregate "Downtime" column, no single manager is accountable and the morning meeting degenerates into mutual blame among supervision, maintenance, cutting and stores. [S06] [S12]

3.22 AGGREGATE DOWNTIME CODES PARALYSE THE DAILY HUDDLE

The TPM loss framework separates equipment-related losses into six distinct mechanisms because different losses have different physical causes and owners, while semiconductor and line-flow studies show that equipment effectiveness logs must also separate equipment-independent starvation and external interruptions. [S02] [S06] To make this separation operational, **Exhibit 14**, p. 51 positions eight core garment-line interruption categories across two engineering dimensions: internal line and maintenance controllability (horizontal axis, from 0 external to 10 internal) and post-stop restart and ramp drag (vertical axis, from 0 immediate resume to 10 protracted recovery). [S02] [S06]

EXHIBIT 14 / ILLUSTRATIVE CONTROL AND RESTART SCORE (0 TO 10)

Loss codes separate internal failure from external interruption



ILLUSTRATIVE [S02] [S06] Illustrative diagnostic matrix applying the six-loss structure in S02 and the equipment-independent starvation distinction in S06. Horizontal axis scores internal line/maintenance controllability (0 fully external to 10 fully internal); vertical axis scores post-stop restart and ramp drag (0 immediate restart to 10 protracted thermal/line re-synchronisation). Scores are analytical placements for taxonomy design, not empirical measurements.

Inspecting the four quadrants of **Exhibit 14**, p. 51 clarifies why an undifferentiated downtime bucket fails: grid outages ($x=1.5, y=8.0$) originate externally but inflict severe boiler and mid-seam restart drag; style changeovers ($x=8.0, y=7.5$), technical breakdowns ($x=8.5, y=6.8$) and quality holds ($x=6.5, y=6.0$) are internally controllable and carry substantial post-stop adjustment tails; material starvation ($x=3.0, y=4.5$) and no-order stand-downs ($x=1.0, y=2.0$) originate upstream in cutting or commercial planning; and needle or thread faults ($x=9.0, y=2.5$) lie inside the workstation with rapid restart but high frequency. [S02] [S06] [S09] Because **Exhibit 14**, p. 51 is an illustrative taxonomy model, its coordinates define governance routing rather than fixed empirical ratios. [S02] [S06]

3.23 A STRUCTURED TAXONOMY ASSIGNS EVERY LOST MINUTE TO A RESPONSE OWNER

To turn **Exhibit 14**, p. 51 into daily governance, GFT binds each loss code to a boundary rule, a primary functional owner and a daily huddle action, as set out in **Exhibit 15**, p. 52. [S01] [S02] [S06]

EXHIBIT 15 /

Every downtime category requires a boundary rule and a response owner

Code	Loss category	OEE clock boundary	Primary owner	Daily huddle action
MCH-BRK	Technical malfunction	Inside planned time (availability loss)	Maintenance lead	Swap spare head if >15 min; log root cause and MTTR
MCH-ADJ	Machine adjustment	Inside planned time (availability loss)	Maintenance and IE	Check gauge setting, feed timing and operator method
CNS-NDL	Needle or thread fault	Inside planned time (>2 min) or tally	Line supervisor	Audit thread cone batch, needle point and tension
CHG-STP	Style changeover	Last good to first approved piece	Industrial engineering	Audit external SMED pre-staging and rolling wave
MAT-STR	Material starvation	Inside planned time (external to machine)	Cutting and stores lead	Verify 2-hour cut buffer and trim kit release before shift
QLT-HLD	Quality containment hold	Inside planned time (availability /quality)	Quality assurance lead	Contain defective bundle; run 5-Whys before restart
PWR-OUT	Grid outage and restart	Inside planned time (utility loss)	Facilities and energy lead	Log outage, transfer and boiler recovery minutes separately
SCH-STD	Unrostered no-order time	Excluded before planned production time	Commercial and planning	Reconcile weekly order book against rostered crew hours

ILLUSTRATIVE [S02] [S04] [S06] Illustrative GFT downtime coding protocol synthesising TPM loss categories (S02), OEE component boundaries (S04) and equipment-independent starvation separation (S06). Designed for manual clipboard capture in Phase 0 and edge-terminal capture in later phases.

In **Exhibit 15**, p. 52, only SCH-STD (unrostered no-order time declared before the shift roster is published) sits outside planned production time. [S01] Every other interruption occurs while a crew is rostered and paid, so every other code remains inside the planned production denominator, with spare-head swaps for MCH-BRK exceeding 15 illustrative minutes and upstream buffer audits for MAT-STR. [S01] [S02] [S06]

WORKED EXAMPLE

How denominator manipulation distorts availability and hides 165 illustrative lost minutes

Consider an illustrative 30-operator garment sewing line in Cameroon operating a single statutory 40-hour week across five shifts of 480 scheduled minutes per day (2,400 scheduled shift minutes per week), with 30 illustrative minutes per shift of pre-declared huddle and rest exclusions (150 minutes per week). [R16] [S01] [S33] During the week, the constraint workstation records 60 illustrative minutes of mechanical breakdown (MCH-BRK), 45 minutes of adjustments and needle/thread stops (MCH-ADJ/CNS-NDL), 75 minutes of style changeover (CHG-STP), 40 minutes of cutting starvation (MAT-STR), 50 minutes of grid blackout and boiler recovery (PWR-OUT), 198 minutes of speed-loss equivalent during running time, and 1,710 first-pass good garments out of 1,800 completed garments (95.00 percent quality). [S02] [S04]

- **Protocol A (shrinking the denominator):** The clerk deducts the 75 minutes of changeover, 40 minutes of starvation and 50 minutes of power loss (165 illustrative minutes) alongside the 150 minutes of planned breaks, shrinking reported planned production time to $2,400 - 315 = 2,085\text{ illustrative minutes}$ and counting only $60 + 45 = 105\text{ minutes}$ of downtime. [S03] [S05] Actual operating time is $2,085 - 105 = 1,980\text{ minutes}$, yielding a flattered availability of $1,980 / 2,085 = 94.96\text{ percent}$, performance of $1,782 / 1,980 = 90.00\text{ percent}$, quality of 95.00 percent, and reported OEE of $0.94964 \times 0.9000 \times 0.9500 = 81.20\text{ percent}$. [S04] [S05]
- **Protocol B (GFT declared time base):** Only the 150 pre-scheduled break minutes are deducted above the line, fixing planned production time at $2,400 - 150 = 2,250\text{ illustrative minutes}$ and total downtime at $105 + 165 = 270\text{ minutes}$ for the same 1,980 operating minutes. [S01] [S02] Total line availability is $1,980 / 2,250 = 88.00\text{ percent}$ (while internal mechanical availability is $2,145 / 2,250 = 95.33\text{ percent}$), yielding a true OEE of $0.8800 \times 0.9000 \times 0.9500 = 75.24\text{ percent}$ and exposing all 165 illustrative minutes of changeover, power and starvation losses for engineering action. [S02] [S04] [S06]

3.24 HOUR-BY-HOUR LINE BOARDS CONVERT TIME ACCOUNTING INTO SHIFT CONTROL

A time-base taxonomy only changes physical throughput when it operates at the rhythm of the shift rather than arriving in a month-end spreadsheet. [S12] In the ILO Factory Improvement Toolset applied in the Asian garment sector, combining operation bulletins, SMV measurement, line planning, hourly balancing and bottleneck management lifted sewing-room line achievement by 9.49 percent while reducing work in progress and defects per hundred units by 22 percent each. [S12] In GFT's Cameroon textile programme, the supervisor records good pieces, rework and coded downtime minutes (MCH-BRK, MCH-ADJ, CNS-NDL, CHG-STP, MAT-STR, QLT-HLD, PWR-OUT) on the line board at the close of every sixty-minute block so that mechanics and supervisors act on abnormalities in the next hour rather than the next week. [S02] [S12]

GFT NOTE

Lock the time-base protocol before buying sensors or setting bonus targets

In GFT's Cameroon textile programme, Phase 0 governance requires plant management, industrial engineering and maintenance to sign off a single two-page *Time-Base and Downtime Protocol* before the first shift begins: [S01] [S03]

1. **Fix the statutory calendar boundary:** Anchor single-shift planning on Cameroon's 40-hour statutory week, keeping overtime strictly separate as an exceptional costed variance. [R16] [S33]
2. **Freeze planned exclusions:** Limit planned exclusions inside paid shift hours to fixed, pre-declared intervals (such as 30 illustrative minutes per shift for huddles and rest), prohibiting retrospective deductions for starvation, changeovers or power cuts. [S01] [S06]
3. **Declare the stop threshold and eight-code taxonomy:** Log every stoppage of 2.0 illustrative minutes or longer using the eight owner-mapped codes in **Exhibit 15**, p. 52, while tallying sub-threshold needle and thread breaks on the station card. [S07] [S09]
4. **Reconcile the clock at every daily huddle:** Verify that operating minutes plus coded downtime minutes plus fixed planned exclusions equal scheduled shift minutes ($\sum D_k + T_{\text{op}} + T_{\text{excl}} = T_{\text{sched}}$) on every line board before reviewing SMV labour efficiency in Chapter 4 or weak-grid power mitigation in paper wp07. [S01] [S13] [S35]

Once the time base is locked, availability ceases to be a negotiable accounting ratio and becomes a physical audit of how the factory converts lawful working hours into active operating minutes. [S01] [S33] Connecting those active minutes to garment work content across styles of different complexity requires Standard Minute Values and operation bulletins, examined in the next chapter. [S04] [S13]

A factory that edits its clock to flatter its availability hides the exact minutes where its margin is leaking.

CHAPTER SOURCE NOTES

S01 International Organization for Standardization. 2014.

S03 National Institute of Standards and Technology. 2020.

S05 Elsevier, Computers and Industrial Engineering. 2020.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.

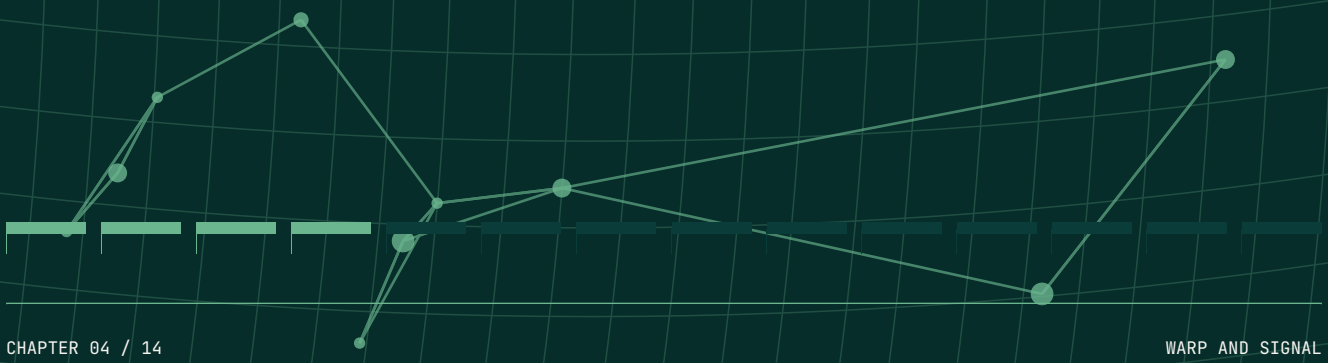
R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.
S02 National Institute of Standards and Technology. 2018.
S33 Republic of Cameroon, English text mirrored by Ministry of Commerce of China. 1992-08-14.
S14 Online Clothing Study. 2024-11-14.
S41 Better Work, International Labour Organization and International Finance Corporation. 2011.
R14 WageIndicator. Publication date unrecorded; inherited source-text check.
R16 WageIndicator. Publication date unrecorded; inherited source-text check.
S35 International Finance Corporation, World Bank Group. 2022.
S04 MDPI, Applied Sciences. 2020-09-17.
S09 Wiley, Engineering Reports. 2025-07-26.
S26 Lean Enterprise Institute. 2020-07-02.
S13 International Finance Corporation and International Labour Organization, Better Work. 2025.
S06 IEEE, IEEE Transactions on Semiconductor Manufacturing. 2005-02-28.
S34 Agence de Régulation du Secteur de l'Electricité, Republic of Cameroon. 2022-12-12.
S08 NIST Manufacturing Extension Partnership. 2022-10-04.
S36 World Bank, Development Research Group. 2023.
S0301 World Bank, World Development Indicators and Enterprise Surveys. 2026-10-08.
S0302 World Bank, World Development Indicators and Enterprise Surveys. 2026-10-08.
S44 United Nations Industrial Development Organization. 2015.
S25 Lean Enterprise Institute. 2020-07-02.
S45 Elsevier, Procedia Manufacturing. 2018.
S07 Springer, International Journal of Advanced Manufacturing Technology. 2017-10-12.
S12 International Labour Organization. 2023.

04

PART I: MEASURE THE FACTORY THAT ACTUALLY EXISTS / ONE OUTPUT LANGUAGE

Standard minutes connect machine effectiveness to sewing labour

SMV translates garment work content into earned minutes, but it must sit beside OEE and quality rather than replace them.



CHAPTER 04
DECISION TEST

SMV translates garment work content into earned minutes, but it must sit beside OEE and quality rather than replace them.

A garment factory cannot manage sewing capacity with machine counters alone, nor can it diagnose equipment and flow losses using payroll efficiency alone. [S04] [S13] Standard minute value (SMV), also called standard allowed minutes (SAM), converts physical garments into human work content by summing the standard time required for every operation in a style. [S13] [S0401] Yet when management replaces overall equipment effectiveness (OEE) with SMV-based line efficiency, or collapses the two into a single hybrid percentage, it loses the ability to separate a broken needle from an unbalanced workstation, a material shortage from a slow operator, or a power outage from a style-change delay. [S04] [S09] [S14] The operating rule for a sewing plant is architectural: use SMV to measure earned labour output across styles of unequal complexity, use the OEE loss tree to isolate availability, speed and defect losses at workstation and line boundaries, and require both measures to count only finished garments that pass quality inspection. [S04] [S09] [S13]

The stakes are immediate for industrial sponsors building or rehabilitating garment capacity in Cameroon. Sector records indicate that approximately 95 percent of Cameroon's cotton fibre is exported raw while roughly 5 percent is processed locally, against a national policy target of 50 percent local processing by 2030. [R06] [R07] Reported capacity utilisation across incumbent textile facilities in July 2023 ranged from 10.83 percent at CICAM 2 to 33.7 percent at Garoua and 48.9 percent at CICAM 1, with underutilisation estimated to have cost around CFAF 2 billion in 2020. [R12] Moving from raw-fibre export to competitive garment assembly requires factories that can quote, schedule and control diverse orders on the same sewing floor without losing visibility into where time goes. [S12] [S13] GFT's Cameroon textile programme (prepared 31 January 2024, with sources refreshed in 2026) treats utilisation and effective labour cost per good garment as the primary operational swing variables in factory feasibility, while separating that engineering analysis from investment, legal or tax advice. [R12] [R14]

This chapter establishes the calculation contract connecting machine effectiveness to sewing labour across four exhibits. First, **Exhibit 17**, p. 63 positions station OEE, SMV-based line efficiency and line-balance efficiency across their diagnostic dimensions. [S04] [S13] [S15] Second, **Exhibit 16**, p. 61 reconciles operation SMVs and earned standard minutes against attended labour minutes on a shift log. [S13] [S0402] Third, **Exhibit 18**, p. 65 uses published apparel-line baseline data to show how two factories lost effectiveness through different combinations of availability, performance and quality. [S09] Fourth, **Exhibit 19**, p. 67 defines the five recurring time standards in sewing-room engineering and specifies which substitutions are prohibited in GFT's data model. [S09] [S13] [S15] [S16]

4.1

Garment SMV is built from the operation breakdown

Every garment style entering a sewing room is a sequence of discrete physical transformations rather than a homogeneous unit of output. [S13] A basic knit shirt may require fewer than twenty assembly steps, whereas a tailored uniform shirt or trouser can require fifty to eighty operations across lockstitch, overlock, flatlock, buttonhole,

bar-tack and pressing stations (illustrative comparison). [S13] [S15] Because work content is governed by seam geometry, fabric handling and quality tolerances, industrial engineers decompose each garment into an ordered operation bulletin before production begins. [S12] [S13] In the Gender Equality and Returns (GEAR) assessment of Bangladesh garment factories by the International Finance Corporation (IFC) and the International Labour Organization (ILO), industrial engineers divide production of each style into sequential steps, determine the time required for a fully efficient operator to complete each step, and sum those values so that the garment SMV equals the total of the SMVs for all steps required to produce the garment. [S13]

4.2 THE OPERATION BULLETIN TURNS GARMENT CONSTRUCTION INTO MEASURABLE WORK ELEMENTS

An operation bulletin is the master engineering ledger linking product design to shop-floor capacity. [S12] [S13] In the ILO Factory Improvement Toolset (FIT) deployed across Asian garment enterprises, preparing an operation bulletin and monitoring SMV calculations are foundational sewing-floor modules used alongside bundle-system management and line balancing. [S12] To function as an auditable planning standard, each row of the bulletin specifies the operation code, seam and stitch specification, machine type, folders or guides attached, precedent operations, required operator skill grade, quality checkpoint criteria, basic time, allowance percentages by category, and resulting operation SMV. [S12] [S13] [S17] [S0401]

When any contextual field is omitted, the numerical SMV loses operational validity. [S26] [S0401] Standardized work provides a documented process for all shifts, reduces variability, eases operator training, lowers strain and creates the baseline for improvement activities. [S26] If an operation SMV of 0.65 minutes (illustrative) was established on a lockstitch machine with an edge-guide folder and automatic thread trimmer, moving that operation to a plain machine where the operator aligns plies by hand and trims thread with scissors invalidates the 0.65-minute standard. [S26] [S0401] Without a documented method boundary, the slowdown is misdiagnosed as poor operator pace rather than an unrecorded change in equipment configuration. [S07] [S26]

Operator skill assumptions are likewise embedded inside every operation standard. [S17] Research on garment assembly-line balancing with labour skill levels notes that worker performance on each task varies across a defined rating scale, such as from 0 for no skill to 1.5 for a fully skilled operator in published skill tables. [S17] Recording the bulletin SMV alongside achieved cycle time separates structural work content from temporary learning variance, a mechanism examined in Chapter 6. [S13] [S17]

4.3 BASIC TIME AND ALLOWANCES MUST BE RECORDED SEPARATELY BEFORE THEY BECOME A STANDARD

In garment work measurement, an operation SMV is never raw stopwatch time. [S0401] Whether derived from predetermined motion-time systems (where motions are measured in Time Measuring Units with 1 TMU equal to 0.0006 minutes) or from direct stopwatch time study, the calculation passes through two explicit stages: establishing basic time, and adding policy and technical allowances. [S0401]

In direct time study, an engineer observes a qualified operator over consecutive cycles, discards abnormal readings from external interruptions, and calculates mean observed cycle time from initial part pickup to the next part pickup. [S0401] The engin-

eer applies a performance rating factor so that basic time equals observed cycle time multiplied by the operator's performance rating. [S0401] In the published garment time-study method, an observed cycle time of 0.60 minutes at an 80 percent rating yields a basic time of 0.48 minutes, whereas a motion analysis totaling 400 TMU yields a basic time of 0.24 minutes. [S0401]

Basic time represents uninterrupted execution and cannot be sustained over a full shift without recovery, material handling and minor machine tending. [S0401] To convert basic time into Standard Allowed Minutes (SAM or SMV), the engineer adds allowances for bundle handling, machine contingencies and personal relaxation needs. [S0401] In the published SAM calculation example, adding a 10 percent bundle allowance (0.048 minutes) and a 20 percent machine and personal allowance (0.096 minutes) to a 0.48-minute basic time produces an operation SAM of 0.624 minutes. [S0401]

METHOD

Construction of operation SMV and garment SMV from time-study inputs

1. **System boundary and unit**: Standard minutes per good piece completed at the operation boundary (`min/piece`). [S13] [S0401]
2. **Observed cycle time (`T_obs`)**: Mean of valid consecutive cycles from pickup to next pickup under a documented layout and standard method. [S26] [S0401]
3. **Basic time (`T_basic`)**: Normalised time at reference pace, `T_basic = T_obs x (R / 100)`, where `R` is performance rating in percent (or `T_basic = TMU x 0.0006`). [S0401]
4. **Operation SMV (`SMV_i`)**: `SMV_i = T_basic,i x (1 + a_bundle + a_machine + a_personal)`, with each allowance fraction stored separately in the operation bulletin. [S0401]
5. **Garment SMV (`SMV_garment`)**: Total work content for the style, `SMV_garment = sum(SMV_i)` across all operations in the bulletin. [S13]
6. **Verification rule**: Neither rating `R` nor allowances may be altered to hit a commercial target price; changing `SMV_i` requires a documented change in method, attachment, bundle size or fabric. [S26] [S0401]

Preserving the separation between basic time and allowances is essential when connecting SMV to OEE. [S04] [S0401] Because an operation SMV already embeds a standard allowance for routine bobbin changes, bundle handling and personal recovery, logging those routine pauses a second time as availability downtime double-counts the loss and inflates operating performance. [S04] [S07] [S0401] Conversely, equipment breakdowns, material starvation, power outages and style changeovers fall outside the allowance envelope and belong in the availability loss tree described in Chapters 2 and 3. [S02] [S04] [S06]

4.4

Line efficiency uses earned minutes, not pieces alone

Once the operation bulletin establishes the garment SMV, the factory possesses a common unit of output across styles: the earned standard minute, also called produced minutes or output minutes. [S13] [S0402] In a commercial garment plant serving workwear, school uniform and retail orders, lines switch between styles whose work content differs by a factor of two to four (illustrative range). [S12] [S13] Evaluating a sewing line by daily piece count alone penalises lines assigned to complex garments and rewards lines running simple styles. [S13] [S0402]

4.5 EARNED STANDARD MINUTES ALLOW FAIR COMPARISON ACROSS STYLES OF UNEQUAL COMPLEXITY

SMV-based line efficiency resolves product-mix distortion by converting physical output into standard minutes accomplished and dividing by labour minutes invested. [S13] [S0402] In the IFC and ILO Better Work assessment of Bangladesh garment factories, daily output minutes equal style SMV multiplied by pieces completed on that day, and line efficiency equals output minutes divided by available labour minutes (workers involved in sewing multiplied by minutes the line operated). [S13] Across 159 production lines in 20 factories analysed in that study, daily line efficiency typically ranged between 45 and 70 percent, with a sample mean of 57.2 percent, showing that even established export lines operate well below 100 percent nominal efficiency because of bottlenecks, breakdowns, input shortages and supervisory variation. [S13]

The numerator of line efficiency is earned standard minutes: `Earned Minutes = Q_good x SMV_garment`, where `Q_good` is completed garments passing end-of-line quality verification. [S13] [S14] [S0402] In practitioner terminology, if a line completes 400 garments of a 25-minute SAM style, total minutes produced equal `400 x 25 = 10,000` standard minutes. [S0402] If the line shifts the next week to a 40-minute SAM garment and completes 250 good pieces in the same shift duration, piece output falls by 37.5 percent (from 400 to 250 pieces), but earned output remains `250 x 40 = 10,000` standard minutes. [S13] [S0402]

4.6 ATTENDED LABOUR MINUTES REQUIRE A DECLARED BOUNDARY FOR HELPERS, OFF-STANDARD WORK AND OVERTIME

Just as the numerator depends on an honest SMV and strict good-unit counting, the denominator depends on an explicit boundary for attended labour minutes. [S13] [S0402] [S0403] In the Better Work GEAR lexicon, available labour minutes equal actual manpower total (machine operators and line helpers present on that day) multiplied by operating hours multiplied by 60 minutes. [S13] Practitioner guides similarly define minutes attended as total manpower (operators plus helpers) multiplied by working hours multiplied by 60, and note that when whole shift hours are used in the denominator regardless of off-standard or idle time, the ratio yields overall line efficiency. [S0402] [S0403]

Two denominator manipulations distort reporting when rules are unwritten. [S03] [S0403] First, excluding sewing helpers, bundle handlers and inline trimmers from headcount while still crediting the SMVs of the manual tasks they perform shrinks attended

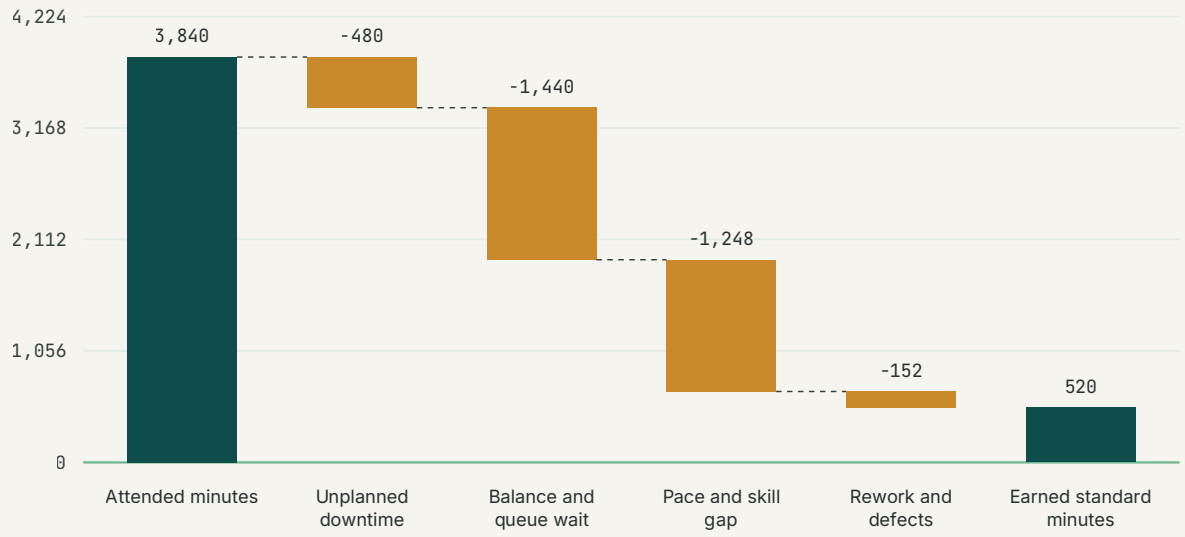
minutes and overstates line efficiency. [S13] [S0402] Every worker whose tasks are included in the operation bulletin SMV must have their attended minutes included in the line's denominator. [S13] [S0402]

Second, undeclared overtime distorts both efficiency and unit cost. [R16] [S14] [S0403] In Cameroon, the statutory working week for non-agricultural establishments is 40 hours, with a 48-hour maximum and overtime compensated at 1.2 times the ordinary rate under the applicable labour rules in the shared register, while the statutory minimum wage (SMIG) was raised to XAF 43,969 per month from 23 February 2024 (up 5 percent from XAF 41,875 in 2023). [R14] [R16] If a line runs two hours of overtime to meet a shipment target but leaves the denominator fixed at a standard 480-minute shift per operator instead of 600 attended minutes, reported efficiency is inflated by 25 percent while unit labour cost rises under the 1.2x overtime premium. [R16] [S14] [S0403]

Exhibit 16, p. 61 illustrates how earned standard minutes reconcile against attended labour minutes on an eight-operator cell. Using the SMV and efficiency structure in the Better Work assessment, a three-operation subassembly has individual operation SMVs of 0.8, 1.2 and 0.6 minutes, summing to 2.6 standard minutes per piece. [S13] Completing 200 good pieces generates `200 x 2.6 = 520` earned standard minutes against `8 x 480 = 3,840` attended minutes, yielding an SMV-based line efficiency of `520 / 3,840 = 13.54` percent. [S13] [S0402]

EXHIBIT 16 / LABOUR MINUTES PER SHIFT

Earned minutes reconcile output to attended labour



DERIVED [S13] [S0402] Derived with illustrative inputs using the SMV and efficiency formulas in S13 and S0402: operation SMVs of 0.8 + 1.2 + 0.6 = 2.6 minutes; 200 good pieces earn 520 standard minutes; 8 operators x 480 minutes = 3,840 attended minutes (13.54 percent efficiency). Intermediate loss buckets are illustrative allocations of the 3,320 unrecovered minutes.

As **Exhibit 16**, p. 61 makes visible, the 13.54 percent efficiency figure shows that 3,320 of the 3,840 attended labour minutes did not convert into good standard minutes (an 86.46 percent capacity loss in this illustrative scenario). [S13] [S0402] Yet the 13.54 percent ratio alone cannot prove how much of that 3,320-minute gap came

from unplanned downtime (480 minutes), line imbalance and waiting (1,440 minutes), pace and skill ramp (1,248 minutes) or rework and scrap (152 minutes). [S04] [S13] [S15] Partitioning those intermediate bars requires pairing SMV accounting with OEE capture. [S04] [S09]

WORKED EXAMPLE

Comparing a multi-style shift by piece count versus earned standard minutes

Consider two sewing lines in a Cameroon garment plant during a 480-minute shift, each with 25 attended workers (12,000 attended minutes) and an illustrative daily wage of XAF 2,000 per worker-shift (above the February 2024 statutory SMIG floor of XAF 43,969 per month in R14). [R14] [S13] [S0402]

- **Line A (Basic T-shirt)**: 14 operations, SMV = 6.0 minutes (illustrative); 1,050 started, 50 defective, Q_good = 1,000 first-pass good pieces. [S04] [S13] [S14]
- **Line B (Workwear shirt)**: 38 operations, SMV = 18.0 minutes (illustrative); 460 started, 10 defective, Q_good = 450 first-pass good pieces. [S04] [S13] [S14]

By raw piece count, Line A appears more than twice as productive (1,000 versus 450 pieces) with lower labour cost per piece (XAF 50,000 shift wage divided by 1,000 pieces equals XAF 50.00 on Line A, versus XAF 111.11 on Line B, illustrative). [S13] [S0402] Converting into earned standard minutes reverses the diagnosis: [S13] [S0402]

- **Line A**: 1,000 x 6.0 = 6,000 earned minutes (50.0% efficiency; XAF 8.33 per earned minute, illustrative). [S13] [S0402]
- **Line B**: 450 x 18.0 = 8,100 earned minutes (67.5% efficiency; XAF 6.17 per earned minute, illustrative). [S13] [S0402]

Line B converts attended labour into saleable work content 35 percent more effectively (67.5 percent versus 50.0 percent) with higher first-pass quality (97.83% versus 95.24%, illustrative). [S04] [S13]

4.7

OEE and line efficiency must not be conflated

Because OEE and SMV-based line efficiency are both expressed as percentages between 0 and 100, factory reports often treat them as interchangeable. [S03] [S14] Overall equipment effectiveness is a multiplicative loss tree (OEE = Availability x Performance x Quality) decomposing planned production time into downtime, speed and defect losses. [S01] [S04] SMV-based line efficiency is a ratio of standard work content earned to human labour time attended. [S13] [S0402] Line-balance efficiency compares total garment work content across stations against the product of workstations and the governing cycle or pitch time. [S15] [S16]

4.8 CANCELLING INTERMEDIATE TERMS IN A SIMPLIFIED FORMULA DESTROYS DIAGNOSTIC VISIBILITY

The temptation to collapse OEE into SMV-based line efficiency appears in garment practitioner literature. [S14] A cited garment OEE tutorial defines line availability as Hours Worked / Planned Hours, line performance as (Line Output x Garment SMV) / (Hours Worked x 60), and line quality as (Line Output - Defective Units) / Line Output. [S14] For a 30-machine line working an 8-hour shift (240

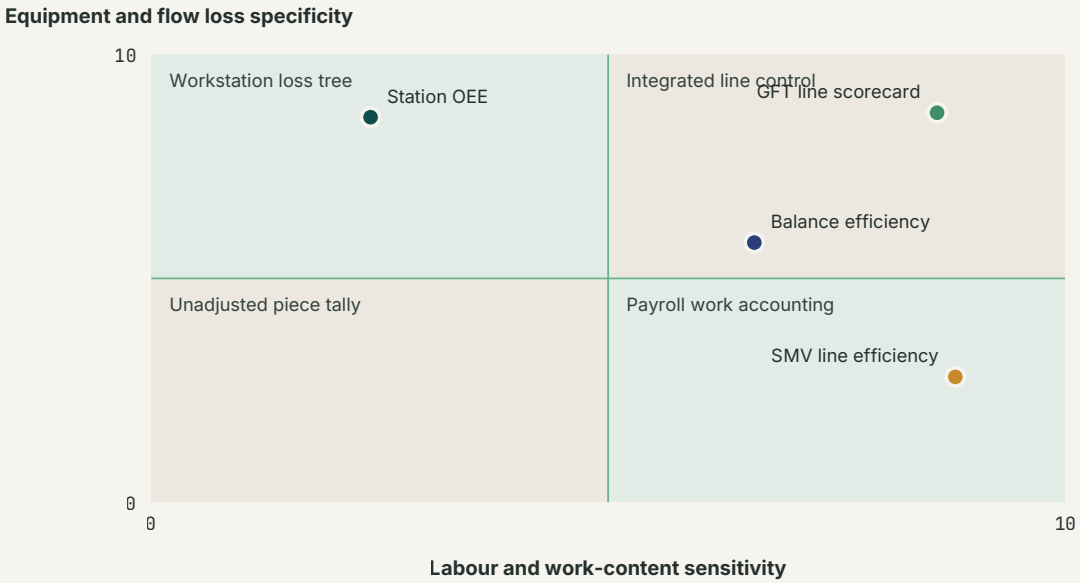
planned machine-hours) with 20 hours of downtime (220 hours worked), producing 400 pieces of a 30-minute SAM style (200 standard hours produced) with 15 defective pieces (385 good pieces), the tutorial computes availability = 0.9166, performance = 0.9090, and quality = 0.9625, multiplying to 80.19 percent. [S14]

The tutorial then cancels the intermediate terms algebraically to avoid double data entry: Simplified Ratio = ((Line Output - Defective Units) x Style SMV) / (Planned Hours x 60). [S14] When Hours Worked and Line Output are cancelled, the remaining expression is simply good earned standard minutes divided by planned operator minutes: it is overall SMV-based line efficiency on good output, not an OEE loss tree. [S04] [S13] [S14] [S0403] A factory that adopts this shortcut stops recording downtime hours and total starts. [S07] [S14] When the score drops from 80.19 percent to 55.00 percent on the next shift (illustrative), management has no evidence to tell whether machines broke down, operators waited for cut panels, a seam slowed sewing pace, or a bad thread cone caused defects. [S02] [S04] [S14]

Exhibit 17, p. 63 maps Station OEE, Balance Efficiency, SMV Line Efficiency and an Integrated Line Scorecard across two axes: sensitivity to garment work content and labour attendance on the horizontal axis, and specificity to workstation availability, speed and quality losses on the vertical axis. [S04] [S13] [S15]

EXHIBIT 17 / ILLUSTRATIVE INDEX (0 TO 10)

Three efficiency measures answer three distinct questions



ILLUSTRATIVE [S04] [S13] [S15] Illustrative diagnostic mapping derived from the definitions in S04 (OEE loss tree), S13 (SMV-based line efficiency) and S15 (assembly-line balance efficiency). Coordinates on the 0 to 10 scale represent analytical coverage of labour content versus equipment loss specificity, not empirical factory measurements.

While **Exhibit 17**, p. 63 illustrates the conceptual trade-off, its illustrative coordinates cannot substitute for calculating all three indicators from shift logs. [S01] [S03] The mathematical contract for each measure is summarised below. [S01] [S04] [S13] [S15]

Measure	Numerator	Denominator	Unit	Decision owner and question answered
OEE	Good units x ideal cycle (A x P x Q) [S04] [S09]	Planned time at station or constraint [S01] [S04]	% [S01] [S04]	Maintenance, quality, supervision: which downtime, speed or defect loss restricts capacity? [S02] [S04]
SMV line efficiency	Good garments x style SMV (sum(SMV_i)) [S13] [S0402]	Attended labour minutes (operators + helpers) [S13] [S0402]	% [S13] [S0402]	Production and costing: how effectively did attended labour convert into standard work content? [S13] [S0403]
Balance efficiency	Sum of operation times (sum(t_i)) [S15]	Workstations x bottleneck time (K x C_max) [S15] [S16]	% [S15]	Industrial engineering: how evenly is work content distributed relative to the bottleneck? [S15] [S16]

4.9 BALANCE EFFICIENCY, LABOUR EFFICIENCY AND STATION OEE DIVERGE UNDER STARVATION AND UNEVEN LOADS

Understanding why these three indicators diverge prevents misdirected engineering effort. [S06] [S15] In a published trouser assembly-line study using ranked positional weight, the initial line had 61 workstations and a balance efficiency of 35.66 percent; unconstrained balancing reduced theoretical stations to 27 at 80.56 percent efficiency, while imposing real machine and resource constraints yielded 39 workstations at 55.77 percent efficiency. [S15] If those 39 operators experience a two-hour power outage, structural balance efficiency remains 55.77 percent, but actual SMV-based labour efficiency and line OEE plunge because attended minutes accumulate while output stands still. [S06] [S13] [S15]

Conversely, high local performance at non-constraint stations often coexists with low balance efficiency and downstream starvation. [S06] [S15] Manufacturing systems research notes that workstation OEE is affected by equipment-independent conditions such as lack of input items (starvation) or downstream blockage. [S06] When upstream stations have shorter SMVs than the collar-attach bottleneck, upstream operators build work in progress ahead of the bottleneck while downstream stations sit starved of panels, recording low availability and low OEE despite sound machines. [S06] [S15] [S16]

Empirical evidence from the apparel industry confirms that different factories lose OEE through different combinations of availability, performance and quality. [S09] In the 2025 study by Koc and Eryuruk examining OEE in the apparel industry, baseline measurements were captured across sewing lines in two firms, Company X and Company Y. [S09] **Exhibit 18**, p. 65 plots the baseline percentages reported for both companies. [S09]

EXHIBIT 18 / PERCENT

Two apparel companies lost effectiveness through different components



SOURCED [S09] Sourced baseline OEE component values reported for Company X and Company Y sewing lines in S09. Company X baseline OEE was 42.91 percent; Company Y baseline OEE was 58.81 percent (0.8339 × 0.7166 × 0.9842). These are case-specific baselines, not universal sector norms.

The component separation in **Exhibit 18**, p. 65 shows why a single composite percentage is insufficient. [S04] [S09] Company X recorded baseline availability of 73.04 percent, performance of 64.64 percent and quality of 89.46 percent (composite OEE of 42.91 percent), suffering a 10.54 percent defect penalty (where lockstitch repair and stain accounted for 54.77 percent of defects and the top five defect categories accounted for 87.56 percent) alongside 4,923 minutes of technical malfunction, 3,694 minutes of machine adjustment, 2,432 minutes of faulty needle stops and 1,427 minutes of thread breakage. [S09] Company Y recorded availability of 83.39 percent, performance of 71.66 percent and quality of 98.42 percent (composite OEE of 58.81 percent), meaning its primary loss sat in performance (a 28.34 percent speed and minor-stoppage gap). [S09] Lean and digital interventions subsequently lifted Company X's OEE from 42.91 percent to 52.27 percent. [S09] However, **Exhibit 18**, p. 65 cannot serve as a universal benchmark target for Cameroon factories, because product mix, machine age and grid stability differ across contexts. [S03] [S09]

4.10

Performance needs an ideal-cycle basis

Of the three OEE components, performance is the most vulnerable to definitional drift in a sewing plant. [S03] [S05] [S09] Availability compares operating time against planned production time, and quality compares good units against total units checked. [S04] [S09] Performance compares actual output achieved during operating time against theoretical output at an ideal cycle time: `Performance = (Actual Output x Ideal Cycle Time) / Operating Time`. [S04] [S09] In a manual sewing operation where an operator guides pliable fabric panels under a needle foot, selecting the right reference cycle is critical. [S07] [S09] [S14]

4.11 MACHINE CYCLE, OBSERVED OPERATOR CYCLE AND SMV MEASURE DIFFERENT PHYSICAL BOUNDARIES

Three operation-level time concepts compete for the role of reference cycle in a sewing room: pure machine cycle, observed operator cycle (`T_obs`), and operation SMV (`SMV_i` or basic time `T_basic,i`). [S09] [S13] [S15] [S0401] 1. **Machine cycle vs basic cycle (`T_basic`)**: A lockstitch machine running at 4,500 stitches per minute (illustrative) completes a 120-stitch seam in 0.0267 minutes (1.6 seconds) of needle movement, yet ply pickup, alignment, pivoting and stacking occupy 60 to 80 percent of the workstation cycle (illustrative range). [S0401] Bare needle time is physically unattainable for the full operation; the validated basic time (`T_basic`) of a skilled operator following the standard work method without minor stoppages provides the rigorous ideal cycle for station OEE. [S09] [S26] [S0401] 2. **Observed operator cycle (`T_obs`)**: In line-balancing research, cycle time is the elapsed time a job remains in a workstation during observation. [S15] Because manual and semi-automatic timing of speeds and short stoppages introduces measurement uncertainty, setting the "ideal cycle" equal to a trailing average of observed cycles artificially pins performance near 100 percent even on poorly methodised stations. [S03] [S07] 3. **Operation SMV (`SMV_i`)**: Because `SMV_i` adds 15 to 30 percent in bundle, machine and personal allowances on top of basic time, using `SMV_i` in the OEE performance numerator while subtracting downtime in availability can push reported performance above 100 percent (for example, 115 to 130 percent under the 30 percent combined allowances in S0401), masking micro-stoppages. [S04] [S14] [S0401] Whichever convention a plant adopts, ISO 22400-2 and NIST guidance require the formula elements, time behaviour and units to be declared explicitly and held constant. [S01] [S03]

4.12 TAKT TIME AND PITCH TIME GOVERN LINE RELEASE AND WORKSTATION CEILING RATHER THAN INDIVIDUAL SPEED

While ideal cycle, observed cycle and SMV describe a single operation, takt time and pitch time govern the whole assembly line. [S15] [S16] [S26] Takt time is available planned production time divided by required good customer demand (`Takt = T_planned / D_good`), translating market demand into a required rhythm (for example, 480 planned minutes divided by 480 required good garments equals 1.00 minute per garment, illustrative). [S15] [S26] Pitch time is the governing workstation time ceiling in mathematical line balancing; as formulated by Zhang et al. (Equation 8), the operating time of each process assigned to a workstation must not exceed the assembly-line pitch time (`C_max ⩽ Pitch Time ⩽ Takt Time`). [S15] [S16]

Exhibit 19, p. 67 codifies the five time definitions, their boundaries and the substitutions prohibited in GFT's data model. [S09] [S13] [S15] [S16] [S0401]

EXHIBIT 19 / MINUTES PER PIECE OR WORKSTATION CYCLE

Cycle-time terms require separate definitions

Term	Operational definition and formula basis	Boundary	Prohibited substitution
Ideal cycle time	Reference shortest sustainable cycle for the standard method in OEE performance (S09; S0401)	Single operation or constraint station	Never replace with trailing average observed cycle to hide slow pace
Observed cycle time	Measured elapsed time a job remains at a workstation from pickup to next pickup (S15; S0401)	Operator and station during study window	Never use raw unrated stopwatch average as a costing or pay standard
Operation or style SMV	Basic time (observed cycle x rating) plus bundle, machine and personal allowances (S13; S0401)	Operation bulletin or whole garment style	Never alter SMV allowances to mask line imbalance or machine downtime
Takt time	Planned available production time divided by required good customer output (S15)	External demand on the whole line	Never treat takt as achieved line capacity without a feasible balance
Pitch time	Governing workstation time ceiling in line balancing that no station may exceed (S16)	Workstation allocation model	Never assume theoretical pitch equals actual bottleneck cycle on floor

ILLUSTRATIVE [S09] [S13] [S15] [S16] [S0401] Illustrative engineering reference table synthesising definitions from S09 (apparel OEE ideal cycle), S13 and S0401 (basic time and SMV), S15 (workstation cycle time) and S16 (assembly-line pitch time). Prohibited substitutions reflect GFT's data-governance rules.

As **Exhibit 19**, p. 67 shows, each time standard belongs to a specific physical boundary. [S01] [S15] [S16] Substituting demand takt time for ideal cycle time in an OEE calculation, or using unrated observed cycle time in place of rated SMV on an operation bulletin, renders downstream efficiency percentages uninterpretable. [S03] [S09] [S0401] **Exhibit 19**, p. 67 defines the vocabulary for a single line and style; Chapter 5 extends these definitions into precedence networks and bottleneck identification. [S15] [S16]

4.13

Only good output earns effective capacity

In both OEE and SMV-based line efficiency, the most common operational failure on the sewing floor is counting pieces sewn rather than pieces that are right first time or verified good. [S04] [S09] In OEE literature, the quality component captures defect losses and reduced yield so that defective and reworked units reduce effective capacity multiplicatively. [S04] [S09] In total productive maintenance (TPM), quality-related losses and startup losses are integral parts of the six-loss structure aimed at zero breakdowns and zero defects. [S02]

4.14 CREDITING STANDARD MINUTES TO DEFECTIVE OR REWORKED GARMENTS INFLATES LABOUR EFFICIENCY

Why do sewing lines credit standard minutes to defective garments? Because in manual bundle-ticket systems, operators clip coupons or clerks tick hourly boards when a bundle leaves the last sewing machine, *before* end-of-line inspection or after an unrecorded return to the operator for repair. [S12] [S14] Consider an illustrative line of 30 operators sewing a 20.0-minute SMV garment during a 480-minute shift (`14,400` attended minutes) that passes 300 garments across the final table, of which 45 garments fail inspection (15 permanently rejected and 30 returned to operators for in-shift unpicking and re-stitching). [S04] [S09] [S14]

If the clerk credits all 300 sewn pieces, the line claims `300 x 20.0 = 6,000` earned minutes (`41.67%` efficiency, illustrative). [S13] [S14] In reality, only 255 garments passed first time (`5,100` first-pass standard minutes, or `35.42%` first-pass efficiency) and 285 good garments reached packing after repair (`5,700` net earned minutes, or `39.58%` net efficiency, illustrative), while the 30 repaired garments consumed sewing labour twice. [S04] [S13] [S14] All rework labour must remain inside the attended-minutes denominator. [S12] [S13]

In the ILO Factory Improvement Toolset implementation in Pakistan (Factory AM), introducing stricter inline quality assurance in the stitching room eliminated the need for third-party contractual workers previously hired for re-working defective garments. [S12] Across the Asian FIT programme, sewing-room line achievement improved by 9.49 percent while work in progress and defects per hundred units (DHU) both declined by 22 percent, proving that tightening quality at the source raises net line achievement. [S12]

> **WARNING**
>
> **Never credit earned standard minutes or piece-rate bonuses before quality verification**
>
> Counting uninspected, rejected or doubly-counted reworked garments in SMV line efficiency creates two hazards: [S04] [S09] [S12] 1. **Phantom capacity in planning**: Planners see 6,000 earned minutes per shift and promise shipment dates on 300 garments a day, discovering at packing that deliverable volume is 5 to 15 percent short (illustrative range). [S09] [S12] 2. **Perverse speed-over-quality incentives**: Operators pushed to maximise raw piece counts run machines past tension and needle limits, generating lockstitch repairs and stains (54.77 percent of all defects in Company X in S09). [S09]
>
> **Resolution**: Reconcile `Units Started`, `First-Pass Good Units`, `Reworked Good Units` and `Rejected Units` every shift. [S04] [S14] Use `First-Pass Good Units` for OEE quality (`FPY = Q_first-pass / Q_checked`), credit earned minutes only for verified good garments accepted into finished-goods flow, and keep all rework labour inside attended minutes. [S04] [S12] [S14]

4.15 FIRST-PASS YIELD AND DEFECTS PER HUNDRED UNITS ANCHOR THE QUALITY BOUNDARY ON THE SEWING FLOOR

While OEE requires a dimensionless quality proportion between 0 and 1 (such as first-pass yield), sewing supervisors also track defects per hundred units (DHU) because a single rejected or reworked garment may carry multiple stitch,

measurement or stain defects. [S09] [S12] [S14] If 100 inspected shirts include 88 defect-free shirts and 12 defective shirts containing 18 distinct defects, first-pass yield is `88 / 100 = 88.0` percent while the defect rate is 18.0 DHU (illustrative). [S09] [S12] [S14] First-pass yield feeds the multiplicative OEE equation (`OEE = A x P x Q`), whereas DHU by defect code feeds the Pareto root-cause huddles treated in Chapter 11. [S04] [S09] [S12]

Furthermore, any manual quality metric is bounded by inspection accuracy. [S07] [R29] Industry inspection evidence in the shared register notes that manual fabric and defect inspection is typically 60 to 70 percent accurate, missing 20 to 30 percent of defects, whereas automated computer-vision systems can exceed 90 percent accuracy across more than 40 defect types at speeds up to 60 metres a minute on fabric rolls. [R29] Standardizing inline and end-of-line inspection lighting, templates and defect codes ensures that rising first-pass yield reflects fewer defects rather than lax inspection; inspection hardware is addressed in a companion paper on quality systems. [S12] [S26] [R29]

4.16

Definitions must survive the move from spreadsheet to platform

Every growing garment factory transitions from clipboards and spreadsheets to digital production monitoring, whether through end-of-line tablets, motor power sensors or manufacturing execution systems (MES) with process monitoring devices (PMDs). [S09] [S14] Assuming that buying software solves measurement inconsistency is a costly mistake: if mathematical definitions of planned time, basic time, SMV allowances, ideal cycle time and good output are not frozen beforehand, software merely automates ambiguity. [S01] [S03] [S05]

4.17 FORMULA DRIFT BETWEEN MANUAL SHIFT SHEETS AND VENDOR SOFTWARE INVALIDATES HISTORICAL BASELINES

The ASME Standards Subcommittee meeting at the National Institute of Standards and Technology (NIST) concluded that industry guidance still requires a generally accepted definition of OEE because multiple definitions and calculations coexist across practitioners and vendors. [S03] Similarly, formal analysis of ISO 22400-2 found that the standard presents two versions of the OEE indicator that appear substantially different without demonstrating their equivalence in the text. [S05]

When a garment factory moves from an engineer's workbook to a vendor platform without a governed specification, three silent discrepancies appear: [S01] [S03] [S05] 1. **Denominator drift**: The manual sheet divided earned minutes by total attended clock minutes of all operators and helpers, whereas the vendor software divides by active terminal login minutes of machine operators only, excluding helpers and subtracting off-standard time so reported "efficiency" jumps from 54 percent to 72 percent (illustrative) with zero change in physical output. [S13] [S0402] [S0403] 2. **Ideal-cycle drift**: The pilot line calculated OEE performance using rated basic time (`T_basic`), whereas the vendor software imports allowance-inclusive `SMV_i` or recalculates a rolling 30-day average of observed cycles. [S03] [S09] [S0401] 3. **Quality-boundary drift**: The manual log tracked first-pass yield, whereas the packing scan calculates net yield after inline repair, erasing rework losses from OEE quality. [S04] [S09] [S14]

4.18 A GOVERNED CALCULATION CONTRACT WITH UNIT TESTS PROTECTS THE TRANSITION FROM LOGBOOK TO EDGE PLATFORM

To prevent formula drift, GFT treats the calculation contract as version-controlled engineering code from Day 1. [S01] [S03] [S26] Under ISO 22400-2, every key performance indicator must be documented by its formula, constituent elements, time behaviour, unit and boundary conditions. [S01] Embedding deterministic numerical unit tests guarantees that any spreadsheet, database query, web simulator or vendor MES reproduces the exact same numbers before acceptance. [S01] [S03] [S05] All inputs in the verification table below are illustrative test vectors. [S01] [S03]

Vector	Inputs (illustrative)	Intermediate values	Output
TV-01: SMV	`T_obs = [0.50, 1.00, 0.50]`; `R = [100%, 96%, 100%]`; `a = [0.60, 0.25, 0.20]` [S13] [S0401]	`T_basic = [0.50, 0.96, 0.50]`; `SMV_i = [0.80, 1.20, 0.60]` [S13] [S0401]	`SMV = 2.60` min [S13]
TV-02: Line eff.	`SMV = 2.60`; started = `210`; rejected = `10`; `Q_good = 200`; `8 x 480 min` [S13] [S0402] [S0403]	Earned = `520.00` min; attended = `3,840.00` min [S13] [S0402]	`13.54%` [S13] [S0402]
TV-03: Balance	`K = 3` stations; `SMV_i = [0.80, 1.20, 0.60]`; `C_max = 1.20` min [S15] [S16]	Content = `2.60` min; capacity = `3.60` min [S15] [S16]	`72.22%` [S15]
TV-04: OEE	Planned = `450`; down = `45`; ideal = `0.96`; total = `360`; good = `342` [S01] [S04] [S09]	Op = `405`; `A = 90.0%`; `P = 85.33%`; `Q = 95.0%` [S04] [S09]	`72.96%` [S04] [S09]

Notice how `TV-02`, `TV-03` and `TV-04` evaluate the same three-operation garment (`SMV_garment = 2.60` minutes, with Operation 2 as the 1.20-minute bottleneck whose basic cycle is 0.96 minutes) and produce three distinct outputs: 13.54 percent line labour efficiency, 72.22 percent structural balance efficiency, and 72.96 percent constraint workstation OEE (illustrative verification suite). [S04] [S13] [S15] Any spreadsheet or software dashboard that conflates those three ratios fails the unit test suite immediately. [S01] [S03]

GFT NOTE

Practical recommendation for GFT's Cameroon textile programme and interactive tools

In GFT's Cameroon textile programme, performance management begins on the first shift with hourly capture of good output, defects and downtime by cause, reviewed in daily line huddles and weekly corrective-action meetings. [S09] [S12] To keep machine effectiveness and labour productivity aligned across paper logs, spreadsheets and digital tools, GFT enforces four operational rules: [S01] [S03] [S13]

1. **Publish an operation bulletin before releasing any style**: Record basic time, rating and allowances separately so `SMV_garment = sum(SMV_i)` is auditable and tied to a specific machine, attachment and standard method. [S12] [S13] [S26] [S0401]
2. **Track SMV-based line efficiency and constraint OEE side by side**: Use earned standard minutes divided by attended operator and helper minutes for style-mix costing, and use the OEE loss tree (`A x P x Q`) to direct maintenance, feeding, changeover and quality containment. [S04] [S09] [S13] [S14]
3. **Count only verified good garments in earned minutes**: Credit standard minutes only after end-of-line quality verification, track first-pass yield separately from net yield after rework, and retain all rework labour inside attended minutes. [S04] [S12] [S14]
4. **Embed the four unit-test vectors (`TV-01` to `TV-04`) into every sheet and tool**: This chapter provides the calculation contract used by GFT's `oee-line` and `line-balancing` tools and feeds the wider KPI cascade. [S01] [S03]

With the measurement foundation of Part I complete (spanning Chapter 1's economic case, Chapter 2's OEE loss tree, Chapter 3's time base, and this chapter's standard-minute labour connection), Part II turns to balancing work content around the constraint so that earned minutes and good garments rise together. [S13] [S15]

Standard minutes measure the garment's work; OEE measures where the line's time went; only good output earns either one.

CHAPTER SOURCE NOTES

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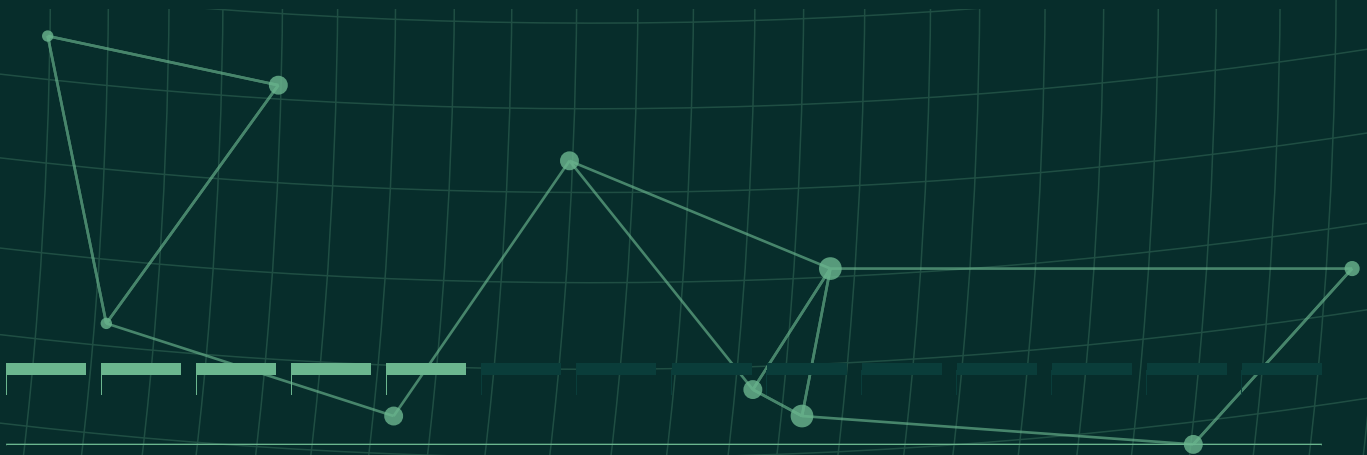
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05

PART II: BALANCE WORK TO THE CONSTRAINT / WORK CONTENT AND DEMAND

A sewing line is a dependent system, not a row of independent stations

Balancing begins with operation precedence and required output, then tests how work can be shared without violating machine, skill or quality constraints.



CHAPTER 05
DECISION TEST

Balancing begins with operation precedence and required output, then tests how work can be shared without violating machine, skill or quality constraints.

A sewing line produces finished garments at the rate of its most restrictive operation, not at the sum or average speed of its individual workstations. [S15] When management treats a garment line as a row of independent machines and pushes every operator to maximise local piece output, upstream stations outrun the constraint, work in progress accumulates between tables, waiting time expands and defect discovery slows. [S20] Balancing a sewing line begins with the system boundary established in Part I: the total standard minute value of the style built from its operation bulletin, customer demand expressed in good garments, and the planned production time remaining after lawful scheduling and declared availability exclusions. [S13] From those inputs, industrial engineering translates required good output into a governing rhythm, assigns operations across workstations without violating sequence, machine or skill constraints, and subordinates non-constraint stations to the pace that the constraint can sustain. [S30]

In Cameroon, where about 95 per cent of cotton fibre is exported raw and about 5 per cent is processed locally against a national target of 50 per cent local processing by 2030, converting installed sewing machines into predictable daily shipments determines whether domestic garment manufacturing can compete. [R06] [R07] Reported capacity utilisation at incumbent textile plants in July 2023 ranged from 10.83 per cent at CICAM 2 to 33.7 per cent at Garoua and 48.9 per cent at CICAM 1, with underutilisation costing about CFAF 2 billion in 2020. [R12] A sewing room cannot recover lost capacity by purchasing more lockstitch or overlock heads if its lines remain unbalanced. [S15] Evidence from the International Labour Organization's SCORE and SIRAYE programme in Ethiopia illustrates the mechanism: at Edget Garment, improving line-balance efficiency from 24 per cent to 75 per cent raised daily output from 50 pieces to 120 pieces on the studied line. [S37] That case is not a forecast for Cameroon, where product mix, skill and power continuity differ, but it proves that aligning workstation assignments to precedence and rhythm releases capacity already on the floor. [S37]

This chapter defines the engineering structure that turns product work content and customer demand into a feasible line balance. It shows why the operation bulletin is the balancing unit, how takt time must be adjusted for first-pass quality, why pitch time and workstation cycle time require separate definitions, how precedence restricts task combinations, how bottleneck stations are identified from utilisation and upstream queues, and why buyer order release belongs in the capacity conversation. [S13] [S16] [S20] [S42] Skill matrices follow in Chapter 6, resource-constrained heuristics in Chapter 7, and daily rebalancing routines in Chapter 8. [S15]

5.1

The operation bulletin is the balancing unit

No sewing line can be balanced from an aggregate garment standard minute value alone. As Better Work's assessment of Bangladesh garment factories states, the standard minute value for a garment is the sum of the standard minute values for each of the steps required to produce it. [S13] The document recording those constituent steps, their sequence, their required equipment and their time standards is the operation bulletin. In the International Labour Organization's Factory Improvement Toolset

for the garment sector, verifying an accurate operation bulletin precedes line planning, hourly balancing and bottleneck management. [S12] Without a verified bulletin, dividing headcount into target output ignores where the work resides.

An operation bulletin serves as an engineering specification rather than an accounting summary because sewing operations are not interchangeable blocks of time. A woven shirt or cotton trouser comprises dozens of discrete operations across preparation, subassembly and main assembly, each governed by fabric handling rules, seam geometry and machine kinematics. [S15] Moving a pocket-setting task to a five-thread overlock station is impossible without changing equipment and folders. Combining a collar-fusing step with final topstitching violates the physical assembly order. Consequently, the balancing unit is the individual operation entry in the bulletin, together with the technical attributes that constrain where and by whom that operation can run. [S13] [S15]

5.2 EVERY OPERATION RECORD REQUIRES SIX TECHNICAL ATTRIBUTES

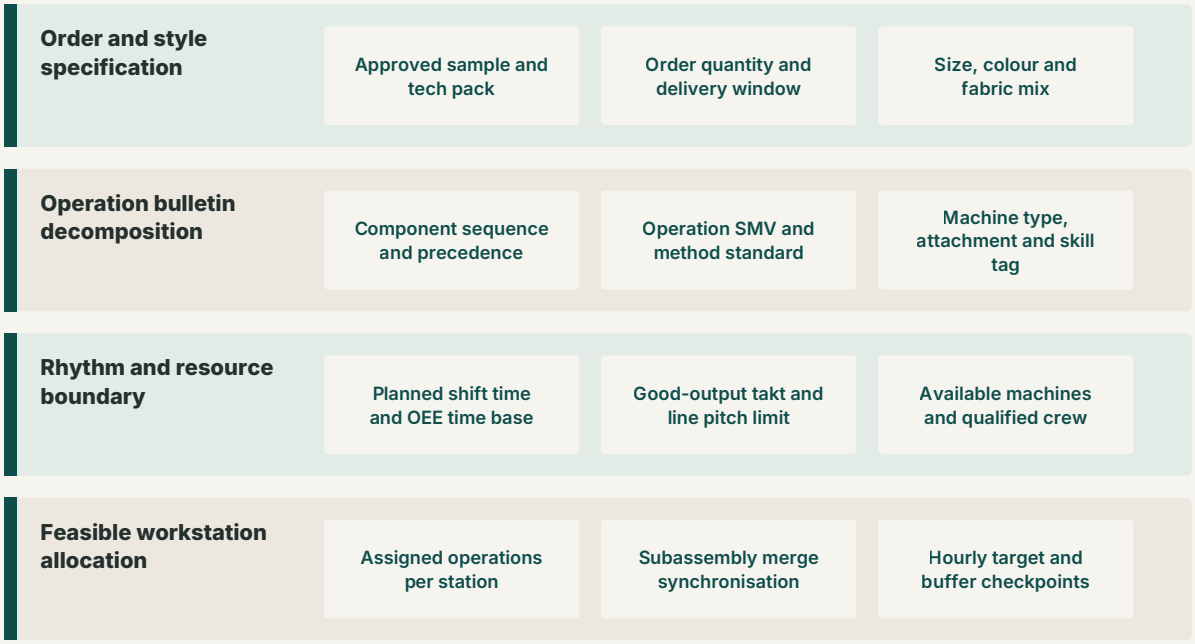
To support feasible balancing rather than paper arithmetic, GFT's performance-management design requires industrial engineers to populate six mandatory attributes for each operation in the bulletin before a style reaches the floor. [S12] [S13]

1. **Operation identifier and component group.** Each step receives a stable code and is assigned to its subassembly, such as collar, cuff, front, back, sleeve or final assembly, making parallel paths and merge points explicit. [S15]
2. **Method description and handling boundary.** Standardised work documents the current process for all shifts, reduces variability, eases training and provides the baseline for improvement. [S26] The method description specifies pickup, alignment, sewing run, trimming and disposal so the standard minute value reflects a reproducible motion sequence. [S13] [S26]
3. **Standard minute value (SMV) and allowance basis.** Each operation carries its measured basic time plus declared bundle, machine and personal allowances in standard minutes per piece, so operation SMVs sum to the garment SMV. [S13]
4. **Machine class, needle configuration and special attachment.** The bulletin states the exact equipment required, such as single-needle lockstitch, twin-needle feed-off-the-arm, four-thread overlock, buttonhole, bartack or iron press, plus folders or guides. [S15]
5. **Skill grade and ergonomic demand.** Because operator performance varies by task difficulty and experience, the bulletin records the required skill grade and whether the operation is performed sitting or standing. [S13] [S26]
6. **Quality checkpoint and critical-to-quality specification.** Because only defect-free output counts toward effective production, the bulletin flags operations where seam allowance, stitch density, symmetry or shade matching must be verified before the subassembly joins the main stream. [S04]

Maintained in a structured table, the operation bulletin becomes the translation layer between garment design and floor control, as shown in **Exhibit 20**, p. 76. [S13] [S15] [S16]

EXHIBIT 20 /

The operation bulletin converts style requirements into a balanced line



ILLUSTRATIVE [S13] [S15] [S16] Illustrative system architecture showing how GFT's line-balancing workflow transforms garment specifications into workstation allocations using operation SMV summation (S13), cycle and precedence constraints (S15) and pitch-time limits (S16).

Exhibit 20, p. 76 shows why skipping any layer in this hierarchy destabilises the line. Moving directly from order quantity to workstation assignment without decomposing the style into its operation bulletin hides when two operations require the same scarce machine or when a subassembly takes longer than the main body stream it feeds. [S15] Conversely, an operation bulletin that lists operation SMVs without tying them to the shift's planned time base and good-output demand cannot tell a supervisor whether a workstation running at 0.85 minutes per piece is ahead of schedule or starving the line. [S13] [S16] What **Exhibit 20**, p. 76 cannot establish on its own is whether the standard minute values in the bulletin match the times achieved by the crew on a specific shift; validating those times requires floor observation and the skill adjustments covered in Chapter 6. [S26]

5.3 SUBASSEMBLY DECOMPOSITION SEPARATES COMPONENT PREP FROM MAIN ASSEMBLY

A garment operation bulletin is rarely a single serial chain from first stitch to final press. In woven shirts, trousers and jackets, cut panels are bundled into distinct component streams: collars, cuffs, plackets, pockets, fronts, backs and sleeves are prepared in subassembly sections before converging at main assembly. [S15]

A subassembly section can be decoupled from the main line by a small buffer of finished components, provided every component in that buffer has passed inspection and matches the size and shade bundle entering the main line. [S04] [S21] Main assembly operations act on the joined garment body; once fronts, backs and sleeves close, any delay or defect at one station blocks upstream work or starves downstream stations up to pressing and packing. [S06] [S20] Recording the component group and

merge point inside the bulletin allows the engineer to pace subassembly preparation to the consumption rhythm of the merge station rather than overproducing collars and pockets while the main line waits. [S15]

5.4

Takt translates demand into a line rhythm

Once the operation bulletin defines the work content of one garment, the second input is the rate at which the line must deliver completed garments. Lean manufacturing formalises this rate through takt time: available production time divided by customer demand. [S0501] Its purpose is to match production rhythm to demand so the line neither falls behind delivery commitments nor builds unrequested inventory. [S0501] While cycle time is the time a job remains in a workstation, takt time is a design ratio calculated from time and demand boundaries. [S15] [S0501]

A naive takt calculation fails on the floor when planners use the wrong numerator or denominator. Using total attendance rather than planned production time inflates the numerator by ignoring scheduled huddles, maintenance windows or known interruptions. [S01] Using gross starts rather than required good output in the denominator ignores that defective garments do not satisfy customer orders. [S04] When OEE measurement and line balancing use different time bases or quality assumptions, a line can look balanced on paper while missing its daily shipment target. [S01] [S04]

5.5 GOOD DEMAND AND THE OEE TIME BASE GOVERN THE TAKT RATIO

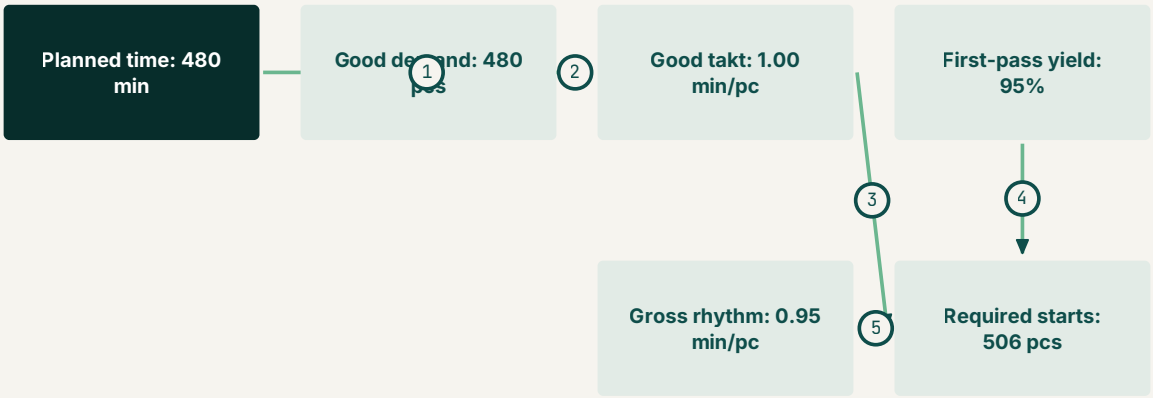
GFT enforces one rule across its planning models: the takt numerator must equal the planned production time declared in the OEE protocol, and the denominator must equal required good output at the line exit. [S01] [S04] [S0501] Under ISO 22400-2, manufacturing indicators must state their formula, elements, time behaviour and unit explicitly. [S01] If an eight-hour shift (480 minutes) includes 30 minutes of planned non-production time for daily huddles and scheduled checks, available production time for takt is 450 minutes, not 480 minutes. [S01] [S0501]

Similarly, OEE defines quality through defect losses and reduced yield. [S04] When a line experiences a defect loss across its shift, bundles started at the first operation must exceed first-pass good garments required at packing, or rework must return repaired pieces within the shift without consuming constraint capacity. [S04] Because end-of-shift rework destabilises flow, the release rate must account for observed first-pass yield while quality-at-source improvements eliminate the defects. [S04] [S12]

Exhibit 21, p. 78 shows how planned time, good demand and first-pass quality interact in an illustrative shift calculation. [S04] [S15] [S0501]

EXHIBIT 21 / MINUTES AND PIECES PER SHIFT

Takt must be calculated from good demand and available time



1. numerator
2. denominator
3. apply yield
4. 480 / 0.95
5. 480 min / 506 pcs

DERIVED [S04] [S15] [S0501] Derived with illustrative inputs: 480 planned production minutes divided by 480 required good pieces gives a good-output takt of 1.00 minute per piece (S0501). With an illustrative 5 per cent quality loss (95 per cent first-pass yield, S04), gross starts required = 480 / 0.95 = 505.26, rounded up to 506 pieces, implying an effective gross release interval of 480 / 506 = 0.949 minutes per piece against workstation cycle time (S15).

In **Exhibit 21**, p. 78, 480 planned minutes and 480 required good garments give a nominal takt of 1.00 minute per good piece. [S0501] At a 95 per cent first-pass yield (an illustrative 5 per cent quality loss), starting 480 pieces yields only 456 first-pass good pieces. [S04] Delivering 480 first-pass good pieces without same-shift repair requires `480 / 0.95 = 505.26` (506 started pieces), tightening the gross rhythm to `480 / 506 = 0.949` minutes per piece. [S04] [S0501] **Exhibit 21**, p. 78 is an illustrative derivation, not a GFT baseline, showing that quality losses compress the time budget at every station. [S04] [S15]

WORKED EXAMPLE: ALIGNING TAKT, QUALITY ALLOWANCE AND WORKSTATION COUNT

Consider an illustrative line planning 2,400 good cotton work shirts over five shifts (480 good shirts per 480-minute shift) with a verified garment SMV of 15.20 standard minutes. [S13] [S0501]

1. **Nominal good-output takt.** Dividing 480 planned minutes by 480 good shirts gives `1.00` minute per shirt. [S0501]
2. **Theoretical minimum stations.** With zero losses, minimum workstations equal `15.20 / 1.00 = 15.2`, or 16 stations. [S13] [S15]
3. **Availability and quality adjustment.** With a 5 per cent availability loss (`456` operating minutes) and a 5 per cent quality loss (`506` required starts), the line must process 506 starts in 456 minutes. [S04]
4. **Effective cycle ceiling.** The constraint cycle ceiling is `456 / 506 = 0.901` minutes (54.1 seconds). [S04] [S15]
5. **Feasible workstation floor.** Dividing 15.20 standard minutes by 0.901 minutes requires at least `16.87` (17 stations) before precedence, and 19 to 20 stations once structural balance loss is included. [S13] [S15]

5.6 HEADCOUNT SIZING MUST SEPARATE BALANCE LOSS FROM PERFORMANCE LOSS

Dividing garment SMV by a single arbitrary efficiency factor (such as 0.50 or 0.65) obscures why extra stations are needed. Requiring 20 operators instead of 16 in the illustrative case above reflects four distinct mechanisms. [S04] [S15]

First, **balance loss** arises because discrete operations with precedence and machine boundaries cannot be sliced into equal fractions of the cycle; if the constraint carries 0.90 minutes and a neighbour carries 0.72 minutes, the 0.18-minute gap is structural balance loss. [S15] [S0502] Second, **availability loss** comes from thread, needle, machine or power stops. [S04] [S06] Third, **performance loss** comes from skill gaps or micro-stops. [S04] Fourth, **quality loss** comes from sewing defective seams. [S04] Anchoring takt to planned time and good demand separates structural balance loss on the operator balance chart from recoverable OEE loss. [S04] [S0502]

5.7

Pitch and cycle are related but not interchangeable

Literature and factory software use three timing terms that sound similar: takt time, cycle time and pitch time. Treating them as synonyms corrupts balancing models and floor control. [S15] [S16] [S0503] Engineers must inspect the exact definition in each source before encoding it. [S01]

In the garment balancing study by Jung et al., **cycle time** is the amount of time a job remains in a workstation, and the maximum workstation time (`max_k T_k`) sets the bottleneck cycle. [S15] On an **operator balance chart** (Yamazumi board), vertical bars compare each operator's workload with takt time, aiming to make each workload nearly equal to, but slightly less than, takt time. [S0502]

In published work, **pitch time** has two distinct meanings. [S16] [S0503] First, in lean logistics, the Lean Enterprise Institute defines pitch as the time to make one container of products (`takt time x pack-out quantity`), while noting that pitch is also used for the time span of a person's job. [S0503] Second, in mathematical sewing-line models such as the *Energies* multi-objective formulation, "assembly line pitch time" is the upper bound on workstation operating time: Equation (8) guarantees that the operating time of each process in any workstation does not exceed assembly-line pitch time. [S16]

RECONCILING TAKT, PITCH AND STATION CYCLE TIME IN GFT MODELS

GFT standardises the timing variables across its papers and balancing tools as follows:

- **Takt time (`T_takt`)**: planned production time divided by required first-pass good output, in minutes per good garment. [S04] [S0501]
- **Workstation cycle time (`C_k`)**: actual or standard time a garment spends at workstation `k`, adjusted for operator proficiency and resource share. [S15]
- **Line cycle time (`C_line`)**: maximum workstation cycle time across sequential stations (`max_k C_k`), capping steady-state output. [S15] [S30]
- **Assembly-line pitch time (`P_line`)**: target workstation ceiling (`C_k ⩽ P_line < T_takt`) in mathematical balancing models. [S16] [S0502]
- **Container or bundle pitch (`P_batch`)**: bundle release interval `T_takt x B` for transfer-batch size `B` (for example, `1.00 x 10 = 10.0` minutes per 10-piece bundle while `P_line` remains below `1.00` minute per piece). [S21] [S0503]

Separating `P_line` (per-piece station ceiling) from `P_batch` (bundle release interval) prevents a common floor blind spot. [S16] [S0503] If a supervisor tracks only 20-piece or 30-piece bundle completions (`P_batch`), an operator running at 1.08 minutes per piece against a 0.95-minute `P_line` ceiling is not flagged until a whole bundle is late and the downstream station has starved. [S06] [S16] [S20] Workstation balancing must constrain per-piece time at every station (`C_k ⩽ P_line < T_takt`). [S16] [S21] [S0502]

5.8

Precedence limits which operations can be combined

Without sequence or machine constraints, line balancing would be simple bin packing up to `P_line`. [S16] [S0502] Real garment assembly has a physical precedence graph dictating which seams must finish before another begins, alongside machine requirements determining which tasks can share a workstation. [S15] [S16]

Jung et al. show that balancing methods must respect precedence, cycle and workstation limits, and that imposing resource constraints materially alters feasible station counts and efficiency compared with unconstrained math. [S15] Likewise, the *Energies* model pairs its pitch-time ceiling with process-assignment constraints to preserve assembly sequence. [S16]

5.9 THREE STRUCTURAL DEPENDENCIES GOVERN TASK GROUPING

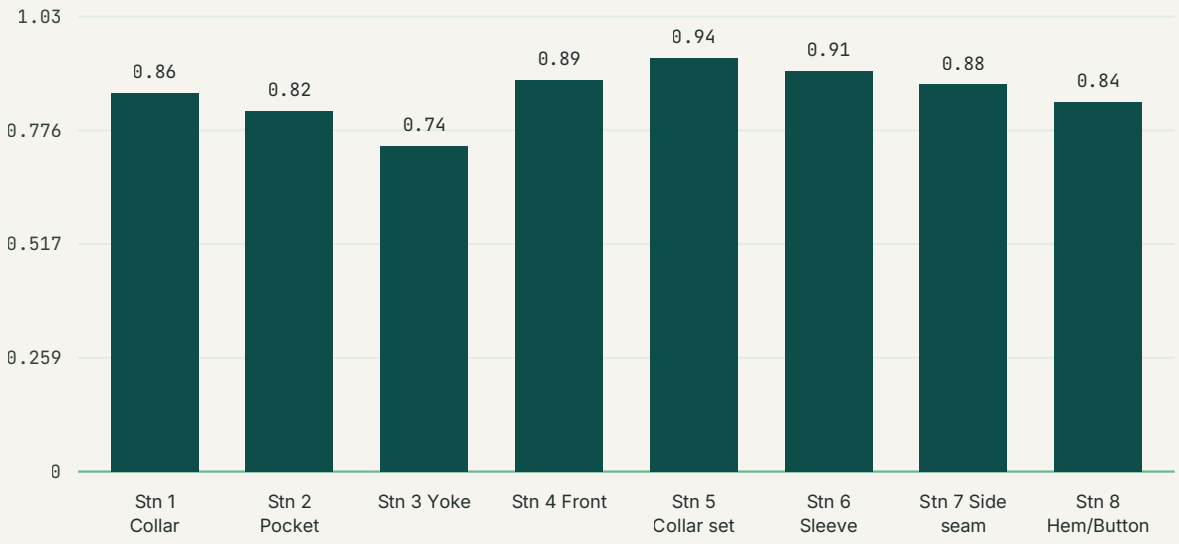
Three structural rules limit which operations from the bulletin can merge into one workstation assignment: [S13] [S15] [S16]

1. **Topological seam precedence.** A pocket facing cannot be stitched to a pocket bag after the bag is closed into the trouser front; a shirt side seam cannot be felled before the shoulder join. [S15] The bulletin forms a directed acyclic graph where `i` → `j` means operation `i` must finish before `j` starts. [S15] Grouping `i` and `k` at one station while placing `j` (`i` → `j` → `k`) at another forces work to travel back and forth, multiplying handling and WIP. [S15] [S21]
2. **Machine, needle and folder compatibility.** Adjacent operations (`i` → `j`) can share a single-machine station only if they use the same machine class, needle gauge, thread and folder. [S15] Combining a 0.35-minute five-thread overlock join with a 0.45-minute lockstitch topstitch requires a multi-machine cell and cross-trained skill, examined in Chapters 6, 7 and 10. [S15]
3. **Quality-hold boundaries.** Where an operation creates a concealed seam or irreversible cut (such as a welt pocket slash or collar trim), combining it with the enclosing step removes the independent check that catches defects before the panel is spoiled. [S04] [S26]

Exhibit 22, p. 81 shows how precedence and machine boundaries shape an operator balance chart across eight illustrative workstation groups under a 0.95-minute pitch ceiling. [S15] [S16] [S0502]

EXHIBIT 22 / MINUTES PER PIECE (ILLUSTRATIVE STATION CYCLE TIME)

Workstation cycle loads expose the governing constraint against pitch



ILLUSTRATIVE [S15] [S16] [S0502] Illustrative operator balance chart (Yamazumi comparison, S0502) across eight sequential workstation groups against a 0.95-minute pitch limit (S16). Station cycle time definitions follow S15. Values are illustrative engineering examples showing why machine and precedence boundaries prevent uniform 0.95-minute loading, leaving Station 5 (0.94 min) as the governing constraint and Station 3 (0.74 min) with structural balance loss.

In **Exhibit 22**, p. 81, every station obeys the pitch constraint ($C_k \leqslant 0.95$ minutes) and sits just below the 1.00-minute takt. [S16] [S0502] Yet Station 3 (illustrative 0.74 minutes) sits 0.20 minutes below Station 5 (illustrative 0.94 minutes) because the operations after yoke attach require a different machine class. [S15] Consequently, steady-state throughput is governed by Station 5 at $60 / 0.94 = 63.8$ pieces per hour, not by the 0.86-minute average (69.8 pieces per hour), and running Stations 1 to 4 at full local speed builds a continuous queue upstream of Station 5. [S15] [S20] [S30] Because **Exhibit 22**, p. 81 is deterministic, it omits cycle variance, which builds queues even faster on a live floor. [S23]

5.10 PARALLEL SUBASSEMBLIES MUST SYNCHRONISE AT THE MERGE STATION

A garment precedence graph resembles a river network: preparation branches (collar, cuff, placket, pocket and front prep) merge into a main trunk (shoulder join, collar set, sleeve set, side seam, hem). [S15] In progressive bundle flow, an unsynchronised branch causes component starvation even when room WIP is high. [S06] [S21] If 300 shirt bodies wait at collar setting (Station 5 in our illustrative chart) while collar prep is delayed by a fusing fault, collar setting loses OEE from lack of input items despite its machine being ready. [S06] Balancing requires **merge synchronisation**: upstream branches must deliver matched components in bundle sequence at the pitch rhythm of the main trunk. [S15] [S16]

5.11

The constraint sets system throughput

The Theory of Constraints (TOC) advocates beginning with the constraint that most limits throughput. [S30] In a dependent sewing line, an hour lost at the bottleneck is an hour lost for the whole line, whereas an hour saved at a non-constraint adds zero finished garments and merely swells intermediate WIP. [S20] [S30]

Traditional garment factories resist this rule because piece-rate habits and station efficiency reports reward local busyness. [S13] [S15] When supervisors push every station to stay busy 100 per cent of the shift, upstream stations run at 0.74 to 0.89 minutes per piece while the constraint runs at 0.94 minutes, piling up partially sewn garments that block aisles, hide defects and lengthen throughput time. [S15] [S20] [S22]

5.12 UTILISATION AND UPSTREAM WIP LOCATE THE BOTTLENECK ON THE FLOOR

Time-serial bottleneck analysis in textile and apparel production defines bottleneck workstations (BN_k) through two signals: highest long-term utilisation or the largest upstream work-in-process buffer in the system. [S20] Both signals are needed because either alone can mislead if flow boundaries are ignored: [S06] [S20]

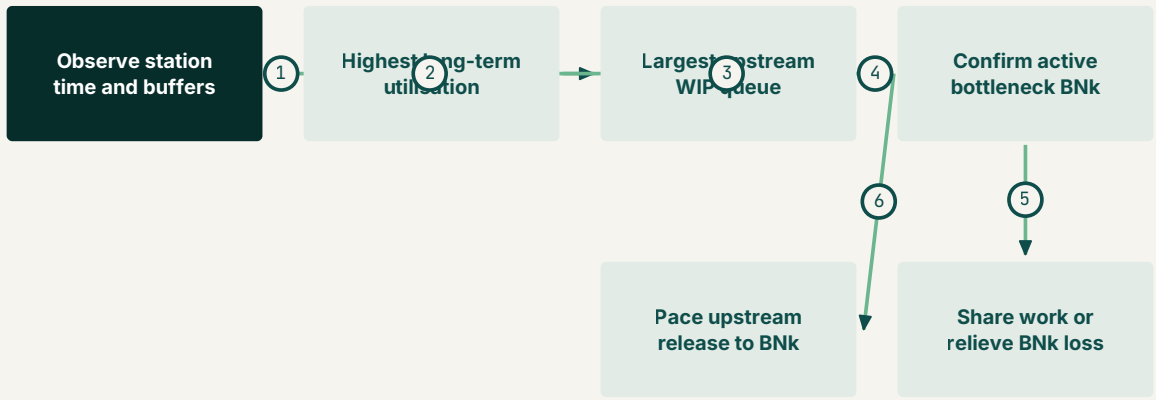
- **Signal 1: Highest sustained workstation utilisation.** A station whose active operating time ratio consistently leads the line works near saturation. [S20] Because waiting time rises nonlinearly with capacity utilisation in variable systems, small cycle variations near 100 per cent utilisation cause upstream queues to surge. [S20] [S23]

- **Signal 2: Largest upstream WIP buffer (and downstream starvation).** Without pull caps, bundles pile up directly in front of the slowest effective stage while the downstream buffer empties out, exposing `lack of input items` at the following station. [S06] [S20]

Exhibit 23, p. 83 traces how these two signals locate `BN_k` and focus action on system throughput. [S20] [S30]

EXHIBIT 23 /

Bottleneck evidence links high utilisation to upstream queues



1. time log
2. buffer count
3. S20 criterion 1
4. S20 criterion 2
5. TOC step: elevate
6. TOC step: subordinate

ILLUSTRATIVE [S20] [S30] Illustrative diagnostic decision flow combining the two apparel bottleneck indicators defined in S20 (highest long-term workstation utilisation and largest upstream WIP buffer) with the Theory of Constraints rule to prioritise the constraint that limits system throughput (S30).

Exhibit 23, p. 83 prevents false diagnostics. [S20] If a station logs low active sewing time, buffer inspection shows why: an empty upstream buffer indicates upstream starvation, whereas a full upstream buffer and empty downstream buffer during a stop prove the station itself is the active constraint in downtime or quality hold. [S06] [S20] Conversely, long-term utilisation separates a persistent bottleneck from a temporary end-of-shift batch dump at pressing. [S20] [S22] Chapter 8 turns this diagnostic into an hourly routine. [S12] [S20]

5.13 LITTLE'S LAW LINKS ACCUMULATED BUFFERS TO THROUGHPUT TIME

In stable systems that are not starting, stopping or surging, Little's Law states that average inventory (`WIP`) equals average throughput rate (`TH`) multiplied by average throughput time (`T_put`). [S22] If the bottleneck caps `TH` at 50 good pieces per hour,

letting upstream stations swell WIP from 100 to 400 pieces cannot raise TH above 50 pieces per hour; by T_put = WIP / TH, it quadruples average throughput time from 2.0 hours to 8.0 hours (illustrative arithmetic under the stability condition). [S22] [S30]

Longer throughput time penalises quality: if Station 2 sews an off-centre pocket, a 50-piece buffer exposes the fault at inspection within an hour, whereas a 300-piece queue hides up to 300 defective garments. [S04] [S12] In the ILO Factory Improvement Toolset programme in Asia, combining operation bulletins, balancing and bottleneck management raised sewing-room line achievement by 9.49 per cent while cutting both WIP and defects per hundred units by 22 per cent. [S12]

5.14 BALANCING TERMS MUST RETAIN THEIR OPERATIONAL DEFINITIONS

Exhibit 24, p. 85 consolidates the seven core balancing terms used across Part II, their formulas and the floor errors caused when definitions blur. [S15] [S16] [S20] [S22] [S0501] [S0503]

EXHIBIT 24 / MINUTES, PIECES AND PIECES PER UNIT TIME

Balancing terms must retain their operational meaning

Term	Operational definition and formula	Primary role in balancing	Common shop-floor error to avoid
Takt time	Available planned production time divided by required good customer demand (S0501)	Sets the external demand pace the line must meet	Using gross attendance time or uninspected starts instead of planned time and good output
Workstation cycle time	Time a job remains at a workstation to complete its assigned operations (S15)	Measures the actual per-piece duration at each station	Confusing one station's fast cycle with the output rate of the whole sewing line
Pitch time	Governing upper bound on station operating time in line models (S16), or takt x pack-out quantity in container release (S0503)	Caps assigned workstation load or paces bundle withdrawal	Mixing per-piece station pitch ceiling with multi-piece bundle release intervals
Station time load	Sum of standard or skill-adjusted operation times assigned to a workstation (S15; S16)	Determines bar height on the operator balance chart	Assuming standard minutes equal actual station cycle without checking operator skill and machine share
Work in progress (WIP)	Started garment pieces or bundles inside the line boundary not yet completed as good output (S20; S22)	Signals bottleneck location via largest upstream buffer (S20)	Treating high inter-station WIP as a sign of high productivity rather than queue delay
System throughput	Good garments completed by the whole line per unit of time, governed by the constraint (S22; S30)	Primary output measure of line-balancing success	Counting pieces completed at upstream non-constraints as achieved factory throughput
Precedence constraint	Required physical sequence of operations from the operation bulletin (S15; S16)	Restricts which operations can be merged or reordered	Combining non-adjacent operations across different machines to flatten bar heights on paper

ILLUSTRATIVE [S15] [S16] [S20] [S22] [S0501] [S0503] Operational definitions, governing relationships and common diagnostic errors for garment line balancing, compiled from S15 (cycle time and precedence), S16 (assembly-line pitch constraint), S20 (bottleneck utilisation and upstream WIP), S22 (Little's Law stability condition), S0501 (takt time) and S0503 (container pitch vs job span).

As **Exhibit 24**, p. 85 summarises, each parameter answers a distinct operational question: takt sets the demand rhythm; station cycle and load measure workstation duration; pitch sets the engineering ceiling per station or container; precedence defines legal task combinations; upstream WIP and utilisation locate the bottleneck; and system throughput measures finished good garments leaving the line. [S15] [S16] [S20] [S22] [S0501] [S0503]

5.15

Buyer feasibility belongs in the capacity conversation

Even a rigorous internal balance fails if buyer order placement, style proliferation or late approvals force the sewing room to switch styles every few hours or absorb unscheduled peaks. [S42] In the International Labour Office's study of garment purchasing practices, some buyers plan orders, lead times and production peaks in advance with suppliers, whereas short-notice purchasing compresses lead times and destabilises schedules. [S42]

Order release and style-mix stability are direct engineering inputs to takt and bulletin calculations across three variables: [S13] [S42]

1. **Order quantity relative to ramp duration.** Switching to a new operation bulletin requires learning new handling sequences, resetting folders and rebalancing stations. [S15] [S26] Lots that finish in two shifts trap the line inside its changeover trough, never reaching steady-state cycle times. [S15]
2. **Delivery window and peak smoothing.** Compressing delivery windows or bunching orders spikes daily demand, drops `T_takt` below the feasible constraint cycle `C_line`, and tempts management into overtime or operator borrowing. [S42] [S0501] Advance buyer-supplier planning smooths required takt across weeks. [S42]
3. **Full-kit readiness before release.** Releasing bundles before cut panels, interlinings, threads, labels, buttons and zippers are verified in size and shade sequence guarantees mid-line starvation (`lack of input items`), creating artificial bottlenecks that reallocation cannot fix. [S06] [S13] [S20]

> **GFT NOTE**
>
> In GFT's Cameroon textile programme, line balancing operates as a two-stage gate between commercial planning and floor execution. First, at order acceptance and monthly sales-and-operations planning, industrial engineering checks whether the style's operation bulletin, total SMV and delivery window yield a good-output takt (`T_takt`) that the line's equipment and crew can meet within statutory hours. [S01] [S13] [S0501] Second, no bundle leaves cutting for sewing until a **full-kit readiness check** confirms that all cut panels, trims, needles, folders and quality standards in the bulletin are physically present. [S06] [S13] Companion GFT papers cover purchasing governance and inventory policy; this paper enforces their floor rule: never release an incomplete or unbalanceable order onto a sewing line just to make cutting or the first station look busy. [S20] [S42]

5.16 FIVE RULES CONNECT THE OPERATION BULLETIN TO DAILY FLOOR CONTROL

Plant managers and industrial engineers can apply five rules from this chapter before moving to skill adjustments (Chapter 6) and optimisation heuristics (Chapter 7):

- **Build every balance from a verified operation bulletin, never from a garment-level SMV estimate.** Verify sequence, machine type, attachment, standard minutes and quality checkpoints on the floor before grouping tasks. [S12] [S13] [S15]

- **Calculate takt time from planned production time and required first-pass good output.** Align the numerator with the OEE planned-time boundary and account for first-pass yield so rhythm matches shippable garments. [S01] [S04] [S0501]
- **Set the workstation pitch ceiling (`P_line`) slightly below good-output takt and keep it distinct from bundle release pitch (`P_batch`).** Ensure every workstation's assigned per-piece operating time obeys `C_k ⩽ P_line < T_takt` on the operator balance chart. [S16] [S0502] [S0503]
- **Respect topological precedence and machine compatibility before chasing flat bar heights.** Never combine operations that violate seam sequence or force an operator to switch machines without measuring the changeover penalty. [S15] [S16]
- **Locate the constraint from utilisation and upstream WIP, then subordinate upstream release to the constraint's throughput.** Use highest sustained station utilisation and largest upstream buffer to identify `BN_k`, relieve `BN_k`, and stop upstream stations from building queues that lengthen throughput time under Little's Law. [S20] [S22] [S30]

> **WARNING**
>
> A static line balance calculated from standard minutes remains an engineering hypothesis until it survives contact with the live crew, equipment fleet and power supply. Three floor conditions will invalidate a paper balance within hours: assigning operations without adjusting for the operator's skill level and learning curve on that task; ignoring shared-machine limits when two workstations require the same speciality attachment; and failing to rebalance when absenteeism, thread faults or power interruptions shift the bottleneck to a new station. [S06] [S15] [S20] Resolving those three constraints requires skill-adjusted time standards (Chapter 6), resource-constrained balancing and trial validation (Chapter 7), and dynamic hourly bottleneck control (Chapter 8). [S12] [S15]

A line moves at the pace of its constraint; busyness elsewhere only sews a longer queue.

CHAPTER SOURCE NOTES

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S30 Lean Enterprise Institute. 2006-09-08.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

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R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.

S37 International Labour Organization, SCORE and SIRAYE. 2022-06-01.

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06

PART II: BALANCE WORK TO THE CONSTRAINT / THE HUMAN TIME STANDARD

Skill and learning change the balance before the layout does

A workstation assignment is feasible only when the operator can perform the method safely and repeatedly at the assumed cycle and quality.

CHAPTER 06
DECISION TEST

A workstation assignment is feasible only when the operator can perform the method safely and repeatedly at the assumed cycle and quality.

A sewing line balance is only as real as the human capability behind its operation times. When an engineer allocates operations across workstations using a single nominal Standard Minute Value (SMV) per step, the paper balance assumes that every operator executes the same motion sequence at the same speed and first-pass quality. On an actual garment floor, where output depends on employee execution rather than automated cycles alone [S14], station time varies with method stability [S26], task-specific skill ratings from 0 for no skill to 1.5 for full proficiency [S17], learning across the first six weeks [S18], action and cognitive complexity [S0601], and early attrition that can remove almost one-third of new entrants within six months and half within the first year [S39]. Before moving machines, a factory must anchor time study in standard work [S26], adjust station capacity for measured skill and learning curves, pair task difficulty with verified proficiency [S19], build targeted cross-training around fragile operations, and model turnover replacement explicitly.

This sequence matters directly to garment industrialisation in Cameroon. Moving the sector from its baseline of roughly 5 per cent local cotton processing and 95 per cent raw fibre export toward the 50 per cent national target by 2030 requires factories that convert installed sewing heads into saleable garments [R06] [R07]. Reported capacity utilisation at incumbent plants ranged from 10.83 per cent at CICAM 2 to 33.7 per cent at Garoua and 48.9 per cent at CICAM 1 in the July 2023 account, with underutilisation costing about CFAF 2 billion in 2020 [R12]. Operating within Cameroon's statutory 40-hour working week, 48-hour maximum and 1.2 overtime multiplier [R16], and recruiting from a labour market where roughly 90 per cent of employment is informal [R16] and the statutory minimum wage rose by 5 per cent to XAF 43,969 per month (about US$76) from 23 February 2024 [R14], a sewing room cannot assume that new cohorts will immediately achieve textbook standard times. In GFT's Cameroon textile programme, unit economics depend on how safely a line converts attended hours into good earned standard minutes.

6.1

Standard work creates the baseline for time study

An operation bulletin is a sum of operation standard times, where the garment SMV equals the sum of the SMVs for all steps required to produce the garment [S13]. Yet a stopwatch average taken before the work method is stabilised measures only the dispersion of operator improvisations. Standardised work establishes the documented process across shifts, reduces variability, eases training, lowers injury and strain, and provides the baseline for improvement and balancing [S26]. Without it, two operators at identical lockstitch machines can sew the same seam through incompatible handling sequences and visual checks, hiding both the faster safe method and the defect risk in the slower workaround [S26] [S38].

6.2 STOPWATCH AVERAGES WITHOUT A STABLE METHOD RECORD NOISE RATHER THAN CAPACITY

In labour-intensive sewing rooms, production counts and times are still frequently recorded on paper sheets and consolidated at the end of the day, while manual and semi-automatic time capture introduces measurement uncertainty into observed

speeds and short stoppages [S07] [S0602]. Timing an unstandardised operation folds three sources of variation into one mean cycle: micro-method differences in picking, aligning and disposing panels; machine and attachment settings such as presser-foot tension or folder alignment; and unrecorded micro-stops from thread breaks, bobbin changes or bundle defects [S04] [S07]. That average provides neither a clean ideal cycle for Overall Equipment Effectiveness (OEE) performance calculations nor a reliable station load for line balancing [S04] [S15].

To prevent paper standards from distorting the balance, GFT separates method definition from time measurement. Before a stopwatch or power-sensing log enters the operation bulletin, the engineer and supervisor verify five physical conditions: component presentation within normal reach; machine class, needle, feed dog, guide or folder setup; hand hold and re-grip points during the seam; the visual check confirming first-pass quality; and placement for the downstream station [S13] [S26]. Only when the operator repeats that sequence without inline re-stitching or awkward posture does the timing sample describe a repeatable operation [S26] [S38].

6.3 COMPLEXITY AND ERGONOMIC LOAD MUST BE SEPARATED BEFORE ALLOWANCES AND RATINGS ARE FIXED

Sewing operations differ in physical handling and cognitive attention as well as seam length. Empirical research on women's windbreaker assembly across 96 main sewing processes performed by 7 standard sewing workers from June to September 2021 demonstrates that action complexity and cognitive complexity are significantly correlated with both sewing operation time fluctuation and sewing defect rates [S0601]. When an operation requires contour alignment, multi-layer matching or speed modulation around corners, the operator processes more visual and tactile cues per cycle, widening cycle variance and raising defect probability [S0601].

Workstation ergonomics simultaneously governs whether an observed pace can be sustained across a full shift. Comparative analysis of sitting and standing workstations in Ethiopian garment factories confirms that sewing operator safety is vital and that poor ergonomics causes long-term health risks [S38]. A brief stopwatch study over ten cycles can capture a sprint achieved through forward trunk flexion, elevated shoulders or skipped recovery pauses. Codifying that sprint with a flat allowance makes the station appear balanced in the morning and turn into the bottleneck by afternoon as fatigue slows the cycle and increases repair work [S04] [S38].

METHOD

Work-measurement boundary for sewing SMV and station cycle time

1. **Method lock:** Document component presentation, machine class, guide or folder, needle and thread specification, hand sequence, inline quality check and disposal path under standard work before timing [S13] [S26].
2. **Sample boundary:** Measure cycle time from initial reach for the next component to placement at the exit point, matching workstation residence in balancing [S15]. Log starvation, breakdown and changeover separately in the availability and micro-stop loss tree [S04] [S07].
3. **Complexity and skill tag:** Record the task's Level of Difficulty (LD), action and cognitive complexity attributes, and the operator's Level of Skill (LS) on that operation and machine [S19] [S0601].
4. **Performance rating and ergonomic check:** Apply pace rating only when the operator follows the standard method within safe posture and reach limits [S26] [S38].
5. **Allowances and quality qualification:** Add relaxation, personal, machine-delay and bundle-handling allowances to normal time to form the operation SMV [S13]. Qualify the standard only when the sample meets the first-pass quality threshold without inline repair [S04] [S0601].

Exhibit 25, p. 93 sets out the method record required before an operation time enters the balancing studio.

EXHIBIT 25 / METHOD RECORD FIELDS

A time standard needs more than a stopwatch average

Field group	Recorded specification	Balancing and OEE consequence	Verification rule
1. Standard method	Component pick, alignment, seam path, trim and disposal sequence	Prevents averaging incompatible operator workarounds into one SMV	Video or direct observation across shifts (S26)
2. Machine and tooling	Machine class, stitch density, folder or guide, needle and feed setup	Separates attachment gain from human skill difference	Physical setup check before timing starts (S13)
3. Task difficulty (LD)	Action and cognitive complexity tier, contour and matching demands	Identifies operations prone to cycle fluctuation and defects	Complexity scoring and variance check (S19; S0601)
4. Operator skill (LS)	Task-specific rating (0 to 1.5 scale), machine familiarity and recency	Converts nominal SMV into expected station cycle time	Audited skill matrix and recent output log (S17; S19)
5. Rating and allowance	Observed pace rating, personal, fatigue and unavoidable delay percentages	Protects sustainable pace and ergonomic recovery across the shift	Posture review and allowance disclosure (S13; S38)
6. Quality and sample gate	Sample count, cycle mean and variance, first-pass yield during timing	Ensures speed is not achieved by passing defects downstream	Zero unrecorded rework inside timed sample (S04; S0601)

ILLUSTRATIVE [S13] [S19] [S26] [S0601] Illustrative GFT method-sheet structure synthesising standard work documentation (S26), garment SMV decomposition (S13), task difficulty and operator skill classification (S19), and action/cognitive complexity controls (S0601).

As **Exhibit 25**, p. 93 shows, a time standard is an engineering contract rather than a single number. It establishes what must remain true on the floor for the SMV to hold, while leaving operator-specific cycle adjustment to the skill matrix in **Section 6.4**, p. 93.

6.4

Skill-adjusted times prevent paper balancing

Even when standard work is documented and the reference SMV is measured on a qualified operator, a sewing line is staffed by individuals with unequal experience across machines and garment components. Garment balancing research rejects the identical-worker assumption: following the skill table of Chan et al., workers' performances for each task are rated from 0 (no skill at all) to 1.5 (fully skilled) [S17]. When an engineer balances a line on paper using only the base SMV, a 0.90-minute operation is treated as consuming 0.90 minutes regardless of who sits at the machine. If the assigned operator holds a skill rating of 0.75 on that operation, the realised cycle approaches 1.20 minutes, breaching a 1.00-minute pitch constraint and turning a nominally balanced station into the active bottleneck [S16] [S17] [S20].

6.5 TASK-SPECIFIC PROFICIENCY ALTERS EFFECTIVE STATION CYCLE TIME

In a multi-objective sewing line balance, the operating time of each process in any workstation must not exceed the assembly-line pitch time [S16]. Let `T_j` denote the reference standard time for operation `j` under standard work, and let `s_ij` (above 0 up to 1.5) denote the verified skill factor of operator `i` on operation `j` [S17]. In an explicit skill-adjusted capacity model, the expected effective processing time `t_ij` follows the illustrative relationship `t_ij = (T_j / s_ij) * (1 + r_ij)` [S04] [S17], where `r_ij` is an illustrative inline rework or micro-stoppage penalty reflecting speed and defect losses [S04] [S0601]. Under this illustrative model, an operator rated at `s_ij = 1.00` with zero inline repair completes a 0.90-minute operation in 0.90 minutes; a specialist at `s_ij = 1.20` completes it in 0.75 minutes; and an operator at `s_ij = 0.75` with a 5 per cent adjustment penalty requires `0.90 / 0.75 * 1.05 = 1.26` minutes.

Suppose the governing pitch time is 1.00 minute per garment [S16]. On a spreadsheet listing only `T_j = 0.90` minutes, the station appears to have 10 per cent headroom. Once the actual assignment (`s_ij = 0.75`, `t_ij = 1.26` minutes) is substituted, the station delivers at most `60 / 1.26 = 47.6` pieces per hour against a 60-piece rhythm. Work in progress (WIP) builds upstream, downstream stations wait for input items, and workstation OEE falls through equipment-independent starvation and speed loss [S04] [S06] [S20].

6.6 AN AUDITABLE SKILL MATRIX RECORDS CYCLE ATTAINMENT, FIRST-PASS QUALITY AND RECENCY

Many garment factories keep a wall chart grading operators A, B or C by seniority or impression. Such charts fail balancing decisions for three reasons. First, sewing proficiency is operation-specific and machine-specific: an operator fast on a five-thread overlock side seam may have low proficiency on a single-needle lockstitch collar attachment [S17] [S19]. Second, speed without quality is not effective capacity: OEE counts only defect-free output, and high action or cognitive complexity increases both time fluctuation and defect rates when skill is low [S04] [S0601]. Third, manual sewing skill degrades when unused; operators returning after a long gap do not immediately resume peak speed [S18].

GFT therefore specifies a quantitative, task-by-operator skill matrix updated from floor evidence:

- **Cycle attainment ratio:** reference operation SMV divided by the operator's sustained median cycle time over a verified sample, mapped onto the 0 to 1.5 skill scale [S17].
- **First-pass quality qualification:** whether the operator maintains first-pass yield above the operation's threshold (such as an illustrative 98 per cent floor) without creating downstream repair [S04].
- **Complexity tier cleared:** the highest action and cognitive complexity level at which the operator has demonstrated stable cycle variance [S19] [S0601].
- **Recency decay flag:** weeks since the operator last ran the operation for a full shift, flagging cells where a refresher ramp is needed [S18].

Exhibit 26, p. 95 illustrates how a task-specific skill matrix exposes structural fragility across a six-operation garment sub-line staffed by eight operators.

EXHIBIT 26 / ILLUSTRATIVE SKILL SCORE (0 TO 1.5 SCALE)

A skill matrix exposes fragile operations

	Op A	Op B	Op C	Op D	Op E	Op F	Op G	Op H
Op 1: Placket fuse & press	1.3	1.1	0.9	0	0.8	0	1	0.7
Op 2: Placket stitch (lockstitch)	1.1	1.3	1	0.8	0	0.6	0.9	0
Op 3: Collar attach (high LD)	0	0.6	1.4	0	0	0	0.5	0
Op 4: Shoulder join (overlock)	0.9	1	0.8	1.3	1.2	1	0	0.9
Op 5: Sleeve set (contour LD)	0	0	0.7	0.6	1.3	0	0.8	0
Op 6: Bottom hem (coverstitch)	0.8	0	0	1.1	0.9	1.2	1.1	1

Cell scale: 0 to 1.4

ILLUSTRATIVE [S17] [S19] Illustrative operator-by-operation matrix using the 0 (no skill) to 1.5 (fully skilled) rating scale reported in S17 and the task difficulty / operator skill (LD/LS) staffing principle in S19. Scores combine cycle attainment and first-pass quality qualification; 0 indicates no qualified capability.

In **Exhibit 26**, p. 95, every operator has at least one task rated at or above 1.0 on the 0 to 1.5 scale [S17], yet row inspection reveals immediate fragility. Operation 3 (collar attach, a high-difficulty contour task) has only one specialist (Operator C at 1.4), while backups score 0.6 and 0.5. Operation 5 (sleeve set) has only one specialist above 1.0 (Operator E at 1.3) and three partial backups between 0.6 and 0.8. If Operator C is absent, the collar station drops from 1.4 proficiency to 0.6, more than doubling station cycle time and starving downstream stations. How quickly a 0.6 backup climbs toward 1.0 depends on the empirical learning curve in **Section 6.7**, p. 95.

6.7

Learning curves belong in ramp capacity

Industrial engineers distinguish between startup and steady state, yet line balances are usually calculated as static snapshots. Every garment line experiences mini-ramps whenever a new cohort is hired, an operator moves to an unfamiliar operation, or a style change alters fabric handling [S17] [S18]. Treating early-week output as fixed capability causes supervisors to over-man easy stations or declare a balance infeasible before learning occurs; assuming week-six proficiency in week one guarantees missed deliveries [S18].

6.8 SIX-WEEK CAPACITY GAINS SHOW WHY WEEK-ONE OUTPUT CANNOT SIZE THE STEADY-STATE LINE

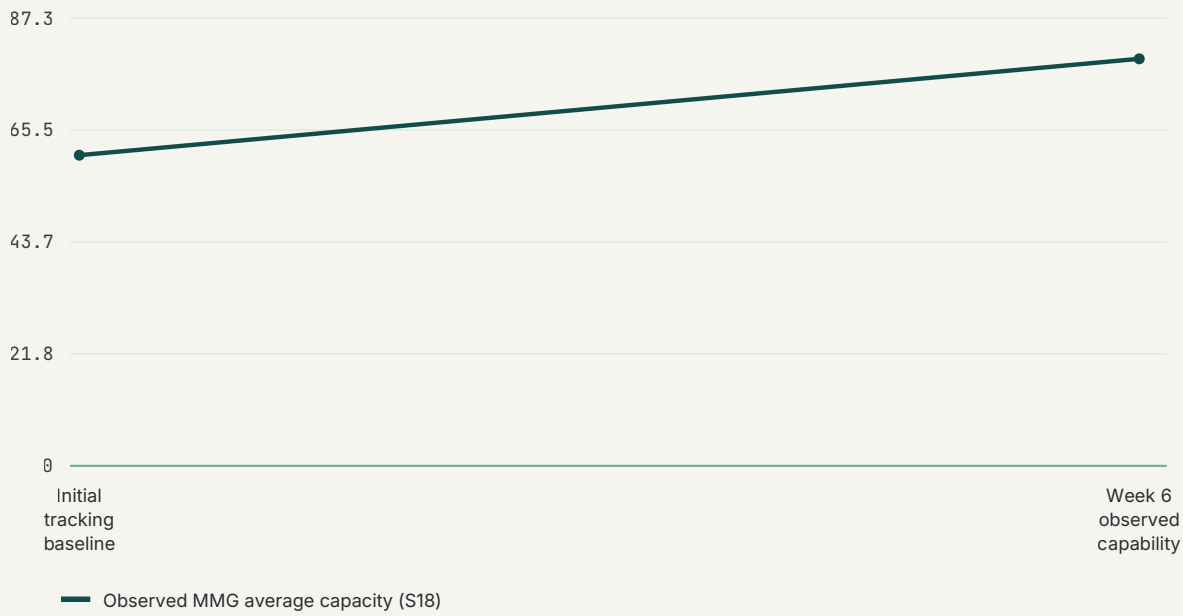
Empirical tracking of manual sewing operators shows how substantially human capacity shifts without any layout or machinery change. In an apparel study evaluating manual skill and learning, the average capacity percentage of the Manual Machine Group (MMG) increased from 60.6 per cent to 79.4 per cent over six weeks, gaining 18.8 percentage points through learning alone [S18]. Over six weeks, the same oper-

ators at the same manual machines delivered nearly one-third more effective output (`79.4 / 60.6 = 1.310`, or 31.0 per cent relative gain) as coordination, pedal control and handling stabilised [S18].

Exhibit 27, p. 96 plots the sourced baseline and six-week achieved capacity from that study.

EXHIBIT 27 / AVERAGE OPERATOR CAPACITY (PER CENT)

Learning can raise operator capacity without a layout change



SOURCED [S18] Sourced endpoints from S18: Manual Machine Group (MMG) average capacity increased from 60.6 per cent at initial tracking to 79.4 per cent after six weeks (+18.8 percentage points, or 31.0 per cent relative gain). Single-study scope; not a universal forecast for all garment styles or cohorts.

Exhibit 27, p. 96 carries two lessons for balancing. First, a station under-capacity in week one may be moving along a normal learning curve rather than suffering from a broken layout. Splitting the operation across two machines in week one creates excess capacity by week six when the operator reaches 79.4 per cent capability [S18]. Second, a schedule promising steady-state volume from day one ignores the 18.8-percentage-point gap between initial and six-week performance [S18]. Because **Exhibit 27**, p. 96 reflects one study, each factory must log its own cohort progression by complexity tier.

6.9 RAMP TRACKING MUST VERIFY FIRST-PASS YIELD ALONGSIDE SPEED

A learning curve measured solely in pieces per hour is dangerous because operators under quota pressure can speed up cycles by relaxing seam tolerances, skipping back-tacks or passing misaligned plies downstream [S0601]. When action and cognitive complexity are high, time fluctuation and defect rates move together [S0601]. Within OEE, quality loss multiplies availability and performance directly [S04]. If a trainee raises raw piece speed by an illustrative 15 per cent between week one and week three while repair and reject rates rise from 2 per cent to 14 per cent, net good throughput barely changes while unpicking disrupts downstream stations [S04] [S12].

GFT's ramp-planner discipline tracks **good earned standard minutes per attended hour** alongside **first-pass yield (FPY)** and **cycle dispersion**:

- **Stage 1 (Method acquisition, illustrative Days 1 to 5):** The operator learns the hand sequence, trim points and quality self-check under standard work [S26], prioritising zero method deviations and first-pass quality even at 50 to 60 per cent cycle attainment [S18] [S26].
- **Stage 2 (Rhythm consolidation, illustrative Weeks 2 to 4):** As repetition lowers cognitive load, micro-pauses shrink [S18] [S0601]. The supervisor verifies that cycle variance narrows without raising defects per hundred units [S12] [S0601].
- **Stage 3 (Target proficiency and balance lock, illustrative Weeks 5 to 6):** As capacity reaches the 75 to 80 per cent range observed in the six-week study [S18], the engineer updates the skill matrix (**Exhibit 26**, p. 95) and re-checks the balance so faster upstream stations do not flood the constraint with WIP [S20].

6.10

Task difficulty and skill jointly inform assignment

Line balancing is often treated as a one-dimensional packing problem: sort operations by precedence, slice standard times into buckets below takt or pitch time, and assign one worker per bucket [S15] [S16]. Garment research shows why that fails. In a study on remote sensing of sewing work levels, researchers established that the **Level of Difficulty (LD)** of the unit process and the **Level of Skill (LS)** of the operator are the first factors to be considered when designing garment production lines and determining staffing requirements [S19]. Assigning a high-LD operation to a low-LS operator, or placing a rare high-LS specialist on a trivial low-LD seam while a complex operation starves, misallocates the line's scarcest capacity resource [S17] [S19].

6.11 LEVEL OF DIFFICULTY AND LEVEL OF SKILL GOVERN STAFFING BEFORE THE LINE STARTS

The windbreaker complexity study divides sewing complexity into physical action complexity (reach, grasp, alignment, guiding and trimming) and cognitive complexity (information processing as plies stretch, shift or curve) [S0601]. On a low-difficulty operation, such as a straight two-ply seam, both action and cognitive complexity are low; the gap between a novice at 0.70 and a veteran at 1.30 is modest, and cycle variance is tight [S17] [S0601]. On a high-difficulty operation, such as setting a contoured sleeve or attaching a collar with matching notches, cognitive and action complexity are simultaneously high [S0601]. An under-skilled operator suffers slower sewing bursts, longer hesitation pauses to realign plies, and higher defect rates [S19] [S0601].

Consequently, the balancing rule is to **match operation difficulty to crew skill so effective cycle time and variance at high-LD operations remain inside the pitch boundary** [S16] [S19]:

- **High-LD operations on the critical path** receive the highest-LS operators first, even when nominal SMV is below average station load, because variance and rework at a high-LD station propagate queues upstream and starvation downstream [S19] [S20] [S0601].
- **Medium-LD operations** are paired with solid 1.0-rated operators and serve as the supervised training ground where 0.8-rated operators build proficiency [S17] [S18].
- **Low-LD operations** absorb newer entrants during their six-week learning curve without endangering quality or destabilising the constraint [S18] [S19].

6.12 POWER SENSING AND DIGITAL LOGS ASSIST OBSERVATION WITHOUT REPLACING WORKER CONSULTATION

Recent garment engineering research shows how to augment manual work study objectively. In the remote-sensing study, researchers attached power-monitoring sensors to sewing machines to capture electrical current waveforms during sewing cycles, extracting working times, consistency and stoppage patterns to classify task difficulty (LD) and operator skill (LS) quantitatively [S19]. Similarly, a low-cost Internet of Things (IoT) architecture using radio-frequency communication and data analytics replaces end-of-day paper tally sheets with real-time station productivity monitoring [S0602].

Motor-power traces and station timestamps reveal whether a 45-second station cycle consists of one smooth run or three hesitant bursts interrupted by fabric realignment [S07] [S19] [S0602]. However, GFT enforces a strict diagnostic boundary:

- **What electrical or cycle sensing can detect:** active motor-running duration versus handling pause duration, cycle-to-cycle variance, micro-stoppage frequency, and learning-curve convergence [S07] [S18] [S19].
- **What sensing cannot detect on its own:** whether a longer handling pause came from poor cut-panel tolerances, a dull needle, an uncalibrated folder, an awkward table height causing shoulder pain, or an unrecorded inline repair [S04] [S26] [S38].

> **GFT NOTE**
>
> **Use machine current and cycle timestamps to locate variance, then walk to the station before changing the standard or the operator grade.** In GFT's Cameroon textile programme, digital and edge monitoring are staged after manual definitions and standard work are running cleanly. When power monitoring or hourly piece logs show high cycle fluctuation at a sewing station [S19] [S0602], the supervisor and engineer must first inspect cut-piece quality, machine adjustment, attachment alignment and workstation ergonomics with the operator [S26] [S38]. Never downgrade an operator's skill rating or tighten a time standard from a remote sensor trace alone.

6.13

Cross-training creates protective flexibility

Once operations are classified by difficulty and operators by skill, the engineer must decide how many tasks each operator should perform and where cross-training should be targeted. While flexible task combinations help a line adapt to changing conditions, garment assembly-line research reveals a critical trap: moving operators from single-task stations into multitasking mode without accounting for task-specific skill disparities can make the line perform worse [S17].

6.14 INDISCRIMINATE MULTITASKING DEGRADES PERFORMANCE WHEN SKILLS ARE UNEVEN

The meta-heuristic garment balancing study by Chen et al. tested single-tasking and multitasking modes using real garment operation standards and the 0 to 1.5 worker skill table [S17]. When the researchers shifted 30 per cent of the labour force from single-tasking into multitasking mode across tasks where workers had disparate skill levels, overall assembly-line performance deteriorated [S17]. Indiscriminate multitasking hurts a sewing line through three mechanisms: 1. **Skill dilution across dissimilar machines:** An operator rated at 1.25 on an overlock seam may score 0.65 on a coverstitch or buttonhole machine [S17]. Splitting that hour replaces 1.25-level output on the primary task with 0.65-level output on the secondary task, plus machine transition time [S11] [S17]. 2. **Cognitive switching and setup loss:** Alternating between different seam geometries increases cognitive complexity and interrupts the muscle memory that drives the six-week learning curve from 60.6 to 79.4 per cent capacity [S18] [S0601]. 3. **Hidden queue amplification:** When a multitasking operator stays too long at a secondary station due to lower skill or thread adjustment, the primary station starves its downstream neighbour, creating oscillating WIP waves [S20].

6.15 TARGETED VERSATILITY PROTECTS THE CONSTRAINT AND HIGH-COMPLEXITY OPERATIONS

Cross-training creates value when **protective versatility** is built around the operations that govern line throughput. In garment bottleneck analysis, system throughput is governed by the bottleneck workstation, identifiable by sustained high utilisation or the largest upstream WIP buffer [S20]. If that bottleneck is also a high-difficulty (high-LD) operation with only one qualified specialist, as in Operation 3 of **Exhibit 26**, p. 95, any absence, fatigue dip or turnover event at that single chair reduces the output of the entire line [S19] [S20] [S39].

GFT governs cross-training through three design rules:

- **Rule 1 (Minimum 2-deep qualification at every high-LD and constraint operation):** Every operation in the top difficulty tier or within 10 per cent of pitch time must have at least one primary operator rated at least 1.0 and two cross-trained backups rated at least 0.9 on the 0 to 1.5 skill scale, verified on first-pass quality [S16] [S17] [S19].
- **Rule 2 (Adjacent-operation pairing along precedence boundaries):** Cross-training pairs adjacent operations in the bulletin that share similar machine handling, so an operator can absorb a 0.15-minute to 0.25-minute workload slice during rebalancing without losing rhythm [S13] [S15] [S17].

- **Rule 3 (Scheduled skill-retention rotation):** Because manual skill degrades when unused [S18], backup operators run their secondary high-LD operation for a scheduled block (such as an illustrative two hours per week) so their recency flag stays green before an absence occurs.

WORKED EXAMPLE

Skill-adjusted balancing and targeted cross-training on an illustrative 6-operation garment sub-assembly

Consider an illustrative 6-operation sub-assembly (matching **Exhibit 26**, p. 95) over 450 planned production minutes (480 shift minutes less 30 planned non-production minutes). Required good output is 450 pieces per shift, setting target takt and pitch time at `450 / 450 = 1.00` minute per good piece [S15] [S16]. Reference SMVs (T_j) under standard work [S13] [S26] are: Op 1 = `0.78` min; Op 2 = `0.88` min; Op 3 (Collar attach, high LD) = `0.95` min; Op 4 = `0.80` min; Op 5 (Sleeve set, high LD) = `0.92` min; and Op 6 = `0.85` min, summing to `5.18` standard minutes per piece [S13].

1. **Case A (Paper balance, $s_{ij} = 1.00$ everywhere):** With 6 operators, the highest nominal station time is Op 3 at `0.95` minutes, within the `1.00`-minute pitch limit [S16]. Nominal balance efficiency is `5.18 / (6 * 0.95) = 90.88` per cent [S15], and the line appears capable of 450 good pieces per shift.
2. **Case B (Unadjusted reality when specialist Op C is absent):** Operators A, B, D, E and F run Operations 1, 2, 4, 5 and 6 at qualified ratings (`1.3` to `1.2`), keeping their cycles between `0.60` and `0.71` minutes. Operator C (`1.4`) is absent, and untrained backup Operator G runs Op 3 at $s_{G3} = 0.50$ [S17] with an illustrative 8 per cent repair penalty ($r_{G3} = 0.08$). Effective cycle time at Op 3 becomes `(0.95 / 0.50) * 1.08 = 2.052` minutes, capping output at `450 / 2.052 = 219.3` (**219 good pieces**) and dropping SMV line efficiency across `2,700` attended minutes from `86.33` to **42.02 per cent** [S13] [S20].
3. **Case C (Indiscriminate multitasking):** Operator B ($s_{B2} = 1.3$) walks between Op 2 and Op 3 to help Operator G, but holds only $s_{B3} = 0.60$ on Op 3 with an illustrative 12 per cent switching loss [S17] [S0601]. Spending 112.5 minutes at Op 3 at `(0.95 / 0.60) * 1.12 = 1.773` minutes per piece adds only `63.5` pieces (**282 pieces** total, 37.3 per cent below target).
4. **Case D (Targeted six-week cross-training on Op 3):** Putting Operator G through a six-week cross-training progression on Op 3, reflecting the `1.310` relative learning gain (`60.6` to `79.4` per cent in six weeks [S18]) and continuing practice to $s_{G3} = 0.95$ with $r_{G3} = 0.02$, reduces backup cycle time to `(0.95 / 0.95) * 1.02 = 1.02` minutes. Output rises to `450 / 1.02 = 441.2` (**441 good pieces**, 98.0 per cent of target), recovering `222` good pieces (`1,149.96` earned SMV) per shift without layout changes.

6.16

Turnover repeatedly resets the learned line

Even the best standard work, skill matrix and six-week ramp plan will fail to sustain high utilisation if trained operators leave as fast as they reach proficiency. In feasibility models, labour is often represented as a static headcount multiplied by a monthly wage. Empirical manufacturing evidence from Africa shows why that assumption is operationally false: in a panel study of the Ethiopian manufacturing industry

(concentrated in textile and garment parks), **almost one-third of workers left before the first six months and half left within the first year** [S39]. When half of a cohort exits within twelve months, the factory runs a training school whose graduates leave just as their learning curve matures [S18] [S39].

6.17 EARLY ATTRITION TURNS STATIC WORKFORCE ASSUMPTIONS INTO RECURRING CAPACITY LOSS

Consider the interaction between the six-week learning curve [S18] and the six-month and twelve-month attrition rates [S39]. An operator entering at 60.6 per cent capacity and reaching 79.4 per cent at week six is only consolidating full 1.0-to-1.5 proficiency and secondary cross-training between months two and six [S17] [S18]. If almost one-third of the cohort exits before month six and half before month twelve [S39], three compounding losses hit the balance: 1. **Direct station derating:** Each departed 1.0-rated operator is replaced by a recruit starting near the 60.6 per cent baseline [S18], pulling down effective station cycle time by an illustrative 25 to 35 per cent unless buffered by a cross-trained reserve. 2. **Constraint migration and balance decay:** Because turnover does not strike stations evenly, a cluster of exits in collar, sleeve or placket operations shifts the bottleneck from week to week, invalidating fixed allocations and inflating upstream WIP buffers [S15] [S20]. 3. **Supervisory and training diversion:** Experienced supervisors and 1.3-rated operators spend shift minutes demonstrating standard work, unpicking trainee defects and re-allocating tasks rather than maintaining flow [S26] [S40].

Exhibit 28, p. 102 surfaces the sourced empirical anchors from the Ethiopian manufacturing turnover panel [S39] alongside the six-week manual learning ramp [S18] and the ILO Asian garment toolset results [S12] so planners can inspect the human parameters that bound line capacity.

EXHIBIT 28 / SOURCED EMPIRICAL INDICATORS

Early attrition can repeatedly restart the learning curve

~1/3

Left before 6 months

Almost one-third of studied Ethiopian manufacturing workers exited within six months (S39)

50%

Left within 1 year

Half of studied workers left within the first year in the Ethiopian panel (S39)

60.6%

Initial MMG capacity

Average initial capacity of the Manual Machine Group in sewing evaluation (S18)

79.4%

Week 6 MMG capacity

Average capacity after six weeks of learning on manual sewing machines (S18)

+9.49%

ILO line achievement gain

Sewing-room line achievement improvement in ILO Factory Improvement Toolset report (S12)

-22%

ILO WIP and defect reduction

Reduction in both WIP and defects per hundred units in the ILO garment programme (S12)

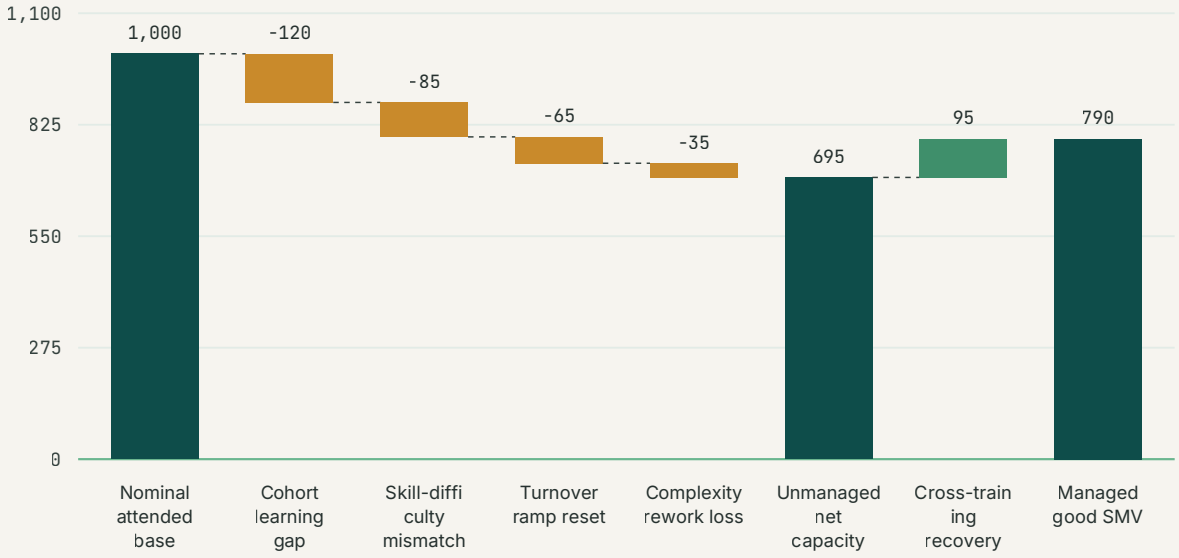
SOURCED [S12] [S18] [S39] Sourced figures from three distinct studies: Ethiopian manufacturing turnover panel (S39), six-week manual sewing capacity tracking (S18), and ILO Factory Improvement Toolset Asian garment programme (S12). Scope and geography differ; not a Cameroon forecast.

The quantities in **Exhibit 28**, p. 102 require strict methodological discipline. The turnover fractions (~1/3 within six months and 50% within one year) come from a panel of Ethiopian manufacturing workers [S39], while the 60.6% to 79.4% ramp comes from a specific manual-machine evaluation [S18]. Neither figure is a Cameroon statistic; both prove that assuming zero turnover and instant proficiency omits a major capacity loss.

To show how skill distribution, learning ramps, inline quality repair and early turnover replacement jointly reduce nominal labour capacity to effective good earned minutes, **Exhibit 29**, p. 103 presents a derived capacity bridge on an illustrative 1,000-standard-minute shift base.

EXHIBIT 29 / ILLUSTRATIVE EARNED STANDARD MINUTES PER SHIFT

Skill gaps, learning ramps and early turnover derate nominal earned minutes



DERIVED [S04] [S13] [S17] [S18] [S39] Derived with illustrative inputs on a 1,000-minute nominal shift base: -120 SMV for initial cohort learning gap (S18 mechanism), -85 SMV for unadjusted skill-to-difficulty mismatch (S17), -65 SMV for early turnover replacement reset (S39), -35 SMV for complexity defect rework (S04), +95 SMV recovered via targeted cross-training and standard work = 790 net good earned minutes.

In **Exhibit 29**, p. 103, starting from an illustrative 1,000 attended labour minutes, an unmanaged line loses 120 minutes to the novice-to-steady-state gap [S18], 85 minutes to placing lower-skilled workers on unbuffered bottleneck tasks [S17], 65 minutes to replacing early leavers who restart the learning curve [S39], and 35 minutes to complexity rework [S04] [S0601], leaving 695 net good earned minutes (a 30.5 per cent human-capability derating before machine breakdown or power outage). Applying standard work, skill-adjusted balancing and targeted cross-training recovers an illustrative 95 standard minutes (+13.67 per cent over the unmanaged baseline), lifting net capacity to 790 earned standard minutes per 1,000 attended minutes.

6.18 RETENTION, REALISTIC ONBOARDING AND SUPERVISOR CAPABILITY PROTECT LEARNED STANDARD MINUTES

In the UNU-WIDER Ethiopian manufacturing study, survey data and qualitative interviews identified three primary drivers of high turnover: **unrealistic expectations about wages and work efforts, poor working conditions, and difficulties combining domestic responsibilities with factory employment** [S0603]. Each driver intersects with how the sewing line is engineered and supervised:

- **Realistic job previews and transparent wage-effort rules:** In Cameroon, where roughly 90 per cent of employment is informal [R16], recruits must see the workstation, standard work sequence, 40-hour statutory schedule and overtime rules [R16], and SMV progression before onboarding so expectations match floor reality [S0603].

- **Ergonomic workstations and humane pacing:** Designing sitting and standing workstations to prevent ergonomic injury [S38] and setting allowances on standard work rather than sprint timing [S26] protect both worker health and six-month retention [S38] [S0603].
- **Predictable shift boundaries and supervisory skill:** Erratic balances that trigger unannounced late shifts worsen work-life conflict [S0603]. Better Work Ethiopia reports that lines led by newly trained supervisors achieved improved productivity, quality and workplace organisation alongside a **reduction of absenteeism** [S40], while the IFC and ILO assessment of the Gender Equality and Returns (GEAR) programme in Bangladesh shows how structured supervisory training for female operators strengthens line performance [S13].

> **WARNING**
>
> **External learning and turnover rates are mechanism evidence, not local Cameroon constants.** Do not copy the 60.6 to 79.4 per cent six-week capacity ramp [S18] or the one-third six-month and 50 per cent one-year turnover rates [S39] into a Cameroon financial model as fixed parameters. Those studies establish that learning curves and early attrition materially alter sewing capacity. To resolve the local values for a Cameroon factory, GFT's pilot protocol requires logging cohort retention at 30, 90, 180 and 360 days alongside weekly earned standard minutes and first-pass yield by operation complexity tier from the first training line.

6.19

How GFT embeds human proficiency into the balancing workflow

In GFT's Cameroon textile programme, human capability is woven into the measurement and balancing spine from the first shift: 1. **Before timing:** Document standard work and verify workstation ergonomics for every operation in the bulletin (**Section 6.1**, p. 90, **Exhibit 25**, p. 93) [S26] [S38]. 2. **Before balancing:** Score each operation's Level of Difficulty (LD) and complexity, and maintain an auditable operator-by-operation skill matrix (**Section 6.4**, p. 93, **Exhibit 26**, p. 95) updated with cycle attainment, first-pass quality and recency [S17] [S19] [S0601]. 3. **During cohort and style ramps:** Size weekly line targets using observed learning curves and first-pass yield gates rather than week-six steady-state SMVs (**Section 6.7**, p. 95, **Exhibit 27**, p. 96) [S04] [S18]. 4. **In station assignment and cross-training:** Pair high-LD bottleneck operations with top-LS operators first, avoid indiscriminate multitasking across disparate skills, and keep at least two cross-trained backups at every fragile constraint (**Section 6.10**, p. 97, **Section 6.13**, p. 99) [S17] [S19] [S20]. 5. **In capacity and workforce planning:** Track 6-month and 12-month retention, absent-station

backup coverage and supervisor training outcomes so learned standard minutes are retained rather than repeatedly lost (**Section 6.16**, p. 100, **Exhibit 28**, p. 102, **Exhibit 29**, p. 103) [S39] [S40] [S0603].

Once operation times are anchored in standard work and adjusted for real operator skill, learning and retention, the engineer is ready to solve the constrained allocation problem across machines, attachments and precedence networks, which the next chapter examines in full.

A balance drawn for an average operator exists only on paper; a balance built on measured skill, learning and safe work runs on the floor.

CHAPTER SOURCE NOTES

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S0601 Elsevier, Heliyon. 2023-02-20.

S39 United Nations University World Institute for Development Economics Research. 2021.

S19 MDPI, Applied Sciences. 2020-04-29.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R16 WageIndicator. Publication date unrecorded; inherited source-text check.

R14 WageIndicator. Publication date unrecorded; inherited source-text check.

S13 International Finance Corporation and International Labour Organization, Better Work. 2025.

S38 Inderscience, International Journal of Human Factors and Ergonomics. 2025-08-07.

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S0602 Cell Press, iScience. 2025-12-24.

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S16 MDPI, Energies. 2019-07-19.

S20 MDPI, Machines. 2023-11-02.

S06 IEEE, IEEE Transactions on Semiconductor Manufacturing. 2005-02-28.

S12 International Labour Organization. 2023.

S11 Elsevier, Heliyon. 2023-12-21.

S40 Better Work, International Labour Organization and International Finance Corporation. 2023.

S0603 United Nations University World Institute for Development Economics Research. 2021.

07

PART II: BALANCE WORK TO THE CONSTRAINT / CONSTRAINTS ARE REAL

Feasible balancing beats a theoretically perfect allocation

A balance that ignores machine availability, skill or precedence can look efficient on screen and fail on the floor.

CHAPTER 07
DECISION TEST

A balance that ignores machine availability, skill or precedence can look efficient on screen and fail on the floor.

A garment factory should never adopt a workstation allocation solely because it maximises mathematical balance efficiency on a planning screen. [S15] An allocation is operationally valid only when every combined task respects operation precedence, fits within the governing pitch time, uses a compatible machine and attachment setup, matches the verified skill of the assigned operator and sustains first-pass quality during a controlled floor trial. [S15] [S16] [S17] Unconstrained paper balances regularly promise workstation reductions and efficiency scores that vanish once real equipment limits, folders and human capability differences are reintroduced. [S15] [S17] In Cameroon, where local cotton processing stands at roughly 5 percent against 95 percent raw export and policy targets 50 percent domestic processing by 2030, capital and supervisory credibility cannot be wasted on layouts that fail on the first shift. [R06] [R07] Reported capacity utilisation at incumbent plants ranged from 10.83 to 48.9 percent in July 2023, proving that factory economics depend on floor execution rather than nominal calculations. [R12] Green Future Tech Limited (GFT) therefore treats line balancing as a constrained engineering discipline: define physical and human boundaries first, use heuristics and simulation to screen options, and require a measured line trial before freezing standard work.

7.1

Balancing seeks flow, not identical activity

Assembly lines remain a primary means of organising series production, yet academic literature has historically concentrated on the simple assembly line balancing problem, which strips away equipment restrictions, parallel stations and operator differences to equalise nominal station times. [S0701] [S0702] On a sewing floor, equalising the sum of standard minute values across workstations is only an arithmetic starting point, never the operational objective. [S10] [S15] Line balancing distributes workload so that garments move through the sequence at the required rhythm without starving the constraint, building excess work in progress or straining operators into producing defects. [S10] [S20] [S30] Chasing a hundred percent nominal balance score by loading every station to the governing cycle limit guarantees that minor variability triggers queues and waiting across the line. [S23]

7.2 NOMINAL TASK EQUALITY MASKS VARIATION ON THE SEWING FLOOR

In a sewing room, overall production performance depends on human execution rather than autonomous machine speed alone. [S14] Two workstations carrying the same nominal standard minute allocation on an operation bulletin behave differently in practice because task difficulty, material handling and operator skill vary across operations. [S13] [S17] [S19] Joining a curved collar or setting a trouser zip demands fine manipulation and alignment adjustments, whereas a straight side seam on an overlock machine shows lower cycle dispersion once plies are matched. [S15] [S19] If both stations are loaded to ninety-eight percent of pitch time in an illustrative paper plan, the complex station will repeatedly breach the pitch boundary whenever thread tension drifts, fabric stiffness varies or the operator pauses to check seam allowance. [S16] [S19]

Operations management theory shows that waiting time rises nonlinearly with capacity utilisation in any variable system. [S23] By Little's Law, average work in progress in a stable system equals average throughput rate multiplied by average throughput

time, so every queue built ahead of a variable station lengthens total throughput time. [S22] In a dependent garment line, loading every station near saturation ensures that natural cycle fluctuations propagate downstream as starvation and upstream as bundle queues. [S20] [S23] Practitioner analysis of one-piece flow and Theory of Constraints confirms that protective excess capacity at non-constraint stations is normal and beneficial when a single constraint governs line throughput. [S28] [S30] A feasible balance therefore protects steady flow through the constraint at the target takt and pitch rather than forcing identical busyness everywhere. [S15] [S16] [S30]

7.3 PROCESS REDESIGN AND WORKSTATION ASSIGNMENT MUST MOVE TOGETHER

Treating line balancing as a combinatorics puzzle obscures the gains available from simplifying work methods before allocating tasks. [S10] [S26] In a 2024 clothing study, researchers redesigned a leggings process sequence and station allocation together; daily output rose from 1,300 to 2,000 leggings per day using the same machines and operators. [S10] Similarly, an International Labour Organization intervention at Edget Garment in Ethiopia raised line-balance efficiency from 24 percent to 75 percent and daily output from 50 to 120 pieces. [S37] Across an Asian garment programme, the International Labour Organization Factory Improvement Toolset recorded an average line achievement gain of 9.49 percent alongside a 22 percent reduction in work in progress and a 22 percent reduction in defects per hundred units. [S12]

These empirical results share one mechanism: effective balancing combines method standardisation, waste removal and realistic workload allocation to release capacity from existing resources while protecting quality and flow. [S10] [S12] [S37] None of those gains came from an unconstrained solver reassigning tasks in isolation from the floor; they required engineers and supervisors to observe the operation breakdown, verify standard work and confirm repeatable execution. [S12] [S26]

7.4

Machine constraints can erase theoretical gains

The most frequent error in spreadsheet balancing is merging two or more operations into one workstation because their standard minute values sum neatly to the target cycle time, while ignoring incompatible sewing machines, stitch types or dedicated mechanical attachments. [S15] In generalized assembly line balancing, equipment selection and resource restrictions fundamentally change the set of valid station combinations. [S0701] [S0702] When a garment factory ignores machine constraints during calculation, the resulting layout either forces an operator to walk between two machines on every garment piece, adding unrecorded handling time that breaks the cycle standard, or forces the supervisor to discard the paper plan at launch and improvise a floor allocation. [S15] [S26]

7.5 UNCONSTRAINED HEURISTICS MISSTATE ATTAINABLE STATION COUNTS

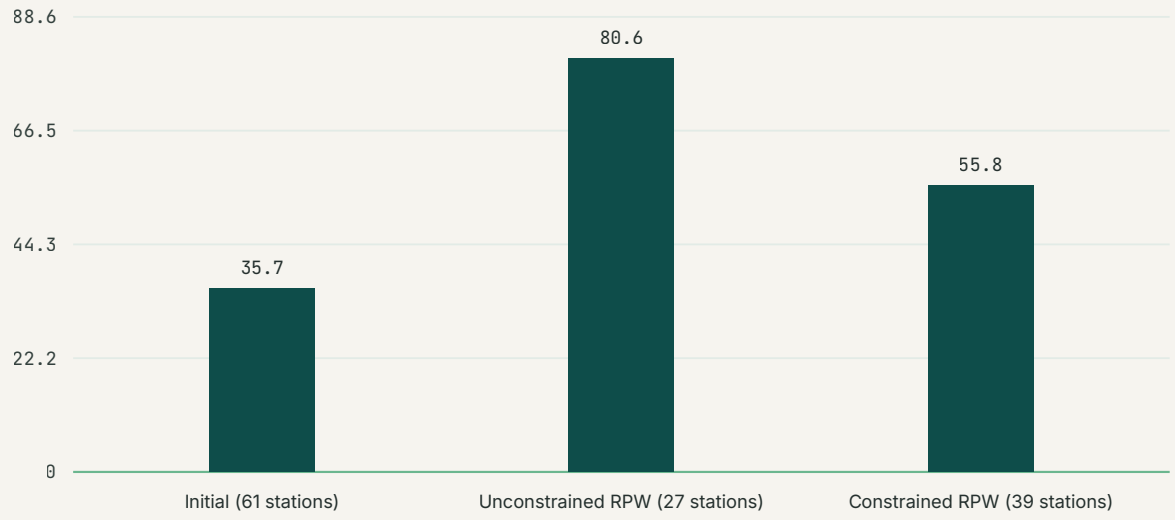
Empirical garment research measures the exact gap between unconstrained mathematical balancing and resource-constrained floor balancing. [S15] In a 2020 trouser assembly line study, industrial engineers applied ranked positional weight to an existing line operating at 35.66 percent line efficiency across 61 workstations. [S15] Solved without resource restrictions, the ranked positional weight algorithm compressed the trouser line to 27 workstations and projected 80.56 percent line effi-

ciency. [S15] When the researchers imposed actual resource constraints reflecting machine types and floor restrictions, the feasible solution required 39 workstations and achieved 55.77 percent line efficiency. [S15]

Exhibit 30, p. 109 compares the three states reported in that trouser-line study: the initial baseline, the unconstrained calculation and the resource-constrained allocation. [S15]

EXHIBIT 30 / PERCENT LINE EFFICIENCY

Resource constraints reduce the apparent balance gain



SOURCED [S15] Sourced from the trouser-line balancing study in S15. Initial configuration recorded 35.66 percent efficiency across 61 workstations; unconstrained ranked positional weight reached 80.56 percent across 27 workstations; imposing resource constraints yielded 55.77 percent across 39 workstations. Single-factory trouser study, not a GFT operating result.

The results in **Exhibit 30**, p. 109 establish two lessons for sponsors and engineers. [S15] First, structured balancing improves an unmanaged baseline: moving from 35.66 percent efficiency with 61 workstations to 55.77 percent efficiency with 39 workstations frees 22 workstations and raises balance efficiency by 20.11 percentage points. [S15] Second, the unconstrained model overstated attainable efficiency by 24.79 percentage points (80.56 percent versus 55.77 percent) and understated required workstations by 12 stations (27 versus 39). [S15] This single-factory study cannot fix a universal ratio for all garments, because the penalty varies with the machine diversity of each style. [S13] [S15] Even so, any capital or staffing plan built on the unconstrained 80.56 percent projection would suffer an immediate twelve-station machine deficit on the floor. [S15]

7.6 MACHINE CLASSES, ATTACHMENTS AND CHANGEOVER BOUNDARIES GOVERN TASK GROUPING

Resource constraints impose a heavy penalty on garment lines because woven trousers and shirts require several machine architectures across the operation bulletin: single-needle and double-needle lockstitch machines, three-thread and five-thread overlock machines, flatlock or feed-off-the-arm machines, bar-tackers, buttonhole machines and button sewers. [S13] [S15] A five-thread overlock operation

cannot share a single-machine station with a lockstitch operation unless the station holds both machines and operator transfer time is included in the standard minute value. [S13] [S15]

Even when consecutive operations use the same base machine class, they often remain incompatible for single-station grouping due to three setup boundaries: [S15] [S26]

- **Mechanical folders, guides and presser feet:** A waistband folder, edge guide or piping attachment is calibrated to a specific seam geometry; unbolting or swinging a folder aside within every cycle ruins rhythm and causes seam defects. [S04] [S15]
- **Needle gauge and thread specification:** Heavy twill panels require a different needle size, thread ticket and tension setting from a pocket bag; combining them forces either an improper stitch specification or constant manual tension adjustment. [S04] [S13]
- **Stitch density and feed calibration:** Operations requiring different stitches per centimetre or differential feed settings cannot share a fixed machine setup without adjustment slowdowns inside the cycle. [S04] [S15]

Every operation in a balancing model must therefore carry a machine-class and attachment-state code. [S13] [S15] Two tasks may share a single-machine workstation only when their machine class, needle gauge, thread colour and attachment state match, or when a multi-machine cell is engineered with measured transfer times included in the workload. [S15] [S26]

7.7

Precedence and pitch bound the search space

Before comparing heuristic rules or running an optimiser, an industrial engineer must formulate the feasible search space mathematically so that the objective function cannot conceal an invalid operation sequence or an overloaded station. [S15] [S16] Two hard boundaries govern every candidate assignment: the technological precedence graph of the garment and the pitch-time ceiling set by required good output. [S13] [S15] [S16]

7.8 FORMAL CONSTRAINTS MUST PRECEDE HEURISTIC SELECTION

In a multi-objective sewing assembly line model published in 2019, process allocation is governed by explicit assignment and time equations: every operation must be assigned to a valid workstation in sequence, and Equation 8 of that formulation guarantees that the operating time of each process in any workstation does not exceed the assembly line pitch time. [S16] Similarly, garment balancing research defines workstation cycle time as the time a job remains in a workstation, bounded by the rhythm required to meet demand. [S15] If an algorithm minimises average balance delay without enforcing a strict ceiling on each station's operating time, it can output an allocation whose average score looks high only because fast upstream stations mathematically offset a downstream station that breaches the pitch limit. [S15] [S16] On a dependent sewing line, fast stations cannot offset a station whose cycle exceeds pitch time: the slowest station becomes the system bottleneck and caps line throughput, while faster upstream stations merely build work-in-progress queues. [S20] [S30]

METHOD

Mathematical boundary of a feasible sewing-line allocation

To prevent paper optimisation from generating invalid layouts, GFT's line-balancing method requires every candidate allocation of bulletin operations across workstations to satisfy five explicit feasibility conditions before its balance efficiency is scored: [S13] [S15] [S16] [S17]

1. **Exclusive and complete assignment:** Every operation in the garment operation bulletin is assigned to a defined workstation (or an engineered parallel station pool), with no operation omitted or duplicated. [S13] [S16]
2. **Technological precedence preservation:** If operation A precedes operation B in garment construction, the workstation index assigned to operation A cannot lie downstream of the workstation index assigned to operation B. [S15] [S0702]
3. **Pitch-time ceiling at every station:** For every workstation, the skill-adjusted total operating time (including any multi-machine transfer allowance) must not exceed the governing assembly line pitch time, following Equation 8 of the multi-objective sewing model. [S16] [S17]
4. **Machine and attachment compatibility:** All operations assigned to a single-machine station must share an identical machine class, needle-and-thread specification and fixed attachment state; otherwise, separate machines must be allocated within the station and bounded by available floor inventory. [S15]
5. **Skill qualification floor:** The operator assigned to each workstation must hold a verified capability rating for every task in that station's assignment that meets both the required cycle time and the first-pass quality threshold. [S04] [S17]

Formulating the problem through this five-part boundary shows why heuristic choice comes second to constraint definition. [S15] [S16] Any allocation that violates one of these five conditions is infeasible and must be rejected regardless of its paper score. [S15] [S16] [S17]

7.9 SUBASSEMBLY CONVERGENCE REQUIRES SYNCHRONISED PITCH CONTROL

Garment precedence graphs are converging trees in which collars, cuffs, sleeve plackets, pockets and body panels are prepared in parallel branches before joining at marriage operations such as shoulder seaming, collar attachment and sleeve setting. [S13] [S15] While parallel branches let early operations run simultaneously, every marriage point enforces a strict synchronisation rule. [S15] [S20] If a collar-preparation station meets its nominal average time only by running large batches or suffers frequent folder adjustments, the collar marriage station will periodically starve for approved collars even while body panels pile up in its buffer. [S06] [S20]

Manufacturing effectiveness research notes that workstation OEE logs capture equipment-independent conditions such as lack of input items. [S06] On a sewing line, starvation at a marriage station is often misread as slow operator pace when its actual cause is an unsynchronised subassembly branch upstream. [S06] [S20] Enforcing pitch-time compliance and small transfer lots across all converging branches ensures that components arrive at marriage stations in matched sets rather than uneven waves of work in progress. [S16] [S21]

7.10

Skill belongs inside the optimisation

Even when precedence, pitch time and machine compatibility are respected, an allocation remains theoretical until it accounts for the people operating the machines. [S14] [S17] Classical line balancing assumes identical workers who execute any assigned task at its nominal standard minute value. [S17] [S0702] On an apparel floor, where sewing is labour intensive and operator dexterity governs stitch speed and handling, two operators assigned to the same operation can differ markedly in cycle time and defect rate. [S14] [S17] [S18]

7.11 WORKER-BY-TASK CAPABILITY MATRICES ALTER THE FEASIBLE FRONTIER

To connect paper standards with floor execution, garment balancing research embeds worker skill ratings directly into meta-heuristic optimisation models. [S17] In a 2021 garment assembly line balancing study, worker performance on each task was rated from 0 (no skill at all) to 1.5 (fully skilled) using an empirical skill table. [S17] Complementary research on remote power monitoring of sewing work stresses that task difficulty and operator skill level are the first factors to consider when designing garment lines and setting staffing requirements. [S19] Moreover, empirical study of manual sewing machine operators shows that group average capacity rose from 60.6 percent to 79.4 percent over six weeks, proving that operator capability changes substantially during ramp-up. [S18]

When skill ratings enter the balancing equations, the effective time required to complete an operation at a workstation is no longer the static bulletin SMV alone; it is the bulletin SMV adjusted by the assigned worker's task-specific skill factor and the operation's difficulty rating. [S13] [S17] [S19] Combining two operations into a multitask station therefore requires an operator who holds verified proficiency across both tasks and can switch seam geometries every cycle without losing rhythm. [S17] [S19] If an operator is fast on straight lockstitch seaming but slow on precision topstitching, merging those tasks to save a fraction of a workstation will push the combined cycle beyond the pitch ceiling and increase rework. [S04] [S17]

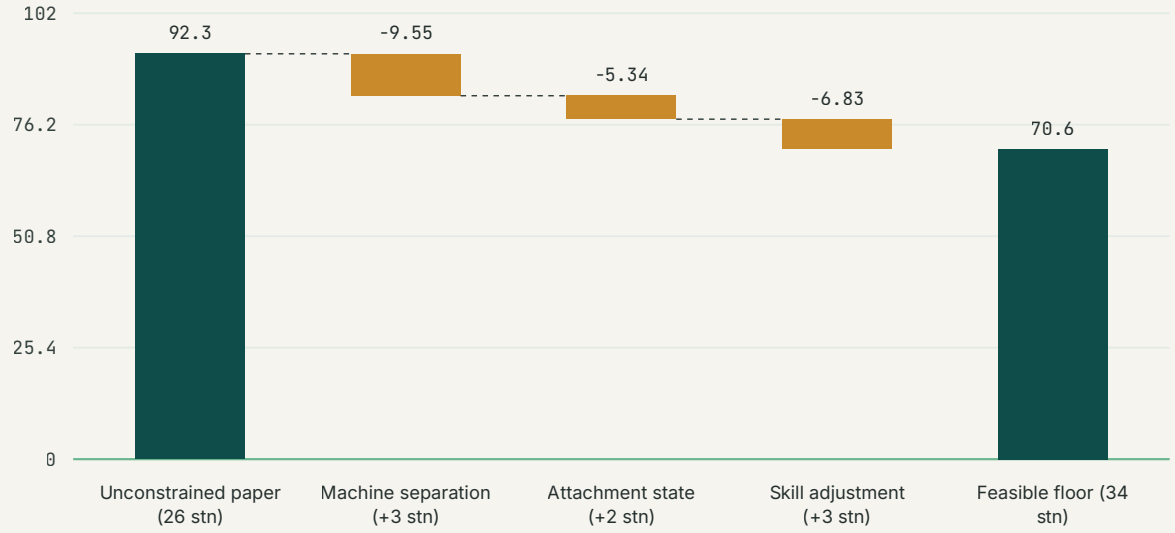
7.12 PROTECTIVE CAPACITY AT CRITICAL OPERATIONS BEATS MINIMAL HEADCOUNT

Once operator skill and task difficulty are modelled inside the allocation, the criterion for a sound balance shifts away from minimising nominal headcount at all costs. [S17] [S28] At a high-difficulty operation on the critical path, such as sleeve setting or collar attachment, loading a moderately skilled operator to ninety-five percent of pitch time invites micro-stops, thread breaks and fatigue. [S04] [S17] [S19] Leaving protective capacity at difficult stations, or splitting a bottleneck across parallel stations with matched folders, protects whole-line throughput against normal human and material variation. [S23] [S28] [S30]

Exhibit 31, p. 113 shows how machine separation, attachment dedication and skill-factor protection step down theoretical balance efficiency into a feasible floor allocation. [S15] [S16] [S17]

EXHIBIT 31 / PERCENT LINE-BALANCE EFFICIENCY

Machine, attachment and skill constraints step down theoretical balance efficiency



DERIVED [S15] [S16] [S17] Derived from an illustrative 12.00-minute garment SMV allocated at a 0.50-minute governing pitch time (theoretical minimum 24 stations). Unconstrained grouping requires 26 stations (92.31 percent efficiency); machine-class separation adds 3 stations to 29 (82.76 percent, minus 9.55 points); folder and attachment dedication adds 2 stations to 31 (77.42 percent, minus 5.34 points); operator skill-factor adjustment adds 3 stations to 34 (70.59 percent, minus 6.83 points). Formula basis from S15, S16 and S17.

The derived bridge in **Exhibit 31**, p. 113 explains why a 70.59 percent feasible balance across 34 workstations outperforms a 92.31 percent unconstrained paper balance across 26 workstations. [S15] [S16] [S17] Each downward step in nominal balance efficiency removes a physical or human impossibility that would otherwise stall the line. [S15] [S17] Because the bridge uses an illustrative 12.00-minute bulletin, it cannot fix the exact percentage steps for every factory style without that style's operation bulletin and crew skill matrix. [S13] [S17]

WORKED EXAMPLE

Reconciling unconstrained paper balance with a feasible crew and machine allocation

Consider an illustrative woven work-shirt line planned to deliver 900 good shirts per 450-minute shift (after deducting 30 minutes of scheduled breaks from a 480-minute day, following [S01] and [S04]). The operation bulletin contains 32 operations whose standard minute values sum to 12.00 minutes per shirt. [S13]

1. **Pitch time and minimum stations:** Dividing 450 planned minutes by 900 required good shirts sets an illustrative pitch time of 450 / 900 = 0.50 minutes per shirt (30.0 seconds), and dividing the 12.00-minute SMV by 0.50 minutes gives a theoretical minimum of 24.0 workstations. [S13] [S15] [S16]
2. **Stage A, Unconstrained allocation:** Enforcing precedence and the 0.50-minute pitch ceiling across indivisible operations requires 26 workstations in this illustrative bulletin, giving 12.00 / (26 × 0.50) = 92.31 percent balance efficiency. [S15] [S16]
3. **Stage B, Machine separation:** Splitting three paper stations that paired incompatible overlock, lockstitch, buttonhole and bartack machines adds 3 stations, raising the line to 29 workstations and reducing efficiency to 12.00 / (29 × 0.50) = 82.76 percent (minus 9.55 points). [S15]
4. **Stage C, Dedicated attachments:** Separating two lockstitch stations that required mid-cycle switching between a hemmer folder and an edge guide adds 2 stations, bringing the count to 31 workstations and efficiency to 12.00 / (31 × 0.50) = 77.42 percent (minus 5.34 points). [S15] [S26]
5. **Stage D, Operator skill adjustment:** Applying the worker-by-task skill table (0 to 1.5 scale in [S17]) shows three operators on collar, sleeve and placket operations working at an illustrative 0.80 skill factor, pushing their effective cycle times to 0.58 minutes above the 0.50-minute pitch ceiling. [S16] [S17] Adding 3 parallel stations brings the feasible line to 34 workstations at 12.00 / (34 × 0.50) = 70.59 percent efficiency (minus 6.83 points). [S15] [S17]
6. **Output consequence:** Staffing the 26-station paper layout would stretch the governing bottleneck cycle to at least 0.65 minutes per shirt, capping shift output at 450 / 0.65 = 692 shirts (208 shirts below target), whereas the 34-station feasible layout holds the 0.50-minute pitch and delivers all 900 good shirts. [S04] [S15] [S16] [S30]

7.13

Simulation is a test bed, not an achieved result

When an engineering team evaluates multiple candidate allocations across varying crew skills, machine counts and buffer limits, discrete-event simulation provides a useful test bed for observing how options behave under variable cycle times before moving heavy equipment on the floor. [S11] A simulation model is an analytical screening tool, however, not an achieved operating result. [S11] Treating a simulated improvement scenario as delivered factory output is a common mistake in both academic papers and capital proposals. [S11]

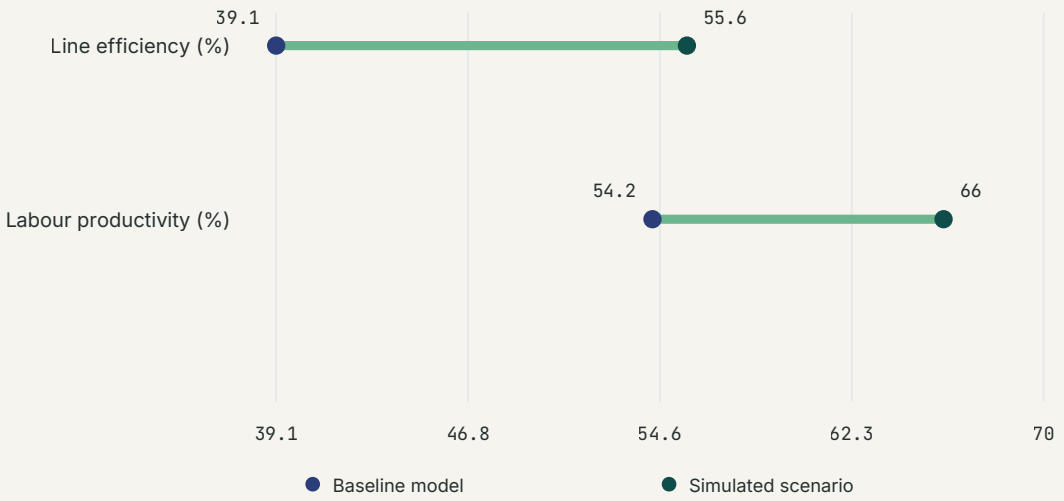
7.14 DISCRETE-EVENT MODELS SCREEN ALTERNATIVES BEFORE PHYSICAL DISRUPTION

In a 2023 study of the Abay garment factory in Gondar, Ethiopia, researchers built a computer simulation model of a polo-shirt sewing line to test balancing scenarios and relieve bottlenecks. [S11] According to the article's abstract, the simulated improved scenario raised daily output from 288 to 381 pieces, increased line efficiency from 39.06 percent to 55.64 percent and lifted labour productivity from 54.25 percent to 66.00 percent. [S11]

Exhibit 32, p. 115 displays the baseline and improved percentage indicators reported in the abstract of that Abay garment simulation study. [S11]

EXHIBIT 32 / PERCENT

Simulation can compare balance scenarios before a line trial



SOURCED [S11] Sourced from the Abay garment simulation study in S11. The abstract reports simulated line efficiency moving from 39.06 to 55.64 percent and labour productivity moving from 54.25 to 66.00 percent, alongside simulated output rising from 288 to 381 units (whereas detailed Table 5 in the same article lists a 293-unit baseline). Results are computer simulations, not verified physical trial outcomes.

As **Exhibit 32**, p. 115 shows, simulation allows engineers to compare baseline and rebalanced configurations across line efficiency (39.06 percent to 55.64 percent) and labour productivity (54.25 percent to 66.00 percent) before disrupting the physical line. [S11] What **Exhibit 32**, p. 115 cannot establish is that the physical sewing line actually produced 381 first-pass good shirts under real attendance, thread breakage, fabric shading and power reliability conditions. [S11] [S35]

7.15 DISCREPANCIES IN PUBLISHED SIMULATION TABLES PROVE THE NEED FOR FLOOR VALIDATION

Inspecting the Abay garment article closely shows why GFT treats simulation outputs strictly as hypotheses requiring floor validation. [S11] First, the improved figures (381 units, 55.64 percent line efficiency and 66.00 percent labour productivity) are computer simulation outputs rather than post-implementation floor logs. [S11] Second, the article contains an internal discrepancy between its abstract and its detailed results table: while the abstract reports baseline output as 288 units rising to 381 units, detailed Table 5 in the body of the paper records existing baseline output as 293 units. [S11]

> **WARNING**
>
> **Why simulation outputs must never be booked directly into a business case**
>
> Computer simulation models of sewing lines depend on the probability distributions fitted to stopwatch samples, the boundary assumptions chosen by the modeller and the stoppages omitted from the code. [S07] [S11] Discrepancies such as the 288-unit abstract baseline versus the 293-unit Table 5 baseline in the Abay study arise when model runs and summary tables are not reconciled to one audited floor log. [S11] Moreover, a standard simulation rarely captures the combined effect of operator fatigue, needle heating, folder drift and power interruptions over an eight-hour shift. [S02] [S17] [S36] GFT therefore requires every simulated balance gain to pass a controlled floor trial measured under identical OEE, SMV and first-pass yield definitions before any capacity increase enters production commitments or financial plans. [S01] [S04] [S13]

Simulation thus holds a specific role in GFT's workflow: when a style involves complex subassembly branches or shared special machines, simulation screens out weak layouts quickly, narrowing candidate balances down to one or two options for a physical pilot trial. [S11] [S15] The floor trial, not the simulation report, authorises standard work. [S11] [S26]

7.16

Digital balancing earns its place after the inputs stabilise

Apparel engineering evidence shows that digital process monitoring and real-time line balancing can raise effectiveness when built on disciplined industrial engineering. [S09] In a 2025 apparel study, Company X increased its Overall Equipment Effectiveness from 42.91 percent to 52.27 percent using process monitoring devices and digital line balancing. [S09] That 9.36 percentage-point OEE improvement demonstrates that real-time station monitoring can help supervisors spot emerging bottlenecks and reallocate tasks faster than end-of-shift paper counts permit. [S09] [S20]

7.17 MONITORING AND REBALANCING WORK ONLY ON VERIFIED OPERATION AND LOSS DATA

Company X's result does not mean that buying digital line-balancing software automatically lifts OEE by nearly ten percentage points. [S09] In that study, digital balancing operated alongside granular loss capture that separated technical malfunctions (4,923 minutes), machine adjustments (3,694 minutes), faulty needles (2,432 minutes) and thread breakages (1,427 minutes), while tracking specific defect categories such as lock-stitch repair and stain (which accounted for 54.77 percent of defects, with the top five categories representing 87.56 percent). [S09] The digital layer succeeded because it rested on an explicit operation breakdown, measured cycle times, classified downtime reasons and tracked defect causes. [S04] [S09] [S13]

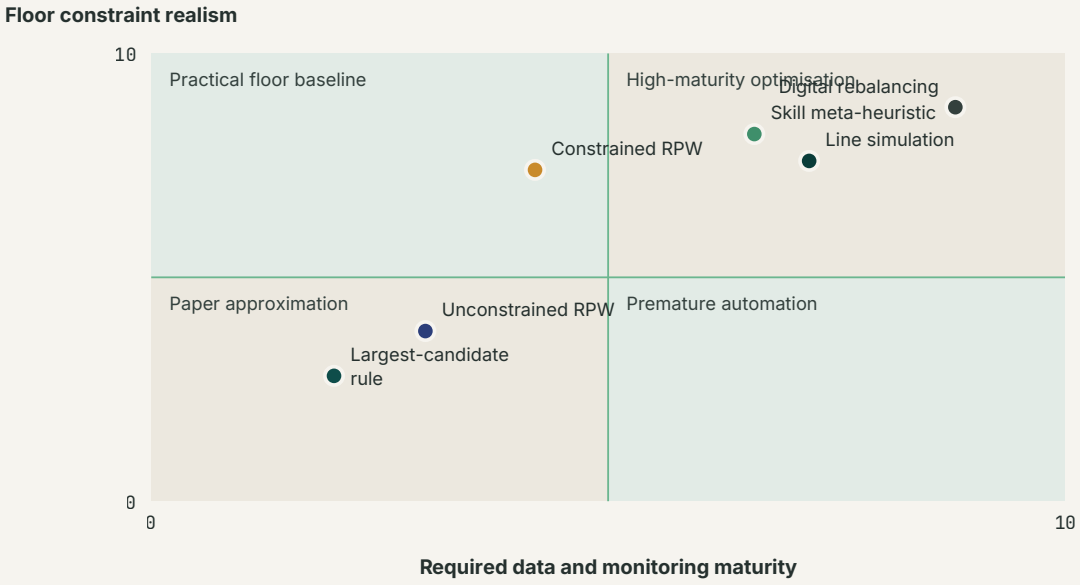
Deploying an automated rebalancing algorithm on top of unverified stopwatch averages, an incomplete machine-and-folder register, an outdated skill spreadsheet and a single undifferentiated downtime code merely generates infeasible task moves faster. [S06] [S07] [S15] [S17] In GFT's white-paper library, data governance is specified in wp14 and edge capture architecture in wp18. [S01] [S09] Within wp15, the operating rule

is sequence: establish clean manual definitions, standard work and constraint-aware balancing first, then add digital monitoring and rebalancing where they shorten the supervisor's decision cycle. [S09] [S12] [S26]

Exhibit 33, p. 117 places five balancing approaches across two dimensions: required input-data maturity on the horizontal axis and floor constraint realism on the vertical axis. [S09] [S10] [S11] [S15] [S17]

EXHIBIT 33 / ILLUSTRATIVE INDEX (0 TO 10)

The balancing method must match the decision and data



ILLUSTRATIVE [S09] [S10] [S11] [S15] [S17] Illustrative GFT decision matrix placing balancing methods by required input-data maturity (x-axis, 0 to 10) and floor constraint realism (y-axis, 0 to 10). Method characteristics draw on S10 (process redesign), S15 (unconstrained versus resource-constrained ranked positional weight), S17 (skill-aware meta-heuristics), S11 (discrete-event simulation) and S09 (monitoring-linked digital line balancing). Coordinates are analytical placements, not empirical measurements.

As **Exhibit 33**, p. 117 illustrates, unconstrained rules in the lower-left quadrant need only task times and a precedence chart, but they score poorly on floor realism because they ignore machines, folders and skills. [S15] [S17] Resource-constrained ranked positional weight paired with a verified skill matrix sits in the upper-left quadrant ("Practical floor baseline"), capturing the decisive physical and human restrictions using structured manual records maintainable from shift one. [S12] [S15] [S17] Skill-aware meta-heuristics, line simulation and digital rebalancing occupy the upper-right quadrant ("High-maturity optimisation"), delivering strong realism only when backed by calibrated time distributions and live station telemetry. [S09] [S11] [S17] Adopting those tools without clean master data drops a plant into the lower-right quadrant ("Premature automation"). [S07] [S09] Because **Exhibit 33**, p. 117 is an illustrative selection framework, its coordinates guide method choice rather than reporting measured factory data. [S15]

Balancing method	Core inputs required	Constraints enforced	Primary floor failure mode	Deployment stage
Unconstrained heuristic [S15]	Operation SMVs, precedence, cycle time [S13] [S15]	Precedence and nominal cycle ceiling [S15]	Merges incompatible machines; understates stations (27 versus 39 in [S15])	Rough capacity screening only [S15]
Resource-constrained RPW [S10] [S15]	Bulletin, machine and folder register, pitch [S13] [S15] [S16]	Precedence, pitch, machine class, attachment [S15] [S16]	Assumes uniform skill unless paired with crew check [S17]	Phase 0 and Phase 1 style launch [S12] [S15]
Skill metaheuristic [S17]	Bulletin, machine register, skill matrix (0 to 1.5 scale) [S17] [S19]	Precedence, pitch, machine, skill, multitasking [S16] [S17]	Degrades if skill matrix ignores learning or turnover [S18]	Phase 1 and Phase 2 crew allocation [S17] [S18]
Line simulation [S11]	Task time distributions, buffers, stoppages [S07] [S11]	Variability, queues, parallel resource pools [S11] [S23]	Baseline discrepancies (288 versus 293 in [S11]) mistaken for floor output	Pre-launch screening before floor pilot [S11]
Digital balancing [S09]	Live station telemetry, downtime and defect codes [S09] [S20]	Live bottlenecks, availability, pace, quality holds [S09] [S20]	Automates bad moves if loss codes or standards are noisy [S07] [S26]	Phase 3 dynamic control after stability [S09]

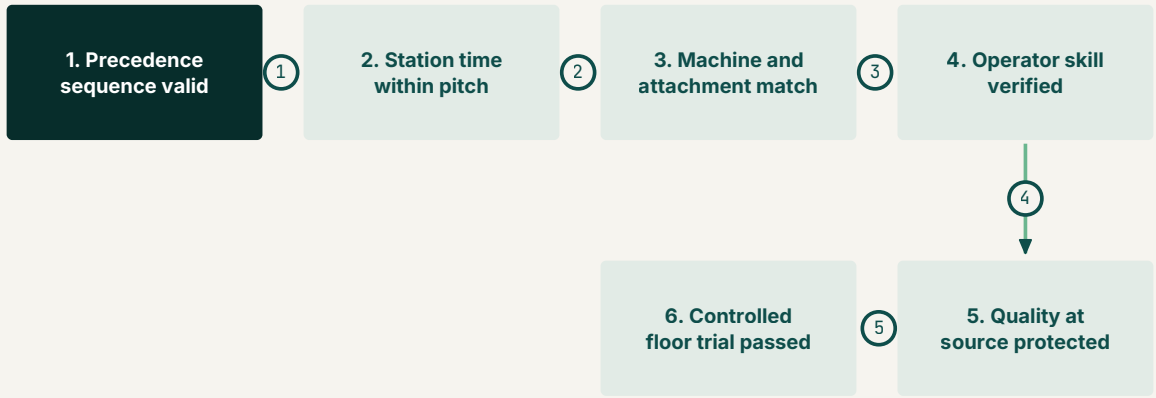
7.18 SIX ACCEPTANCE GATES GOVERN THE RELEASE OF ANY LINE BALANCE

To ensure that neither a manual worksheet nor an optimisation algorithm releases an unworkable layout to supervisors, GFT subjects every proposed line balance to a six-gate acceptance sequence. [S15] [S16] [S17] This sequence is built into GFT's `line-balancing` studio and governs how industrial engineering hands over a style setup to production. [S12] [S26]

Exhibit 34, p. 119 maps the six acceptance tests that a candidate allocation must pass before becoming authorised standard work. [S15] [S16] [S17]

EXHIBIT 34 /

A feasible balance passes through six acceptance tests



1. Sequence OK
2. Pitch OK
3. Equipment OK
4. Capability OK
5. Release trial

ILLUSTRATIVE [S15] [S16] [S17] Illustrative GFT six-gate validation sequence for accepting a proposed sewing-line balance. Precedence and resource constraints follow S15; pitch-time bounds follow S16; operator skill-level matching follows S17. Every candidate allocation must pass a physical line trial before becoming standard work.

The flow sequence in **Exhibit 34**, p. 119 converts the chapter's evidence into an operational gate checklist: [S15] [S16] [S17]

1. **Gate 1, Precedence validity:** Confirm every station assignment respects the garment construction graph, including subassembly convergence ahead of marriage operations. [S13] [S15]
2. **Gate 2, Pitch compliance:** Verify each station's total operating time stays within the governing assembly line pitch time (Equation 8 in [S16]), keeping protective capacity at difficult tasks. [S19] [S23]
3. **Gate 3, Machine and attachment match:** Confirm each single-machine station groups only tasks with identical machine class, needle gauge, stitch density and fixed folder state, within available inventory. [S02] [S15]
4. **Gate 4, Operator skill and ergonomics:** Check assignments against the current crew's skill matrix and task difficulty ratings so every station is staffed by a capable operator without unsafe strain. [S17] [S19] [S38]
5. **Gate 5, Quality at source:** Verify that combining tasks does not remove an inspection point, obscure seam guides or pair incompatible thread colours. [S04] [S09]

6. **Gate 6, Controlled floor trial:** Run a physical pilot over a defined observation window (such as two hours of steady flow in an illustrative trial protocol), recording station cycles, upstream queues, first-pass yield and earned standard minutes before signing off standard work. [S04] [S11] [S12] [S13] [S20] [S26]

Because **Exhibit 34**, p. 119 is an illustrative governance workflow for GFT's operating system, it specifies verification gates rather than reporting historical deployment metrics. [S15] [S26]

> **GFT NOTE**
>
> **Practical recommendation for GFT's Cameroon textile programme and line-balancing studio**
>
> In GFT's Cameroon textile programme, where feasibility analysis, performance-management design and digital strategy work together to build local processing, [R06] [R07] industrial engineers should configure the `line-balancing` studio to block unconstrained optimisation outputs from being exported to shop-floor boards. [S15] [S16] Every operation in the bulletin must carry mandatory fields for machine class, folder code, task difficulty and required skill rating. [S13] [S17] [S19] When a planner runs ranked positional weight or a meta-heuristic solver, the tool should display both the unconstrained theoretical bound and the resource-and-skill-constrained feasible allocation side by side, showing which machine shortage, folder conflict or skill gap explains the difference. [S15] [S17] That comparison turns the gap between theoretical and feasible balance into a practical action list: it shows whether buying one additional folder or cross-training two operators on an overlock bottleneck will recover three workstations of capacity, before any sensor or software licence is purchased. [S09] [S15] [S17] This analysis provides engineering and operational methodology, not investment, legal or tax advice.

Even after a sewing line passes all six acceptance gates and freezes a feasible balance for launch, that allocation decays over time. [S18] [S20] As the next chapter shows, operator learning, morning absences, fabric batch differences and style changes cause the active constraint to move across stations from shift to shift, turning line balancing from a one-off pre-launch calculation into a daily floor practice. [S12] [S18] [S20]

An allocation that ignores a constraint on paper merely instructs the factory floor to discover that constraint through queues, defects and missed shipments.

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GREEN FUTURE TECH

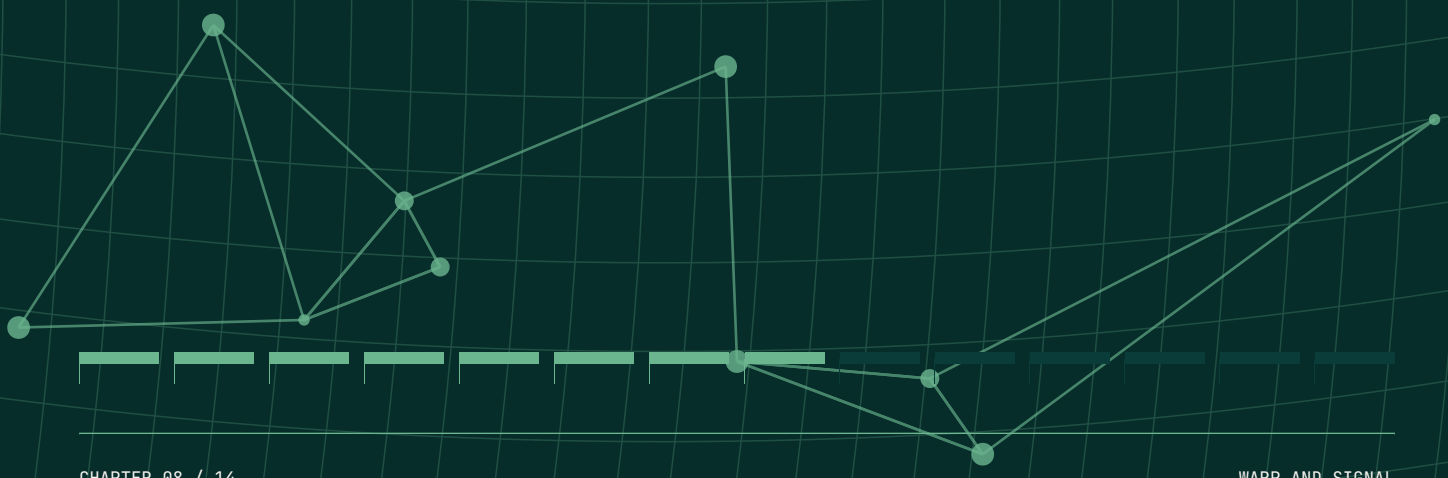
LIMITED / HONG KONG SAR

08

PART II: BALANCE WORK TO THE CONSTRAINT / DYNAMIC LINE CONTROL

The constraint moves, so balancing must become a daily practice

A balance calculated for one style and crew decays as absence, learning, defects and order mix change the work.



CHAPTER 08
DECISION TEST

A balance calculated for one style and crew decays as absence, learning, defects and order mix change the work.

A garment assembly line does not keep the balance it was given on the first morning of a style run. [S0801] Even when an industrial engineer builds a feasible workstation allocation around operation precedence, machine types, attachments and operator skill ratings, the active constraint migrates across the floor as conditions shift from hour to hour. [S15] [S17] [S20] An unscheduled absence, a bundle of collar ribs with tension defects, a switch from lightweight jersey to heavier pique fabric, a transferred operator still climbing the six-week learning curve, or a brief feeder trip can turn yesterday's smoothly flowing station into today's bottleneck. [S18] [S20] [S35] Treating line balancing as a pre-production calculation performed once per order leaves the factory exposed to every disturbance that arrives after the first bundle enters the line. [S0801] Good throughput is protected only when balancing becomes a structured daily and hourly practice that reads workstation utilisation and upstream work-in-progress queues together, verifies that a proposed adjustment is physically and ergonomically safe, and locks the response into a formal management cadence. [S12] [S20] [S38]

In Cameroon's textile sector, where about 95 per cent of cotton fibre is exported raw and roughly 5 per cent is processed locally against a 50 per cent target by 2030, holding a sewing line near its feasible rhythm is a core condition of industrial viability. [R06] [R07] Incumbent plant utilisation reported as of July 2023 ranged from 10.83 per cent at CICAM 2 to 33.7 per cent at Garoua and 48.9 per cent at CICAM 1, showing how severely idle and disrupted capacity erodes fixed-cost recovery. [R12] While macro underutilisation reflects market, power and working-capital pressures examined elsewhere in this series, floor-level capacity loss inside an active sewing room often stems from static line management: supervisors keep feeding bundles into a fixed station layout long after the constraint has moved. [S12] [S20] This chapter sets out the operating mechanics of dynamic line control within Green Future Tech Limited's (GFT) Cameroon textile programme, showing how teams detect a shifting bottleneck early, execute bounded intra-shift corrections, and escalate structural limits without sacrificing quality or decent work. [S09] [S12] [S38]

8.1

Static bottleneck labels miss changing conditions

A sewing line is an interdependent network of human-machine workstations rather than a rigid mechanical transfer line. [S14] [S15] Because sewing performance depends on operator dexterity, material handling and coordination, the time a garment component spends at a workstation fluctuates even when the operation bulletin stays constant. [S14] [S15] Production-engineering reviews emphasise that line balancing is not an isolated static plan, but is tightly coupled with dynamic, real-time decisions on the floor. [S0801] An allocation that looks balanced on a pre-production spreadsheet becomes fragile as soon as floor disturbances interact with sequential precedence chains. [S15] [S0801]

Time-serial bottleneck research in textile and apparel manufacturing identifies bottleneck workstations through two observable signatures: they are either the workstations with the highest sustained utilisation over the observation window, or those whose upstream buffer holds the largest work-in-progress inventory in the system.

[S20] Neither signature is fixed to a permanent physical table. [S20] As upstream feeding, machine condition, operator pace and rework flows vary across a shift, both the peak utilisation ratio and the largest upstream queue migrate from one operation to another. [S20] When factory management treats "the bottleneck" as a permanent badge pinned to a single operation such as collar attachment, supervision looks in the wrong place whenever the true constraint moves elsewhere. [S20] [S30]

8.2 FOUR FLOOR DISTURBANCES DRIVE CONSTRAINT MIGRATION

Four recurring mechanisms push the active constraint from one workstation to another within a single production week. [S17] [S18] [S20] First, operator attendance and morning substitutions alter station capability immediately. [S17] [S40] When a primary operator with a high task-specific skill rating is absent and replaced by a relief operator with lower proficiency on that seam, the effective cycle time at that workstation rises even though the garment's standard minute value (SMV) on the operation bulletin is unchanged. [S13] [S17] Second, learning and forgetting curves shift relative station speeds over days and weeks. [S18] [S0801] In empirical apparel research, manual-machine operators raised their average capacity from 60.6 per cent to 79.4 per cent over six weeks. [S18] Because individual operators on a line do not progress at identical weekly rates, a station manned by a fast-learning operator can shed its bottleneck status mid-month while an adjacent station manned by a newly transferred worker becomes the new pacing constraint. [S17] [S18]

Third, material and quality disturbances create temporary capacity sinks. [S02] [S04] If a cutting lot arrives with notch variance or a sewing station suffers frequent thread breakage and tension adjustments, minor stoppages and inline repairs consume operating minutes planned for first-pass output. [S02] [S04] [S09] Because OEE availability and performance losses reduce effective operating time at that station, net throughput drops below the line's pitch time and starves downstream workstations. [S04] [S06] [S16] Fourth, order mix and style details alter work content across machine groups. [S13] [S15] Even within knitted polo shirts, switching from a plain hem to a split side-vent with bartack reinforcement adds standard minutes to late-stage operations while leaving collar preparation unchanged. [S13] [S15]

Exhibit 35, p. 125 illustrates how these four mechanisms cause the active constraint to migrate across six sequential workstation groups over five operating periods within an illustrative week. [S17] [S18] [S20]

EXHIBIT 35 / ILLUSTRATIVE SCORE (1 TO 5)

A moving constraint appears in station time and queue evidence

	Mon AM	Mon PM	Tue AM	Wed AM	Thu AM
Placket set	2	2	5	3	3
Shoulder join	2	5	3	2	2
Collar attach	5	4	3	4	3
Sleeve set	3	3	2	3	3
Side seam	3	2	2	5	3
Bottom hem	2	2	2	2	2

Cell scale: 2 to 5

ILLUSTRATIVE [S20] [S17] [S18] Illustrative shift-by-station diagnostic matrix combining workstation utilisation and upstream work-in-progress queue accumulation, following the dual bottleneck definitions in S20 and skill-variation effects in S17 and S18. Scores from 1 (ample protective capacity) to 5 (active system constraint) are illustrative operational examples, not observed GFT factory telemetry.

In **Exhibit 35**, p. 125, the illustrative polo-shirt line opens Monday morning (Mon AM) with its design constraint at Collar attach (score 5), where curved feeding produces the longest effective cycle time relative to pitch. [S16] [S20] On Monday afternoon (Mon PM), an unplanned absence at Shoulder join requires a less experienced replacement; effective cycle time at Shoulder join rises above pitch, upstream bundles pile up before the overlock machine, and Collar attach is partially starved of joined bodies (moving the score of 5 to Shoulder join). [S06] [S17] [S20] By Tuesday morning (Tue AM), attendance recovers, but a fusible interlining defect causes rework at Placket set, moving the active queue and peak utilisation upstream to the first workstation group. [S04] [S20] On Wednesday morning (Wed AM), a heavier pique lot with side vents increases work content at Side seam (score 5), before task sharing and operator reallocation on Thursday morning (Thu AM) bring all six groups back to controlled mid-range loads (scores of 2 to 3). [S15] [S17] [S20] Because this matrix is an illustrative model rather than plant telemetry, it does not predict how often a specific factory's bottleneck will move; it demonstrates why static labels fail whenever attendance, quality or style mix changes. [S20] [S0801]

8.3 WHY NON-CONSTRAINT BUSYNESS HIDES THE SHIFT

The Theory of Constraints directs improvement to the specific operation that currently limits system throughput. [S30] When a constraint moves from Station C to Station B at the start of a shift, but the line is still managed as though Station C were the sole pacing resource, two operational errors follow. [S20] [S30] First, upstream Station A continues producing at full local speed, building an unscheduled work-in-progress pile before newly constrained Station B. [S20] [S23] Second, engineers and mechanics focus on keeping Station C busy, overlooking that Station C's apparent idle intervals are actually equipment-independent starvation caused by the slowdown at Station B. [S06] [S20]

In variable production systems, waiting time rises nonlinearly as capacity utilisation approaches saturation. [S23] When a workstation's effective utilisation spikes due to a lower-skilled replacement or recurring minor stops, the upstream queue expands rapidly. [S04] [S17] [S23] Conversely, lean analysis of one-piece flow notes that excess capacity at non-constraint stations is normal and beneficial because protective capacity absorbs natural cycle-time variation without letting queues cascade. [S28] Daily line reviews must therefore stop rewarding upstream operators for high local piece counts when those pieces merely swell a buffer in front of a shifted constraint. [S20] [S28] [S30]

8.4

WIP is a signal before it becomes a storage problem

On a garment floor, work in progress (WIP) is often viewed either as a comforting buffer against starvation or as clutter in narrow aisles. [S12] [S21] Both views miss its diagnostic function. [S20] Before excess WIP becomes a working-capital burden, its physical location and growth rate act as the fastest leading indicator of a moving constraint. [S20] Because time-serial bottleneck analysis identifies a constraint by sustained high utilisation or by the largest upstream WIP buffer, watching where bundles accumulate tells a supervisor where effective station time has breached the line's pitch rhythm hours before end-of-shift efficiency reports are compiled. [S16] [S20]

8.5 READING UPSTREAM ACCUMULATION AND DOWNSTREAM STARVATION TOGETHER

In strict single-piece flow, there is no WIP between adjacent operators, so a slowdown at one station immediately blocks the upstream operator and starves the downstream operator. [S21] In most garment factories, however, lines run progressive bundles or small transfer lots with bounded buffers between operations. [S12] [S21] When a station's effective cycle time exceeds the governing pitch time, the buffer immediately upstream grows while the buffer immediately downstream drains. [S16] [S20]

Reading both sides of the workstation together prevents false diagnosis. [S06] [S20] If a supervisor looks only at low hourly output at Station 6, they may fault the Station 6 operator for low speed when Station 6 actually has zero upstream WIP and is starved by a bottleneck at Station 4. [S06] [S20] Conversely, a large bundle pile before Station 4 is not always proof that Station 4 slowed down: if cutting or an upstream subassembly released an unscheduled surge of bundles at once, the queue at Station 4 may reflect undisciplined upstream push rather than a slower cycle at Station 4. [S20] [S24]

8.6 QUEUE AGE SEPARATES THROUGHPUT CONSTRAINTS FROM BLOCKED COMPONENTS

Counting pieces in an upstream buffer is necessary but insufficient for accurate diagnosis. [S20] [S22] Under Little's Law, average WIP equals average throughput rate multiplied by average throughput time, a relationship that strictly applies to long-term averages of stable systems that are not starting, stopping or surging. [S22] During an active shift disturbance, the line is outside equilibrium, so a supervisor cannot simply divide floor WIP by the hourly target to know how long each bundle has waited. [S22]

Instead, supervision must record both **queue position** (which station the bundles sit before) and **queue age** (how long the oldest bundle in that buffer has waited). [S20] [S22]

A growing queue of fresh bundles whose oldest unit arrived twenty minutes ago signals an active cycle-time bottleneck: the station is working, but its effective cycle time exceeds upstream arrivals. [S15] [S20] By contrast, a small buffer holding two bundles untouched for three hours while newer bundles pass them signals a blocked lot: a missing trim, a shade-lot mismatch, a waiting print panel or an unresolved quality hold. [S04] [S20] Treating a three-hour quality hold as a cycle-time bottleneck would lead a supervisor to add a sewing operator to an operation that cannot release the held bundles anyway. [S04] [S12]

METHOD

Field protocol for hourly WIP and constraint logging

To use WIP as a constraint signal without installing electronic sensors on every table, GFT's performance-management design specifies a four-field manual check during each hourly board walk. [S07] [S12] [S20]

1. **Checkpoint zones:** Group the sewing line into 6 to 10 sequential checkpoint zones at major assembly merges (such as placket set, collar assembly, shoulder join, sleeve set, side seam, hem and final inspection) in an illustrative 25-to-35-machine line. [S13] [S15]
2. **Two-zone buffer cap:** Mark each checkpoint tray with a green zone for authorised standard in-process stock (an illustrative cap of 15 pieces per operator) and an ochre warning zone up to an illustrative ceiling of 30 pieces. [S20] [S26]
3. **Hourly count and oldest-bundle timestamp:** At each clock hour, record good pieces completed at the checkpoint, count or estimate upstream buffer pieces, and read the ticket timestamp on the oldest bundle in the tray. [S07] [S12] [S20]
4. **Dual-signal rule:** Flag a workstation as the active hourly constraint when its upstream buffer breaches the ochre cap AND its downstream station holds less than half of its standard buffer, or when the station runs continuously with zero recovery gap. [S06] [S20] If a buffer breaches the cap only because a single bundle is more than two illustrative hours old, log a **blocked-lot hold** rather than a balancing bottleneck. [S04] [S20]

8.7

Hourly balance converts observation into correction

Detecting that the constraint has moved from collar attachment to shoulder joining produces no additional garments unless observation triggers a bounded correction within the shift. [S12] [S30] The International Labour Organization's (ILO) Factory Improvement Toolset for the garment sector combines operation bulletins, SMV, line planning, **hourly balancing** and bottleneck management as one operating discipline. [S12] Across Asian garment factories applying that toolset, the ILO recorded a 9.49 per cent improvement in sewing-room line achievement alongside a 22 per cent

reduction in both WIP and defects per hundred units. [S12] Similarly, under the ILO SCORE and SIRAYE programme in Ethiopia, Edget Garment raised line-balance efficiency from 24 per cent to 75 per cent and daily line output from 50 to 120 pieces through structured line balancing and workplace cooperation. [S37] These outcomes are context-specific programme results rather than automatic forecasts for Cameroon, but they confirm the operational mechanism: pairing SMV planning with hourly bottleneck management raises good output while shrinking floor queues. [S12] [S37]

8.8 FIVE BOUNDED INTERVENTIONS FOR INTRA-SHIFT REBALANCING

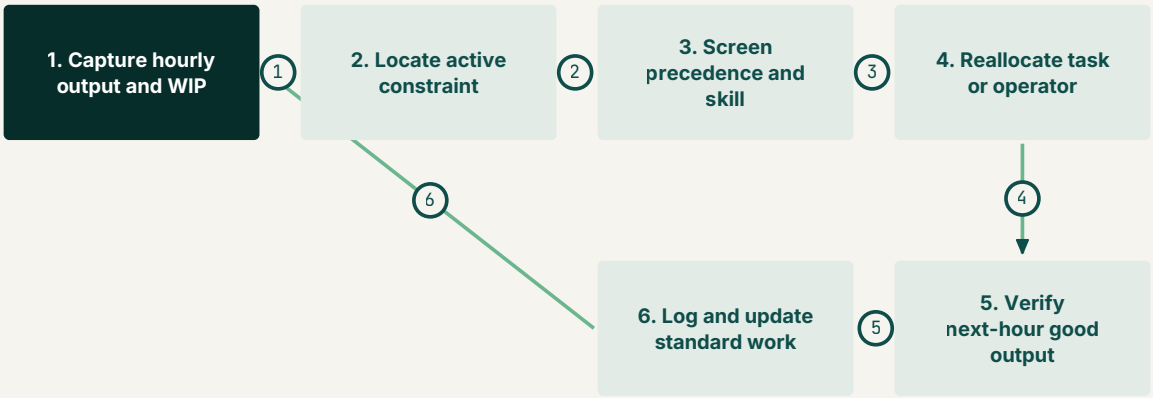
When an hourly walk confirms that a workstation's effective cycle time has exceeded pitch time and built an upstream queue, the supervisor and industrial engineer have five practical levers within the shift. [S12] [S15] [S17]

- **Deploy a cross-trained floater:** Assign a multi-skilled utility operator whose proficiency on the constrained task is verified in the skill matrix to add parallel capacity for a bounded two-hour or four-hour window. [S17]
- **Split a shareable work element across an adjacent station:** Garment operations combine sewing with manual bundle handling, positioning or thread trimming. [S13] [S26] Where precedence and machine rules allow, an adjacent station with protective capacity can absorb a manual sub-element, lowering net cycle time at the constrained machine. [S15] [S16] [S28]
- **Swap operators using task-specific skill ratings:** Garment balancing models rate worker task performance from 0 (no skill) to 1.5 (fully skilled). [S17] Swapping two operators whose relative strengths better match paired operations can reduce peak station time without adding headcount. [S17]
- **Fix equipment or attachment micro-stops at source:** A station often slows down because a worn folder, needle fault or thread break forces repeated short stops and stitch unpicking. [S02] [S04] [S09] Immediate mechanic or quality intervention restores speed without changing task allocations. [S02] [S09]
- **Throttle upstream release:** When the constraint cannot be sped up immediately, pull discipline pauses upstream bundle release and shifts the freed upstream operator to clear mid-line work, preventing excess WIP buildup. [S24] [S28]

Exhibit 36, p. 129 maps the closed six-stage decision sequence that stops ad-hoc tinkering from creating secondary bottlenecks or quality defects. [S09] [S12] [S20] [S26]

EXHIBIT 36 / DECISION SEQUENCE

Dynamic balancing is a closed decision loop



1. Queue + utilisation
2. Confirm cause
3. Feasible move
4. First-piece check
5. Gain holds
6. Next hour

ILLUSTRATIVE [S09] [S12] [S20] [S26] Illustrative six-stage control loop integrating hourly output and queue capture (S12; S20), constraint verification, feasibility screening, task or operator reallocation (S09), good-output verification, and standard-work updating (S26).

As **Exhibit 36**, p. 129 shows, an hourly rebalance is not finished at Stage 4 (`Reallocate task or operator`). [S09] [S12] Floor interventions fail when a supervisor moves an operator at 10:00 and discovers at 14:00 that the reassigned operator sewed defective seams or starved the vacated station. [S04] [S17] Stage 5 (`Verify next-hour good output`) mandates an immediate first-bundle quality check after the move and a queue check at the next hourly walk. [S04] [S20] Stage 6 (`Log and update standard work`) records proven contingency allocations so future shifts can reuse them. [S26] While **Exhibit 36**, p. 129 structures internal line adjustments, it cannot resolve external halts such as grid outages or plant-wide material shortages, which must escalate through management. [S06] [S35]

8.9 PRECEDENCE, ERGONOMICS AND FIRST-PASS QUALITY REMAIN HARD BOUNDARIES

Dynamic rebalancing must respect the same hard boundaries as initial line balancing. [S15] [S16] [S38] First, **precedence constraints** forbid assigning a downstream assembly step before its prerequisite seams are closed. [S15] Second, **pitch-time limits** require that every workstation's assigned operating time remain within the assembly line pitch time (`Equation (8)` in S16); shifting a 20-second element onto a neighbour whose total cycle time then exceeds pitch merely moves the bottleneck one station away. [S16] [S20] Third, **ergonomics and working-time limits** protect operator health and sustainable output. [S38] [S41] Ergonomic research in Ethiopian garment factories shows that poor workstation posture and setup create long-term

health risks for sewing operators. [S38] Any shared-task or standing-to-sitting adjustment must verify reach, table height and recovery, and supervisors must not use chronic overtime to mask a mid-shift bottleneck, as Better Work evidence shows extended hours do not yield proportionate output gains and can reduce long-run output. [S38] [S41]

WORKED EXAMPLE: INTRA-SHIFT REBALANCING OF A 5-ZONE POLO-SHIRT SUBASSEMBLY

Consider an **illustrative** five-zone sewing line producing knitted polo shirts over an 8-hour shift (480 scheduled minutes less 30 minutes of planned breaks, leaving 450 planned production minutes). [S01] [S04] Target output is 450 good shirts, setting a governing takt and pitch time of `450 minutes / 450 good pieces = 1.00 minute (60.0 seconds) per piece`. [S15] [S16]

Under full attendance, the five checkpoint zones have the following illustrative base SMVs and task skill ratings (`1.00` standard on the `0` to `1.5` scale in S17): [S13] [S17]

- **Zone 1 (Placket set):** Base SMV `1.10 minutes` (66.0 seconds), 2 operators (`1.00` skill); effective cycle = `33.0 seconds` (illustrative). [S13] [S15]
- **Zone 2 (Shoulder join):** Base SMV `0.85 minutes` (51.0 seconds), 1 operator (`1.10` skill); effective cycle = `46.4 seconds` (illustrative). [S15] [S17]
- **Zone 3 (Collar attach):** Base SMV `1.90 minutes` (114.0 seconds), 2 operators (`1.00` skill); effective cycle = `57.0 seconds` (initial constraint at 95.0 per cent of the 60.0-second pitch, illustrative). [S16] [S17] [S20]
- **Zone 4 (Sleeve set):** Base SMV `1.60 minutes` (96.0 seconds), 2 operators (`1.00` skill); effective cycle = `48.0 seconds` (illustrative). [S15] [S17]
- **Zone 5 (Side seam and hem):** Base SMV `1.70 minutes` (102.0 seconds), 2 operators (`1.00` skill); effective cycle = `51.0 seconds` (illustrative). [S15] [S17]

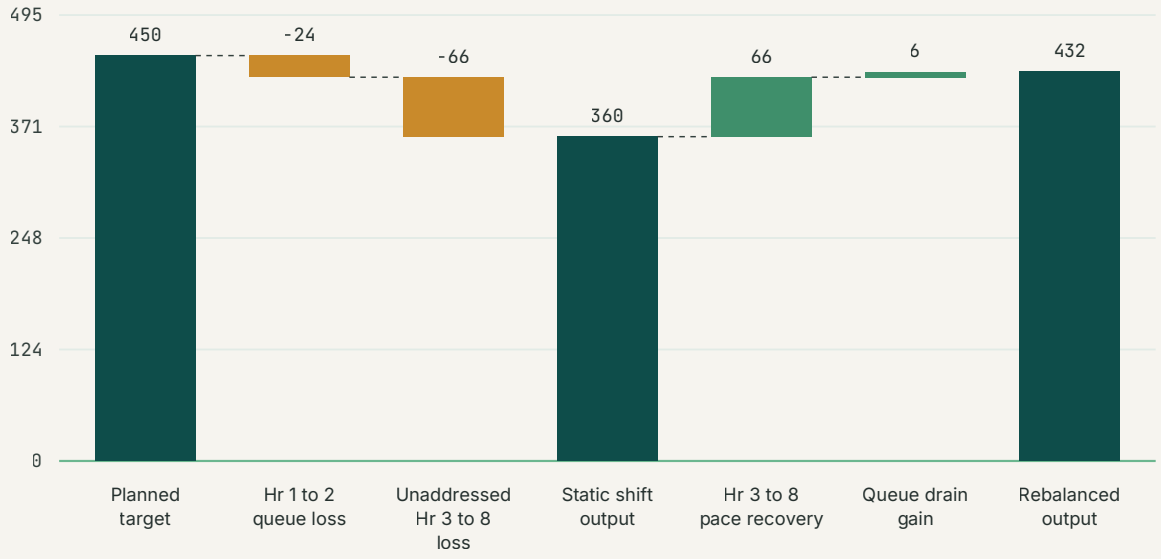
Hours 1 to 2 disturbance: The skilled Zone 2 operator (`1.10`) is absent and replaced by a trainee at a `0.68` skill factor (consistent with early learning in S18). [S17] [S18] Zone 2's cycle jumps to `51.0 / 0.68 = 75.0 seconds` per piece (illustrative), breaching the 60.0-second pitch (S16) and capping Zone 2 at `48 pieces per hour`. [S16] [S20] Across the first two operating hours (120 minutes), Zone 1 completes `120` plackets, Zone 2 finishes `96` bodies, a 24-piece queue builds before Zone 2 (S20), and Zones 3 to 5 are starved to `96` good pieces (S06), losing `24` good garments against the two-hour target of `120` (illustrative). [S06] [S20]

Hour 2 rebalance and shift reconciliation: At Hour 2, the supervisor and engineer split `15.0 base seconds` of manual bundle matching and neck-tape clipping from Zone 2 to the second operator in Zone 1. [S12] [S15] Zone 1's cycle rises to `(66.0 + 15.0) / 2 = 40.5 seconds` (within pitch), while Zone 2's remaining `36.0 base seconds` at `0.68` skill yields `36.0 / 0.68 = 52.9 seconds` (illustrative), restoring pitch compliance (S16) and returning the constraint to Zone 3 (`57.0 seconds`). [S16] [S17] Over the remaining 5.5 operating hours (330 minutes), the line produces `330` pieces at its restored 60-piece hourly rate plus `6` queued pieces drained through Zone 3's spare cycle margin (`336` pieces in Hours 3 to 8, illustrative). [S12] [S20] Shift output closes at `96 + 336 = 432 good pieces` (`96.0 per cent` of target), versus `48 x 7.5 = 360 good pieces` (`80.0 per cent`) under an unchanged static balance, recovering `72` good garments (illustrative). [S12] [S17] [S20]

Exhibit 37, p. 131 reconciles the shift output bridge from this worked example, comparing static shift losses with the volume recovered after Hour 2. [S12] [S16] [S17] [S20]

EXHIBIT 37 / GOOD GARMENTS PER SHIFT

Hourly rebalancing recovers shift output lost to a morning constraint shift



DERIVED [S12] [S16] [S17] [S20] Derived from the illustrative 5-zone polo-shirt worked example: 450 planned good pieces across 450 operating minutes (1.00 piece/minute takt); an unaddressed Zone 2 replacement operator at 0.68 skill rating (S17; S18) caps output at 360 pieces (-90 loss: -24 in Hours 1 to 2 and -66 in Hours 3 to 8); splitting 15 base seconds to Zone 1 after Hour 2 restores pitch compliance (S16) and recovers 66 pieces in Hours 3 to 8 plus 6 queued pieces, closing at 432 good garments.

As **Exhibit 37**, p. 131 shows, the 24-piece shortfall from Hours 1 and 2 is mostly sunk because Zone 3 (57.0 seconds against a 60.0-second pitch) has minimal sprint margin, but acting at Hour 2 prevents the 66-piece loss across Hours 3 to 8 and recovers 72 good garments in total in this illustrative case. [S12] [S16] [S20] The bridge also shows its own limit: hourly balancing cannot recover constraint minutes lost before detection, making detection latency an economic variable. [S09] [S12]

8.10

Real-time monitoring should shorten the decision loop

Because constraint minutes lost before detection can rarely be recovered within statutory hours, shortening the delay between a bottleneck shift and supervisor action has direct operational value. [S09] [S30] [S33] In apparel OEE research, Company X improved its OEE from 42.91 per cent to 52.27 per cent by pairing process monitoring devices (PMDs) with digital line balancing. [S09] That 9.36 percentage-point gain in one case study is not a guaranteed benchmark for every plant, but it demonstrates the mechanism: real-time monitoring pays only when wired directly into task reallocation and fault response. [S09] [S0801]

8.11 WHY DETACHED DASHBOARDS FAIL TO MOVE A SINGLE BUNDLE

Digitalisation projects often mount displays in a manager's office while leaving the supervisor's floor routine unchanged. [S03] [S09] Detached dashboards fail in three ways. [S03] [S07] [S09] First, a low station OEE figure does not separate mechanical breakdown, needle or thread faults, absence, and upstream starvation. [S02] [S06] [S09] Because equipment effectiveness metrics can include equipment-independent starvation from missing inputs, raw machine counters can blame a starved downstream operator for an upstream bottleneck. [S06] [S20] Second, manual and semi-automatic logs carry speed and stoppage-duration uncertainty whenever operators must tap screens during busy runs. [S07] Third, learning at 17:30 that Station 14 slowed down at 09:15 turns telemetry into a post-mortem rather than a control loop. [S09] [S12]

8.12 PROGRESSIVE CAPTURE: FROM MANUAL BOARDS TO POWER-SENSING AND PMDS

GFT sequences monitoring across three progressive stages. [S07] [S09] [S12] **Stage 1 (Manual hourly board and bundle tickets)** records checkpoint good output, upstream queue counts, oldest-bundle age, defects and coded downtime on a physical board at the line head, requiring zero software and working through grid outages. [S04] [S12] [S35] **Stage 2 (Checkpoint barcode or RFID scans)** automates time-serial queue counting and waiting-time alerts across the 6 to 10 line checkpoints. [S20] **Stage 3 (Machine PMDs and power-monitoring sensors)** uses non-intrusive electrical power sensing and PMDs to capture cycle times and micro-stops automatically; research on sewing power monitoring shows that power signatures can help evaluate task difficulty (LD) and operator skill (LS) for staffing and balancing. [S09] [S19] Even at Stage 3, digital alerts must feed a supervisor's floor check rather than trigger blind algorithmic moves that ignore ergonomics or material defects. [S19] [S38] [S0801]

> **GFT NOTE**
>
> **Practical recommendation for Cameroon garment operations**
>
> Do not deploy workstation-level process monitoring devices until the line has run a clean manual hourly balance board, a verified skill matrix and a six-code downtime log for at least four consecutive weeks. [S02] [S12] [S17] Because Cameroon's electricity supply is limited and unreliable, any digital balancing tool introduced later must run on local battery-backed edge hardware with a paper fallback so power interruptions never blind floor supervision. [S09] [S20] [S35] Governance and edge architecture remain with wp14 and wp18. [S01] [S09]

8.13

Learning and absence alter effective station time

Balancing solely from garment SMVs assumes every assigned operator achieves 100 per cent standard speed all day. [S13] [S17] In reality, garment assembly is labour-intensive and line output depends on employee capability alongside machine availability. [S14] [S0802] While target output is set by the garment's standard allowable minutes and available line minutes, actual station cycle times shift with who sits at the machine today and where they stand on the learning curve. [S13] [S18] [S0802]

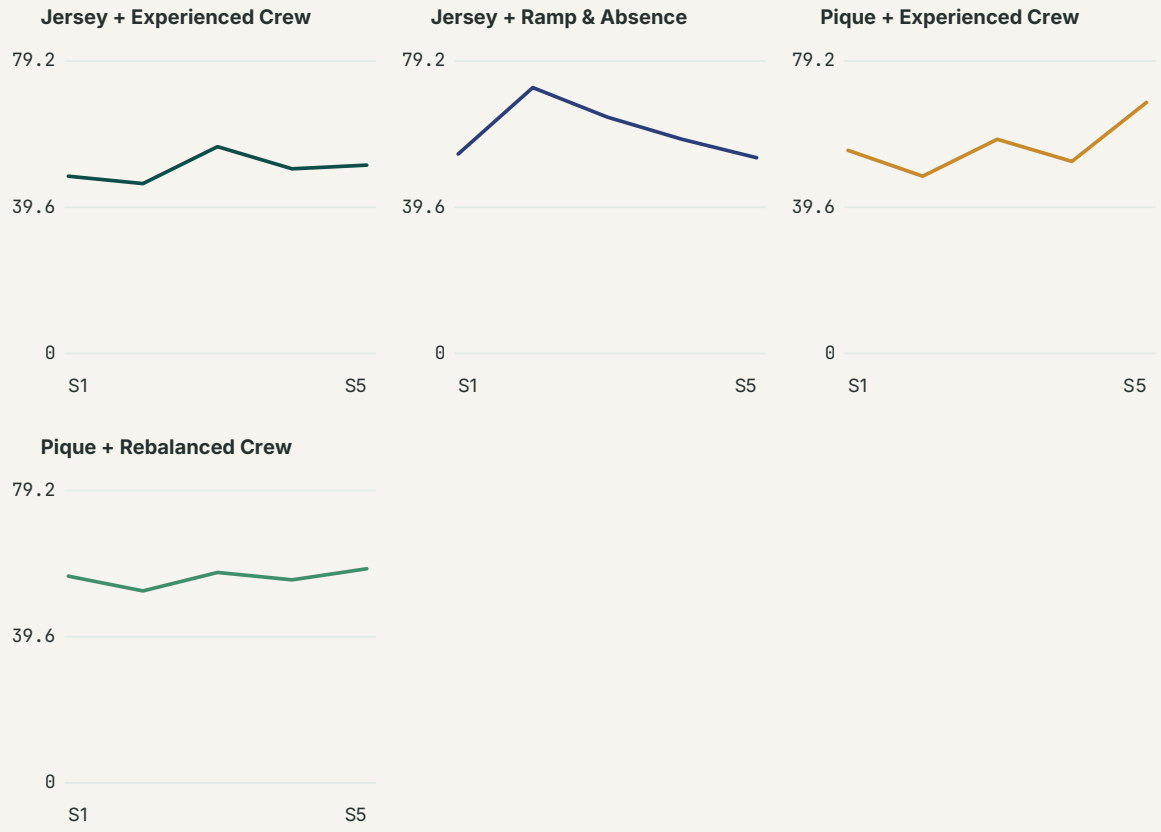
8.14 HOW LEARNING, TURNOVER AND ABSENTEEISM RESHAPE THE STATION PROFILE

Three workforce dynamics reshape station times. [S17] [S18] [S39] First, **task-specific skill ratings** vary across operations: garment balancing research rates workers from 0 (no skill) to 1.5 (fully skilled) by task, so moving an operator from a 1.25-rated seam to a 0.75-rated seam alters station capacity immediately. [S17] Second, **learning curves** shift relative speeds during ramps: manual-machine operators in an apparel study increased average capacity from 60.6 per cent to 79.4 per cent over six weeks, meaning a Week 1 balance becomes obsolete by Week 6. [S18] Third, **turnover and absenteeism** repeatedly reset proficiency: in an Ethiopian manufacturing panel weighted toward textiles and garments, almost one-third of workers left within six months and half within one year. [S39] While not a Cameroon forecast, this shows why retention and supervision matter; Better Work Ethiopia reports that lines led by newly trained supervisors achieved lower absenteeism alongside higher productivity and quality. [S40]

Exhibit 38, p. 133 compares illustrative effective station cycle times across four style and crew combinations against a 60-second pitch limit. [S15] [S16] [S17] [S18]

EXHIBIT 38 / SECONDS PER PIECE

Style and crew scenarios require different balances



ILLUSTRATIVE [S15] [S16] [S17] [S18] Illustrative station-load comparison across five workstation groups (S1 Placket, S2 Shoulder, S3 Collar, S4 Sleeve, S5 Hem) under a 60-second pitch ceiling (S16). Panels compare two style mixes (Basic Jersey vs Vented Pique) and two crew states (Experienced Crew vs Ramp Crew with one absence replacement), using task-skill and learning logic from S15, S17 and S18. Values are illustrative engineering scenarios, not measured GFT plant outputs.

In **Exhibit 38**, p. 133, Panel 1 (Jersey + Experienced Crew) keeps all five stations (S1 to S5) between 46 and 56 illustrative seconds, below the 60-second pitch ceiling. [S15] [S16] Panel 2 (Jersey + Ramp & Absence) shows the same style with a ramp crew and an absence replacement at S2, pushing S2 to 72 seconds and S3 to 64 seconds. [S16] [S17] [S18] Panel 3 (Pique + Experienced Crew) switches to a vented pique style whose side-vent and bartack work pushes S5 to 68 seconds, while Panel 4 (Pique + Rebalanced Crew) restores all five stations to 52 to 58 seconds via task sharing and floater support. [S15] [S16] [S17] These illustrative panels show the mechanism linking style SMV (S13) and skill (S17; S18), not a plant forecast. [S15]

8.15 PRE-SHIFT ATTENDANCE VERIFICATION AND TARGETED CROSS-TRAINING

Dynamic balancing starts in the first ten minutes of the shift. [S12] [S40] During roll call, the supervisor checks attendance against critical-path stations (those loaded above an illustrative 85 per cent of pitch time). [S16] [S17] If a critical station is vacant, the supervisor executes a **domino substitution**: moving a present operator with a verified skill rating (S17) onto the critical station to keep it below pitch, and placing the reserve or ramp operator on the vacated lower-load non-constraint station where protective capacity (S28) absorbs their slower pace. [S16] [S17] [S28] Using task difficulty (LD) and skill (LS) assessments (S19), GFT specifies at least two qualified backups on the shift roster for every critical-path operation (an illustrative 3-deep coverage rule) and trains floaters on adjacent operation pairs. [S17] [S19] [S26]

> **WARNING**
>
> **Operational failure mode: Over-rotating operators destroys learned rhythm**
>
> Moving operators between machines mid-shift incurs setup and adjustment slowdowns, restart learning dips and first-piece defect risks. [S02] [S04] [S18] Supervisors should never shuffle operators hourly to chase minor random variation (S07); intra-shift rebalancing is authorised only when the dual bottleneck threshold (S20) is breached or when an absence, breakdown or changeover alters station capacity. [S12] [S20]

8.16

Cadence locks the improvement into management

Sustained dynamic balancing requires a formal management cadence so floor adjustments, root-cause engineering and order planning reinforce one another. [S12] [S26] [S42] **Exhibit 39**, p. 135 defines the four governance horizons in GFT's Cameroon textile programme. [S09] [S12] [S20] [S26] [S42]

EXHIBIT 39 / GOVERNANCE HORIZON

Each management cadence owns a different balancing decision

Cadence	Primary owner	Diagnostic signal	Authorised action	Escalation trigger
Hourly line check	Line supervisor and IE tech	Checkpoint good output, upstream WIP buffer and queue age (S12; S20)	Deploy floater, split manual element, call mechanic or throttle release (S09; S15)	Constraint persists for 2 consecutive hours or breaches quality hold
Daily shift huddle	Line supervisor and quality/maint leads	Attendance roster vs skill matrix, previous shift OEE loss tree and FPY (S04; S17)	Domino substitution for absences, pre-stage attachments and set shift pitch (S16; S17)	Critical operation lacks qualified backup or machine down over 60 minutes
Weekly root-cause review	Industrial engineering and plant manager	Recurring bottleneck shifts, 5 Whys logs, learning curves and rework pareto (S09; S18; S29)	Update standard work, revise SMV skill ratings, retrain or redesign folders (S17; S26)	Style family or machine count cannot meet takt within 40-hour week (S33)
Monthly S&OP capacity review	Operating director, planning and commercial	Plant utilisation, order peaks, turnover, outage losses and lead times (S35; S39; S42)	Smooth order release with buyers, adjust machine fleet or hiring pipeline (S39; S42)	Capital expenditure or buyer contract revision required

ILLUSTRATIVE [S09] [S12] [S20] [S26] [S42] Illustrative management cadence applying GFT's Cameroon textile programme structure alongside hourly balancing (S12), bottleneck diagnostics (S20), digital monitoring support (S09), standard work (S26), and advance order planning (S42).

8.17 DAILY FLOW PROTECTION VERSUS WEEKLY AND MONTHLY STRUCTURAL REMOVAL

In **Exhibit 39**, p. 135, the **hourly line check** (an illustrative 3-to-5-minute walk) and **daily shift huddle** (an illustrative 10-minute stand-up) protect today's flow by matching attendance to the skill matrix (S17), staging attachments (S02), and executing bounded intra-shift moves when upstream WIP and utilisation (S20) flag a shifted constraint. [S02] [S12] [S17] [S20] If the same station requires emergency floater support repeatedly across a week, the **weekly root-cause review** applies 5 Whys analysis (S29) to eliminate the underlying cause: updating standard work (S26), recalibrating skill ratings (S17; S18), fixing worn folders (S02), or correcting piece-rate incentives that encourage upstream overproduction of defective bundles (S32; S0802). [S17] [S26] [S29] [S32]

When a constraint stems from volatile style mixes, special-machine shortages (S15), grid outages (S35; S36), or attrition (S39) that cannot be balanced away within Cameroon's statutory 40-hour week (S33; R16), the **monthly sales-and-operations planning (S&OP) review** escalates the evidence to commercial and executive leadership. [S15] [S33] [S35] [S39] ILO supply-chain cases document companies that plan

orders, lead times and production peaks in advance with suppliers; monthly S&OP gives the plant the measured throughput and skill-coverage data required to level order release before impossible peaks hit the floor. [S42]

Within GFT's toolset, the **line-balancing studio** (`line-balancing`), **OEE and sewing-line simulator** (`oee-line`), **ramp planner** (`ramp-planner`) and **supervisor pipeline** (`supervisor-pipeline`) operationalise these cadences while connecting to `wp02` on the KPI cascade and `wp18` on edge monitoring. [S09] [S17] [S18] [S40] Yet even the best daily balance breaks down if faster upstream stations are allowed to flood the line with inventory. [S21] [S24] Part III therefore turns to material flow: Chapter 9 shows how pull authorisation, small transfer lots and Little's Law keep work moving to the constraint without mistaking local busyness for finished garments. [S21] [S22] [S24] [S28]

A line balance is a hypothesis written before the shift begins; the queues on the floor tell the supervisor where the constraint actually lives today.

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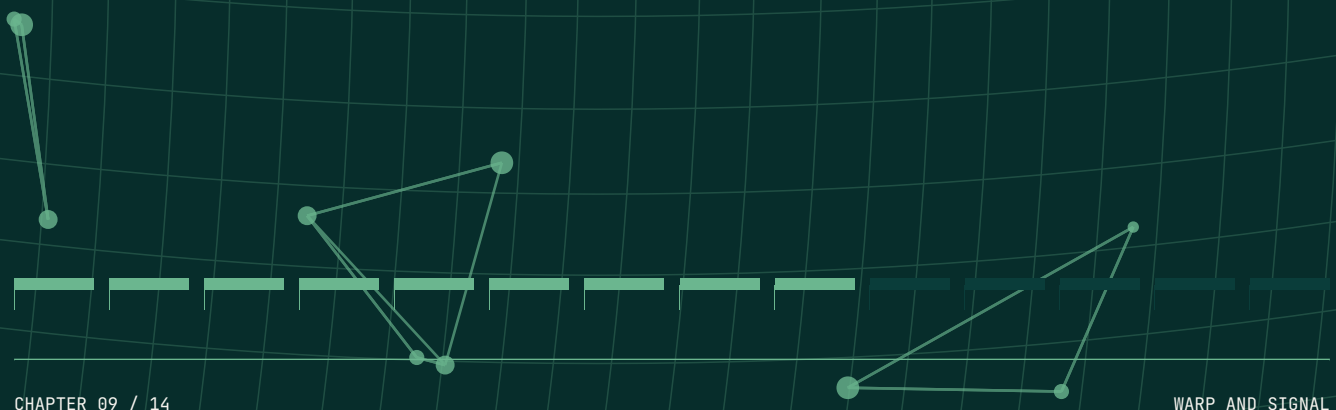
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09

PART III: DESIGN FLOW INSTEAD OF LOCAL BUSYNESS / PULL, WIP AND RELEASE

Lean flow converts balanced work into shorter throughput time

Balanced work needs controlled release. A line shortens delivery time when it admits work that downstream operations can use, makes queues visible and protects good output at its constraint.



CHAPTER 09
DECISION TEST

Balanced work needs controlled release. A line shortens delivery time when it admits work that downstream operations can use, makes queues visible and protects good output at its constraint.

Lean flow requires a release rule, an explicit work-in-progress boundary and a response when that boundary fills. Balancing establishes a feasible distribution of work; controlled release prevents that distribution being overwhelmed by material admitted faster than the line can finish it. GFT recommends managing accepted garments leaving the line together with the quantity and age of work inside it. An operator's activity is useful when it advances authorised work towards completion. Producing components without a downstream need can increase activity while leaving delivery unchanged. This chapter sets out a proposed control design, distinguishes evidence from assumptions and explains how a factory can test the design before extending it.

9.1

Pull authorises production from downstream need

The Lean Enterprise Institute defines pull through a downstream request specifying what is needed, how much, where and when. Upstream production follows that request. Its supermarket approach replenishes withdrawals from a controlled store, whereas sequential pull uses a planned product sequence where stocking every item would be impractical. These are different ways of authorising work; a kanban card is a carrier of the instruction. [S24]

GFT proposes defining a release decision before choosing its technology. The instruction should identify the garment family, operation, permitted quantity, destination and material status. It should also name the person responsible for rejecting an incomplete instruction. A brightly coloured card that travels with every bundle irrespective of downstream capacity changes the label on production rather than its governing decision. An electronic message has the same limitation if the receiving process cannot refuse work when its agreed space is full.

For a proposed sewing pilot, the control boundary should start when a complete, approved kit enters the line and end when the garment passes the agreed exit inspection. The kit definition must specify matching panels and required trims, without equating a loose panel with a garment. Record partially completed kits separately until their relationship to a complete garment is known. Otherwise, the release count can appear conservative while incomplete pieces occupy machines and floor space inside the boundary.

A release permission should be consumed by a stated event and returned by another stated event. GFT recommends consuming it when the kit crosses the entry point and returning it when an accepted garment leaves. Scrapped work needs an authorised closure event, with the material discrepancy recorded. Rework retains its identity and remains visible within the boundary. These proposed rules prevent a rejected garment from generating fresh admission merely because it has been moved to a repair table.

The supervisor should also have a documented refusal rule. If the permitted queue is full, the default action is to stop further admission at that interface and investigate. A planner may authorise a temporary exception, but the exception should state the extra quantity, reason, expiry and expected recovery. Treating every urgent order as an

unrestricted exception would make the nominal limit meaningless. A visible exception record lets management distinguish an unsuitable limit from repeated avoidance of a suitable one.

Pull should not be confused with an instruction to run down all upstream material stocks. A sewing-line admission limit answers how much authorised work may occupy the sewing system. The purchasing and fabric policies answer different questions about replenishment and supply risk. GFT recommends maintaining separate records for these boundaries so that a line pilot cannot claim success by moving its queue into the cutting room. Inventory policy across the wider supply chain belongs in the paper addressing that subject; here the question is disciplined admission to production.

> **GFT NOTE**
>
> Begin with a visible entry point, identifiable kits and a release ledger that can be reconciled by the supervisor. Give the downstream process authority to refuse excess work. Add electronic signalling when it reduces missed instructions or makes exceptions easier to resolve. Retain a usable manual release method during loss of connectivity.

The practical test is whether anyone can point to the permission for a garment now inside the line. If the answer depends on remembering a conversation, the design needs a clearer record. If permission exists but no usable material accompanies it, investigate preparation. If material exists but the permitted space is occupied, investigate flow. Keeping these questions separate makes the response specific without attributing every delay to a machine or to an operator.

GFT recommends a release ledger whose record can survive a shift handover. Its minimum fields should describe the kit identity, product, quantity, admission time, current location, disposition and permission status. Corrections should preserve the original event and explain why it changed. A counted garment without a matching event is an exception to investigate, not a reason to backfill a convenient admission time. This proposed discipline gives the next supervisor a recoverable operating state.

A lost card should trigger reconciliation before replacement. Check the physical kit, its last recorded location and any completed exit. Cancelling the original permission and issuing its replacement should be linked in the record. Otherwise, both may later circulate as apparently valid instructions. The same rule applies to an electronic instruction resent after a connection failure: a repeated message should refer to the existing permission rather than create additional authorised quantity.

During a power interruption, GFT proposes freezing new admission unless the approved contingency method can preserve identity, safety and the permitted inventory boundary. At restart, reconcile work still on machines, work under inspection and work awaiting repair before releasing replacements. A recovered connection should not automatically replay every queued instruction as fresh production. The proposed control objective is continuity of authorisation across the interruption, rather than continuity of machine activity at any cost.

9.2

Single-piece flow changes the visibility of problems

MIT's lean glossary describes single-piece flow as work moving immediately from an operation to the next, with no intervening buffer between workers. This concerns the transfer arrangement, not an empty production system: work can still be undergoing processing at each operation. For this chapter, a progressive bundle means that a group waits to move together, while a small transfer bundle is a deliberately bounded intermediate design. [S22]

GFT recommends comparing those arrangements by the response they require when work cannot advance. In a strict direct handover, a downstream refusal should become immediately visible upstream. In a bounded transfer queue, the same refusal first consumes the agreed waiting space. With unrestricted bundles, material can continue accumulating without forcing an explicit decision. These are proposed diagnostic questions for a line walk, rather than a claim that every observed bundle system behaves identically.

Choose the first pilot boundary where adjacent operations have compatible work and an available response to abnormalities. Require the receiving operator to confirm identity and condition at handover. Agree who answers a stop signal and what work is safe while the issue is resolved. Removing waiting space before the team can answer that signal would test endurance rather than the proposed control method. The trial should expose problems in a way that the team can act on.

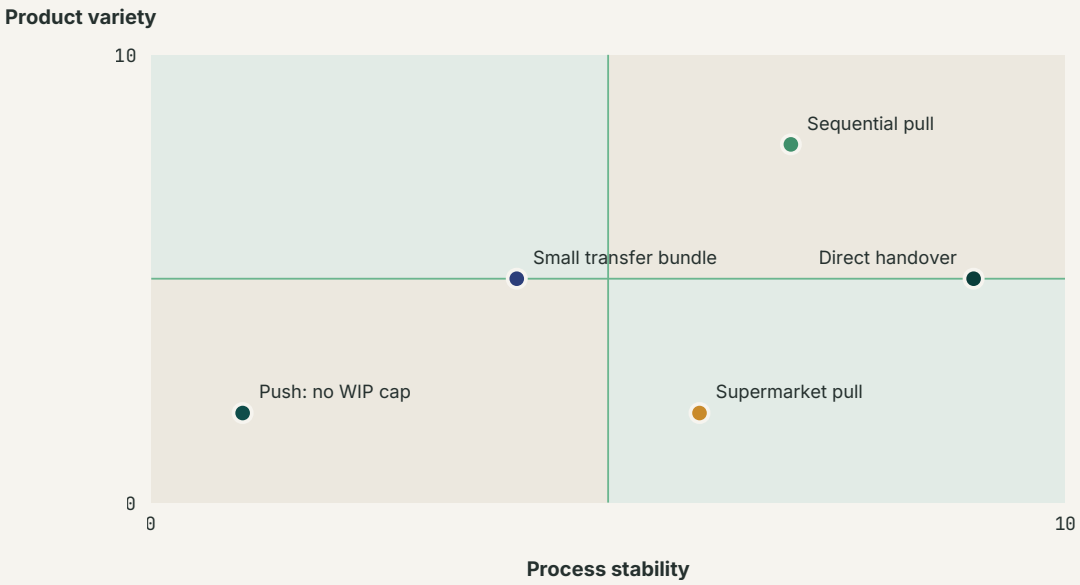
Small transfer bundles can be a reasoned starting point where direct handover is not yet workable. Define the bundle by its maximum quantity and identity, and define the receiving queue separately. The production lot, transfer bundle and release allowance need not be equal. A style may remain the planned production lot while its components move in smaller groups. That distinction lets a pilot alter transfer behaviour without silently rewriting purchasing quantities or the entire style schedule.

Quality containment needs its own rule. GFT recommends recording the last confirmed conforming handover when a seam fault is found, then tracing the potentially affected work using its identities. Do not send doubtful pieces forward to preserve apparent flow. Mark their status, retain them in the inventory reconciliation and give their disposition an owner. The useful question is whether a defect is found while the response can still contain it, rather than whether an inspection point has been removed.

The proposed design comparison in **Exhibit 40**, p. 142 uses invented ordinal positions to structure discussion. Its horizontal direction represents increasing stability of the local process. Its vertical direction represents increasing product variety. The positions are illustrative judgements, not measurements or an optimisation. Push describes an authorisation policy; bundles and direct handover describe transfer arrangements. They are shown together to expose design choices, not to imply mutually exclusive manufacturing categories.

EXHIBIT 40 / ILLUSTRATIVE ORDINAL DISCUSSION SCALE

Release and transfer choices need different operating conditions



ILLUSTRATIVE [S22] [S24] GFT discussion model, not measured scores. Axes run from low to high on an arbitrary 0 to 10 scale. Push is an authorisation policy; bundle and direct handover are transfer arrangements and may coexist with different release policies. Positions indicate questions for a trial, not rankings or recommended limits.

Before selecting a point on this illustrative map, GFT recommends asking the team to demonstrate the assumed conditions. Can the chosen sequence be maintained? Can matching components be delivered together? Can a refusal be resolved without bypassing inspection? Record each answer as observed, untested or failed. A transfer design should proceed on the strength of those observations, with an agreed fallback, rather than because its name appears further towards the stable end of a diagram.

A proposed handover test should also cover component separation. If a garment's panels travel along different preparatory routes, direct transfer of an isolated panel does not prove that the complete garment can advance. Require matching identities at the joining operation and record missing counterparts as a preparation exception. Keep the transfer rule distinct from the completion count, so that a fast stream of available panels cannot hide an older queue of incomplete garments.

GFT recommends involving operators in choosing the physical holding method. A permitted queue should have a defined location and safe presentation, without requiring excessive reach or obstructing access. Demonstrate how work is returned when a handover is refused. If the agreed space cannot hold the permitted work safely, revise the allowance or the arrangement before the trial. The inventory rule and the physical method should describe the same feasible operation.

9.3

Little's Law makes WIP a time decision

Little's Law relates average WIP to average throughput rate multiplied by average time inside the same system. MIT's glossary states the long-run stability condition explicitly. Here, throughput time means elapsed residence from kit admission to exit, including waiting and repair. It must not be confused with the shorter repeat time of a workstation. The relationship concerns compatible averages, not a promise for an individual garment. [S22]

For a proposed pilot, GFT recommends drawing the boundary on the floor plan and on the collection sheet. Count work waiting, being processed and held for repair or disposition inside it. Use an elapsed-time clock for residence time and an output rate expressed on that same clock. An overnight stop remains part of calendar residence if the garment stays inside. Alternatively, a declared operating-time clock can answer a different question, provided all terms use it consistently.

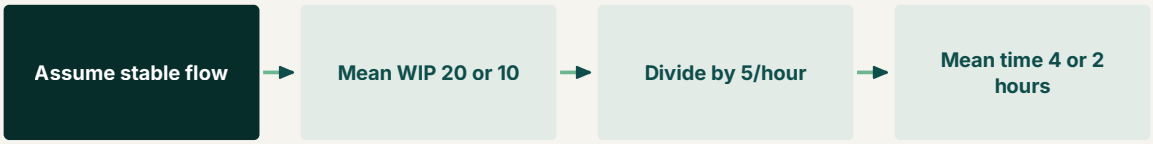
The time-weighted inventory average deserves particular attention. A photograph of an unusually tidy queue at the end of a shift is not an average. GFT proposes logging each entry and exit where practical, then integrating the inventory level over the observation interval. Where manual collection requires snapshots, spread them across the interval and report the approximation. Keep opening and closing inventory visible, and explain any transfers whose time or identity could not be reconciled.

> **WORKED EXAMPLE: IDENTICAL THROUGHPUT CAN COEXIST WITH DIFFERENT WIP**
>
> This illustrative model assumes a stable sewing boundary with no scrap, bypass or rework, matching kits, and accepted throughput of 5 garments per elapsed hour. At an assumed mean residence of 2 hours, mean WIP is 5 multiplied by 2, or 10 garment equivalents. At the same throughput, mean WIP of 20 implies mean residence of 20 divided by 5, or 4 hours. The relationship follows Little's Law; all operating inputs are assumptions, not factory observations. [S22]
>
> In this illustrative comparison, reducing mean WIP from 20 to 10 while sustaining throughput reduces mean residence from 4 to 2 hours. The arithmetic does not establish that the lower inventory is physically attainable. A trial must show that material availability, quality and the constraint remain adequate after the change. If accepted throughput instead falls to an illustrative 2.5 garments per hour with mean WIP of 10, mean residence returns to 4 hours. Cutting inventory alone does not guarantee faster delivery. [S22]

The illustrative relationship is made explicit in **Exhibit 41**, p. 144. The diagram is a calculation aid with assumed inputs. It does not size the required stock ahead of a constraint or establish the time needed for replenishment. Those decisions require evidence about actual interruptions and recovery.

EXHIBIT 41 / ILLUSTRATIVE GARMENT EQUIVALENTS AND ELAPSED HOURS

The same output rate can carry different residence times



ILLUSTRATIVE [S22] Illustrative stable boundary with no scrap, rework or bypass. Assume accepted throughput is 5 garments/hour. Little's Law gives mean time = mean WIP / throughput: 20/5 = 4 hours; 10/5 = 2 hours. Assumed values demonstrate the identity and do not establish feasible inventory limits.

GFT recommends treating a discrepancy between the measured averages as a reconciliation task. Check whether the inventory counts include repair while the output count excludes its eventual exit. Check whether work crossed an unrecorded boundary, whether time bases differ, or whether the observation covered a deliberate inventory drawdown. Do not adjust the inventory count solely to force agreement. A transparent explanation of a transient period is more useful than a precise-looking time figure built from incompatible data.

For a line losing work to scrap, the proposed collection sheet should retain accepted output and scrap exits separately. Physical flow conservation must account for every exit; the simple good-output-only example above deliberately excludes that complication. Report cohort residence for accepted garments separately if that is the customer-service question. Do not divide all inventory indiscriminately by good exits and describe the result as a universal residence measure. The boundary and population should remain inspectable by the reader.

A proposed observation plan should retain unfinished work at the end of the measurement window. Completed garments alone can present a favourable picture if difficult jobs remain inside. Record the age and status of those open jobs, then follow them to disposition where practical. Describe whether the residence measure covers an admission cohort, an exit cohort or a continuing steady period. These are different views, and GFT recommends naming the chosen view before calculating its average.

The same discipline applies to unusually old work. Do not reset admission time when a garment moves to a repair bench or changes supervisor. Preserve the original time and add a separate repair event. A reviewer can then distinguish a short repair operation from a garment that waited a long time to receive it. The proposed record should support both the production decision and an honest explanation of customer delay.

9.4

High utilisation can increase waiting

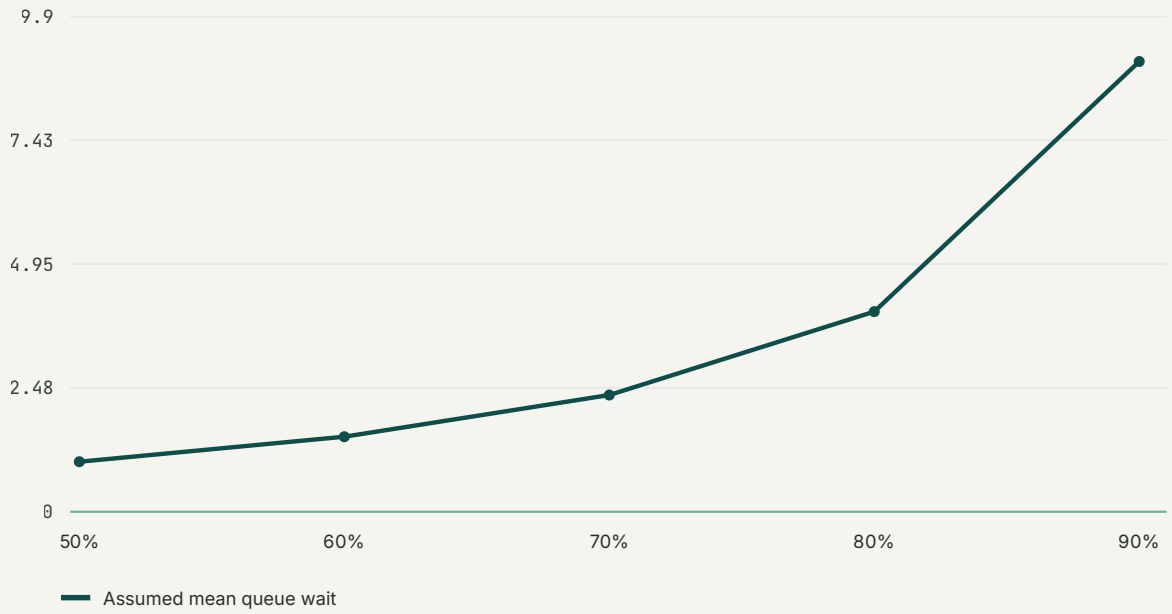
MIT's capacity lecture shows that the relationship between utilisation and waiting is strongly nonlinear under its queueing framework. The teaching distinguishes stable long-run queueing from short-run accumulation and notes the importance of arrival and service variability. It supports investigating congestion, not adopting a single utilisation target for every garment operation. [S23]

GFT's proposed interpretation is that unused capacity needs a purpose and a location. At a non-constraint, the team can use available time for authorised recovery, preparation, inspection or learning, subject to competence and safe methods. At the current constraint, lost productive time requires a different response because it can affect completed output. The same idle-time observation should therefore trigger a question about its cause and system consequence before it triggers an instruction to make more pieces.

The illustrative curve in **Exhibit 42**, p. 145 uses an assumed single-server model with independent exponential arrivals and service, unlimited waiting space, no break-downs, no changeovers and a mean service time of one arbitrary time unit. Its mean queue wait is utilisation divided by the remaining capacity fraction, multiplied by mean service time. These are constructed conditions chosen to show curvature; the curve is not calibrated to a garment line or to Cameroon. The lecture provides the queueing framework. [S23]

EXHIBIT 42 / ILLUSTRATIVE MEAN QUEUE WAIT IN SERVICE-TIME UNITS

An assumed queue becomes more sensitive near saturation



ILLUSTRATIVE [S23] GFT illustrative M/M/1 model, not measured garment data. Independent exponential arrivals and service; one server; infinite buffer; stable utilisation below 1; mean service time = 1 arbitrary unit. Wq = rho/(1-rho). Assumed rho = 0.50, 0.60, 0.70, 0.80, 0.90 produces 1, 1.5, 2.3333, 4, 9. No recommended operating limit is inferred.

Use this illustrative curve as a prompt for observation rather than as a scheduling calculator. A proposed line review should distinguish work arriving irregularly from work taking irregular amounts of service. Record whether the queue forms before a difficult operation, after a material shortage or because an exit inspection is blocked. A common symptom, more waiting, can justify different actions. Increasing the admission allowance before identifying the cause could make the symptom larger without addressing it.

A protective queue should be explicit, counted and justified. GFT recommends placing it only where the trial shows it protects accepted output against a specific interruption. Its purpose is different from an unidentified pile left by habitual overproduction. Name the replenishment event, the response when its contents fall and the action when its upper limit is reached. When the interruption changes, reconsider the queue instead of preserving an inherited allowance indefinitely.

The team should also record occasions when admission is deliberately paused. A pause caused by a full permitted queue may indicate that the release rule is working. A pause caused by missing components may indicate a preparation failure. A pause that starves the constraint may indicate an unsuitable limit or slow replenishment. Separate these states before calculating an occupancy measure. Otherwise, a useful refusal can be reported as a loss and the supervisor may be encouraged to defeat the release rule.

GFT proposes reducing permitted WIP gradually during a controlled trial while keeping the observation method stable. Predetermine the conditions requiring a return to the previous allowance, including deteriorating accepted output, unresolved quality containment or unsafe handling. A reversal should retain the record of what happened. It is evidence about the operating conditions, not a reason to erase the trial. The objective is a defensible release design whose response is understood.

GFT recommends reviewing replenishment reliability before changing a protective allowance. Ask the upstream owner to demonstrate how a falling queue generates action, who supplies the next complete kit and what happens when that kit is unavailable. A queue can be correctly sized for a nominal replenishment process that nobody actually follows. The trial should therefore observe the response as well as the stock level, and retain failures to respond as evidence for redesign.

9.5

Apparel evidence supports testing pull and small-batch flow

A published Ethiopian shirt-factory case combined kanban and single-piece flow with other process-loss interventions. Its abstract reports reductions in WIP of 48.5 percent and throughput time of 80.3 percent. It also describes work on bundle tickets and packing. These are reported results from the study setting, not GFT results, a Cameroon benchmark or an isolated estimate of the effect of kanban alone. [S31]

The sourced quantities appear in **Exhibit 43**, p. 147. The case supports a practical hypothesis: a controlled change to release and transfer arrangements merits testing. Its reported reductions do not establish what a different factory should promise to a buyer or assume in a financing model. The authors themselves propose further work across different product types. [S31]

EXHIBIT 43 / REPORTED REDUCTION FROM THE STUDY BASELINE

An Ethiopian case reports lower WIP and throughput time

48.5%

WIP reduction

Study-reported change

80.3%

Throughput-time reduction

Study-reported change

SOURCED [S31] Published 3 March 2022. Single Ethiopian shirt-factory case combining kanban, single-piece flow and related process-loss work. The abstract reports these reductions. Baseline counts, elapsed-time definitions and causal attribution are not supplied by these tiles. These are not GFT results or Cameroon targets.

For a proposed Cameroon pilot, GFT recommends selecting a defined garment family with identifiable entry and exit events, then observing an unchanged release arrangement before altering it. Record style, size mix, crew, working-time basis, repairs, power interruptions and missing materials in both periods. Select the comparison window before reviewing the results. If the intended conditions cannot be matched, retain the observations but describe the exercise as a learning trial rather than a clean causal comparison.

The pilot should have a written intervention description. Specify whether it changes kit admission, permitted queue size, transfer bundle, handover inspection or more than one feature. If operational needs require simultaneous changes, record the package as such. Do not attribute the entire improvement to a card system when methods, staffing or equipment changed at the same time. A usable factory decision may concern the package, but its explanation must preserve that boundary.

A proposed measurement record should combine accepted output, time-weighted WIP, cohort residence, repairs, missed component matches and reported handling problems. Keep the oldest open work visible alongside averages. Report intervals affected by outages or style changes instead of silently excluding them. Compare the work awaiting entry and finished work awaiting dispatch as well, because an apparent improvement inside sewing could simply relocate the queue. The admission rule is only successful within the boundary actually demonstrated.

GFT recommends agreeing a decision before the trial begins: extend, revise or stop. Extension requires sustained good output and better flow without a deterioration in quality, worker conditions or delivery. Revision is appropriate when a specific interface or exception defeats the proposed rule. Stopping is appropriate when the design cannot operate safely or maintain required output under the tested conditions. These criteria make an unsuccessful experiment useful and limit pressure to report a favourable percentage.

Keep the records practical enough for the people who must use them after the trial team leaves. A supervisor should be able to reconstruct why an urgent kit was admitted, where it waited and what event released the next permission. The reviewer should be able to trace a claimed improvement back to the same definitions used for the baseline. That traceability is the proposed acceptance evidence; a photograph of an orderly line or a larger hourly tally is insufficient on its own.

For a proposed exception review, group deviations by the decision that produced them. An unauthorised admission, an incorrect kit, a missing exit and an unresolved repair each require a different owner. Close an exception only when its physical disposition and record agree. Repeated administrative closure without reconciliation should prevent extension of the trial, because the apparent inventory reduction would then depend on the quality of the bookkeeping rather than on demonstrated production flow.

GFT recommends preserving the trial's unsuccessful intervals in the handover record. A design that works only with its originator present has not yet shown that the ordinary shift team can maintain it. Ask the receiving supervisor to run the admission and reconciliation routine using the written instructions, while the trial lead observes rather than intervenes. Record ambiguities and revise the method before expanding the operating boundary.

9.6

Local efficiency can damage system output

A Lean Enterprise Institute practitioner account argues that spare capacity can be normal in a flow arrangement, and illustrates the failure of producing components when a stopped operation prevents saleable completion. This is an operational argument from practitioner experience, not a quantified causal trial. It is useful here because it challenges the assumption that every machine should keep producing regardless of what the line can finish. [S28]

The Institute's account of the Theory of Constraints also emphasises identifying the limiting factor and subordinating other activities to it before considering additional capacity. Its financial meaning of throughput concerns money generated through sales. In this chapter, physical throughput means garments per declared unit of time. GFT recommends retaining the units explicitly so that accepted line output is never mistaken for invoiced sales or cash received. [S30]

Consider an illustrative line whose upstream operation can prepare 8 kits per hour but whose constraint completes 5 garments per hour, with no losses and adequate downstream capability. Releasing all 8 creates a net accumulation of 3 garment equi-

valents per hour. Over an illustrative 4-hour interval, the accumulation is 12. The upstream operator may appear fully occupied while completed output remains limited to 5 per hour. This is assumed flow-balance arithmetic, not an observed factory result.

If, in the same illustrative model, release instead matches completion at 5 per hour, upstream productive occupancy is 5 divided by 8, or 62.5 percent of its assumed capacity. That percentage is neither a target nor a judgement about the operator. It follows from the deliberately unequal capacities. The remaining time needs an authorised use consistent with skills and safety. Increasing release purely to raise occupancy would restore the inventory accumulation without increasing constraint capacity.

The arithmetic is reconciled in **Exhibit 44**, p. 149. Unlike the sourced case tiles, these figures are illustrative assumptions. They isolate a simple mechanism and exclude outages, repair and mix changes. The comparison therefore establishes neither the necessary protective queue nor a labour requirement.

EXHIBIT 44 / ILLUSTRATIVE KITS OR GARMENTS PER HOUR

Extra admission can add inventory without adding completions

Release rule	Admit/hour	Finish/hour	WIP change/hour
Use upstream capacity	8	5	3
Match accepted exits	5	5	0

ILLUSTRATIVE GFT assumed steady-rate comparison with upstream capacity 8 kits/hour and constraint capacity 5 garments/hour, adequate starting WIP and downstream capability, no losses or rework. Net WIP change = release minus completion. Over 4 hours the excess-admission case adds (8-5)*4 = 12 garment equivalents. Controlled release occupancy is 5/8 = 62.5 percent, not a target.

GFT proposes reviewing incentives against this mechanism. A supervisor should not be penalised for honouring a full-queue refusal while another report rewards unauthorised pieces. Present accepted completion, admission, WIP change and unresolved exceptions together. Keep local output counts for diagnosis, but require the reviewer to explain their relationship to completed garments. The purpose is to make an overproduction instruction visible before it becomes a routine response to a low local efficiency score.

The proposed oee-line simulator should preserve that same logic. Let an increased release setting enlarge the queue when completion cannot rise; do not automatically translate higher local running time into additional accepted output. Identify all assumed capacities, quality boundaries and interruption conditions. Link the model to observed records only after reconciling their definitions. This is a recommendation for model behaviour, not a claim that a simulator or a factory implementation has passed those checks.

The handover to the next chapter is therefore concrete. Once a workable admission rule and transfer boundary have been demonstrated, test whether changeovers, preparation and layout prevent smaller transfers from being sustained. Keep their capa-

city effects visible rather than reopening unlimited release to conceal them. GFT's recommended operating decision remains the same: admit work that can progress, protect the actual constraint and judge the system by good completion and elapsed time, with its inventory and human consequences in view.

A busy station makes pieces; a controlled line makes delivery possible.

CHAPTER SOURCE NOTES

S24 Lean Enterprise Institute. 2020-07-02.

S22 Massachusetts Institute of Technology, MIT OpenCourseWare. 2012.

S23 Massachusetts Institute of Technology, MIT OpenCourseWare. 2004.

S31 Journal of Textile and Apparel, Technology and Management, North Carolina State University. 2022-03-03.

S28 Lean Enterprise Institute. 2016-01-13.

S30 Lean Enterprise Institute. 2006-09-08.

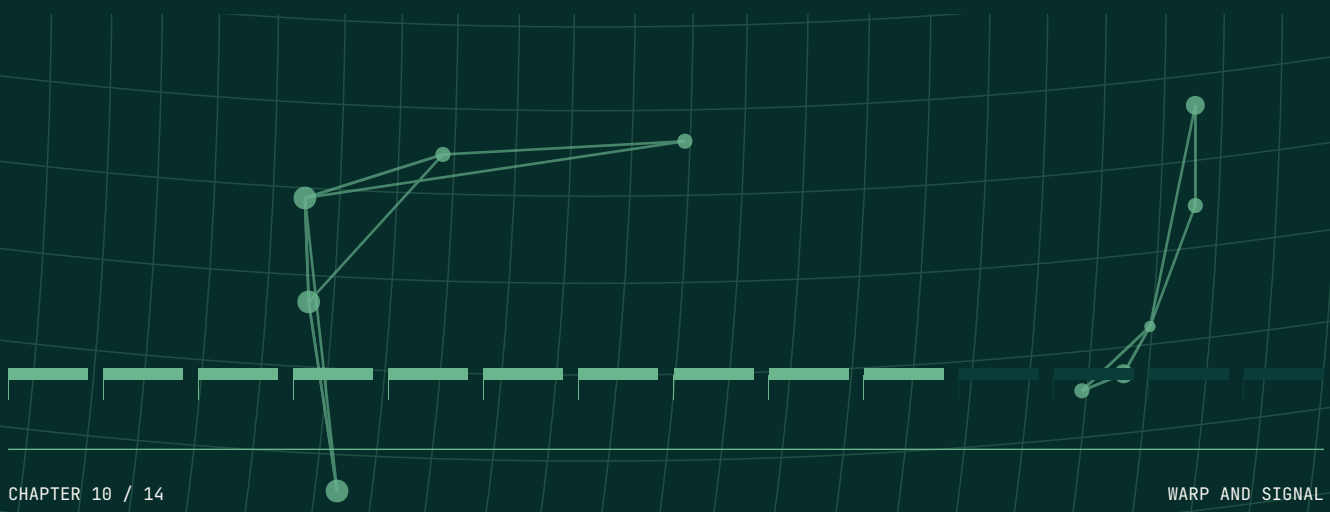
GREEN FUTURE TECH
LIMITED / HONG KONG SAR

10

PART III: DESIGN FLOW INSTEAD OF LOCAL BUSYNESS / DESIGN FOR FLOW

Changeover and layout determine whether small batches pay

Small batches become practical when style changes are short, methods are standard and the layout lets qualified operators share work around the constraint.



CHAPTER 10
DECISION TEST

Small batches become practical when style changes are short, methods are standard and the layout lets qualified operators share work around the constraint.

Small batches pay when the value of earlier, dependable delivery exceeds the extra cost of changing products, preparing materials and restarting good production. GFT's proposed method is to shorten the stopped interval, stabilise the restart, and place compatible operations close enough for qualified people to share work. Batch size then follows from a feasible production schedule and an explicit economic comparison. A cell outline or a faster machine adjustment alone cannot establish that comparison. This chapter supplies a decision method, with constructed calculations clearly separated from published evidence.

10.1

SMED separates stopped work from work done while running

The Lean Enterprise Institute describes SMED as equipment changeover reduction through separating tasks that require a stopped machine from preparation possible while it runs, then converting internal work to external work where feasible. Its single-digit-minute ambition is a method's target, not evidence that a particular garment change can meet it. The relevant distinction is whether production must stop for the task, rather than whether somebody performs the task near a machine. [S25]

GFT recommends beginning with observation of a complete style transition. Follow the outgoing order until its last accepted garment, and follow the incoming order until its first accepted garment. Record intermediate events rather than treating the change as an indivisible stop. Include outgoing material clearance, settings, attachments, thread changes, trial sewing, inspection and release. Keep subsequent recovery to a stable production rhythm as a separate interval. This proposed boundary makes it possible to distinguish a short adjustment from a long return to reliable output.

For each observed task, the industrial engineer should ask what prevents earlier completion. A folder might need fitting during the stop, while its identity, condition and availability can be confirmed beforehand. Thread can be presented in advance without threading a running machine. An operator briefing can occur before the transition if there is safe cover for current work. These are proposed garment applications of the internal and external distinction, subject to the machine's instructions and the actual process. Externalising a task never authorises unsafe intervention.

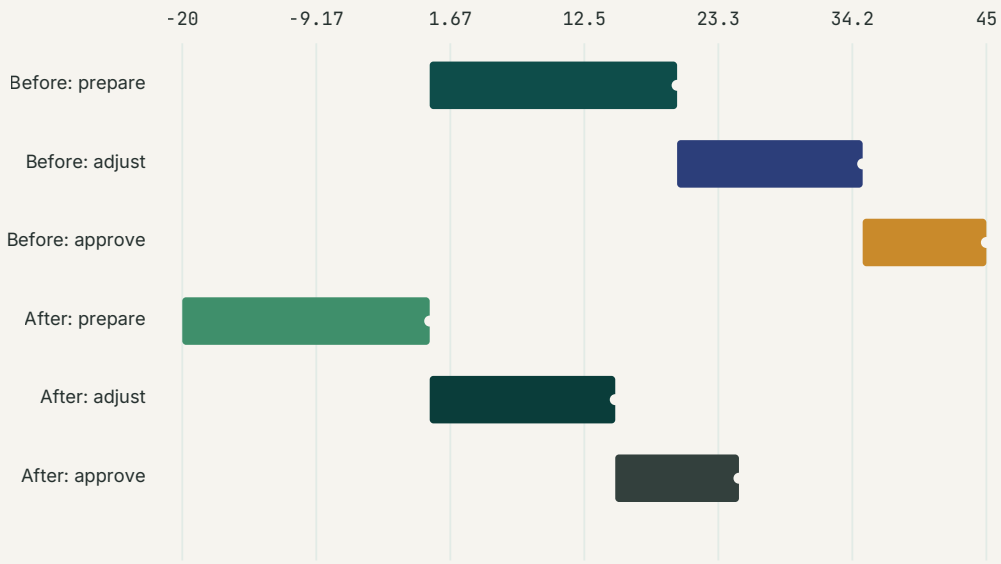
Preparation needs its own capacity budget. Moving work outside the stopped interval does not remove its labour, inspection or storage requirements. GFT recommends recording the preparer's time, location and competing responsibilities alongside the production clock. If preparation takes a qualified operator away from the current constraint, the apparent improvement may have consumed good output before the measured stop begins. The comparison should therefore preserve both elapsed interruption and total paid effort, with an explicit explanation when they move in opposite directions.

In the illustrative schedule in **Exhibit 45**, p. 153, preparation originally occupies the first 20 minutes after the last good piece. Relocating it to the preceding 20 minutes leaves 15 minutes of stopped adjustment and 10 minutes of trial and approval. The assumed interruption falls from 45 to 25 minutes. These invented durations isolate

external preparation only: they do not assume faster adjustment, extra people or relaxed inspection. The schedule assumes the same preparer can work before the stop without reducing current production.

EXHIBIT 45 / ILLUSTRATIVE MINUTES RELATIVE TO LAST GOOD PIECE

Earlier preparation removes time from the stopped interval



ILLUSTRATIVE [S25] Illustrative task plan. Before: preparation 0 to 20, adjustment 20 to 35, approval 35 to 45. After: preparation -20 to 0, adjustment 0 to 15, approval 15 to 25. Same task durations; interruption falls from 45 to 25 minutes only if advance preparation does not reduce outgoing production. Not a resource or dependency solver.

The proposed release check occurs before the outgoing run ends. Planning confirms the authorised next style and revision; materials confirms the kit; maintenance confirms required equipment condition; supervision confirms qualified staffing; quality confirms the acceptance reference. A missing item remains visible as an unready transition. Stopping the line to discover which revision applies is a different failure from a difficult physical adjustment. The improvement log should retain that distinction so the responsible function can change its preparation method.

GFT proposes a physical readiness kit with a matching information record. The kit should identify the next authorised style, the approved revision, required consumables and the person who checked completeness. Keep trial material distinguishable from saleable work and give unused components an explicit return route. A kit that is complete when assembled may become incomplete if another line borrows an attachment. The readiness check should therefore occur at the agreed release event, with ownership of subsequent changes. This is a proposed control against rediscovery during the stop, not a requirement to duplicate every tool or carry unrestricted spares. Compare any duplication cost with the delay it is intended to avoid.

Sequence also needs attention. GFT recommends mapping transitions by product family, since a change between similar operations need not resemble a change requiring different attachments and skills. Record the direction of each transition and retain exceptions. A quick outward change does not prove a quick return. Grouping

compatible work can be tested, but order priority and promised delivery must remain constraints. The purpose of preparation is to make authorised demand easier to serve, rather than to manufacture convenient products without a downstream requirement.

10.2

Changeover reduction releases capacity without new machines

A published cork-stopper equipment study reports a 43 per cent reduction in total changeover time after applying SMED. This is manufacturing evidence from cork production, not apparel evidence or a Cameroon factory result. The authors studied an existing process and its working conditions. Their result supports testing changeover improvement as a mechanism; it does not provide a percentage to insert into a garment forecast. [S1001]

The sourced figure in **Exhibit 46**, p. 154 deliberately retains that boundary. It reports a change in changeover time, with no conversion to garments, profit or national productivity. Such conversions would require further inputs about production rate, demand, labour, materials and the affected resource. GFT's proposed garment test should collect those inputs directly, rather than attach them to a result from a different manufacturing process. [S1001]

EXHIBIT 46 / REPORTED REDUCTION IN TOTAL CHANGEOVER TIME

A cork-production study reports shorter total changeover time

43%

Reported reduction

Cork equipment case, 2018

SOURCED [S1001] Sousa and colleagues, 2018, cork-stopper equipment case. This published non-apparel result is not a GFT result, garment benchmark or predicted Cameroon improvement.

GFT recommends defining capacity released at the resource that actually limits the delivery schedule. If an attachment change stops only an unconstrained feeder while its buffer supplies the line, shortening that stop may not add finished garments. If the same change stops the governing sewing resource and material is ready, the released interval may permit extra output. These are conditional scheduling statements. A trial should show which condition applies through time records and downstream good-output reconciliation, rather than value every minute as interchangeable capacity.

WORKED EXAMPLE: SAVED MINUTES BECOME CONDITIONAL OUTPUT

In an illustrative case, a baseline is assumed to be 60 minutes per transition and the proposed method is assumed to take 20 minutes. The difference is 40 minutes. Assume four identical transitions in the planning period, all stopping the same governing resource, with a stable effective rate of 0.5 accepted garments per minute outside those interruptions. Released time is 4 × (60 - 20) = 160 minutes. Conditional output headroom is 160 × 0.5 = 80 accepted garments. Every input is invented to demonstrate the calculation.

The illustrative 80 garments become additional delivery only if authorised demand, components, qualified labour and downstream finishing are available. The effective rate already includes normal operating quality and pace; do not multiply it by a second quality allowance for the same loss. If a new restart introduces an additional 10 minutes of loss per transition, the revised headroom is (160 - 4 × 10) × 0.5 = 60 accepted garments. Record that restart loss separately before deciding whether the method improved the schedule.

The financial treatment should be stricter than the capacity calculation. GFT recommends classifying released time by its actual use: additional contribution from accepted deliveries, paid hours genuinely avoided, contingency against a late order, or idle time. Salaried labour retained on the same schedule is not automatically a cash saving. Additional output that merely waits in finished stock is not automatically revenue. A proposal can still have value through delivery reliability, but the decision record should state that value separately and explain the evidence needed to price it.

GFT recommends keeping labour concurrency visible in the trial record. If a technician and an operator work safely in parallel, elapsed time can fall while combined labour effort rises or remains unchanged. Record each person's task interval and identify the work they would otherwise have performed. Conversely, a single shared technician cannot prepare several simultaneous transitions merely because the scheduling diagram contains overlapping bars. Resource availability should be reconciled across affected lines before the promised capacity is accepted. This protects the estimate from depending on support that was present for the demonstration but is unavailable during the next ordinary production period.

Changeover should also have a repeatability test. GFT recommends comparing like transitions, retaining product revision, team composition, machine condition and material readiness. Record the distribution of durations rather than only a favoured demonstration. A faster transition supported by unusually intensive engineering attention may be useful learning, but its staffing assumption must remain visible. The operating standard should describe who can repeat the method during ordinary production and which support must be booked. Savings remain provisional until routine shifts can reproduce them.

10.3

Standard work stabilises the new method

The Lean Enterprise Institute places takt, work sequence and standard in-process inventory at the centre of standardised work. Its guidance treats the resulting documents as a baseline for continuing improvement, with training and quality require-

ments supported by associated work standards and job instructions. This is a useful foundation for a changeover standard because the new running condition matters as well as the adjustment sequence. [S26]

GFT proposes a changeover sheet linked to the current operation bulletin. It should name the outgoing and incoming configurations, required attachments, material identities, ownership of each action and the point at which inspection authorises release. Use a controlled revision that can be read at the workstation. Include the abnormal condition that requires escalation and the temporary method that is permitted while waiting. A record that merely says to set up correctly transfers the decision back to the operator without supplying the necessary engineering definition.

The proposed checklist in **Exhibit 47**, p. 156 separates evidence of readiness from evidence of acceptance. It is a design template, not an observed GFT operating procedure. Each row needs a local instruction with product-specific details before production use. The owner named by role performs or confirms the check; the event record preserves who actually did so. Assignment of responsibility should therefore be accompanied by access to the approved sample, tools and authority required to act.

EXHIBIT 47 / PROPOSED CONTROL POINTS

The changeover standard ends with authorised good output

Gate	Owner	Evidence
Ready to stop	Supervisor	Kit and revision checked
Safe to adjust	Technician	Isolation confirmed
Ready to trial	Operator	Settings recorded
Good piece accepted	Quality	Sample result retained
Stable handover	Supervisor	Pace and issues logged

ILLUSTRATIVE [S26] Illustrative GFT checklist derived as a proposed application of standard-work principles. Local machine instructions and product acceptance rules must supply the detailed criteria. This is not a completed factory procedure.

GFT recommends distinguishing the first accepted piece from stable output. An accepted sample proves that a piece met its stated checks at that event. It does not establish that the whole line can maintain the required pace or that later bundles are correctly identified. The handover should therefore preserve an agreed observation boundary for pace, quality and unresolved faults. This chapter proposes that control boundary; the adjacent quality chapter owns detailed defect classification and corrective-action methods, which need not be recreated inside the changeover sheet.

Standard in-process stock should be a purposeful part of the restart method. Specify where permitted stock sits and how it remains identified through the transition. Keep outgoing components separate from incoming components until disposition is clear. If buffer stock is used to protect a downstream process, include its preparation and clearance in the comparison. Otherwise an apparently uninterrupted line may have

borrowed from inventory built earlier. The proposed method is to reconcile stock movement with the production clock, rather than infer flow from the absence of a visible stop.

After each trial, GFT recommends reviewing the sheet with the people who performed the work. Preserve deviations that prevented safe or correct execution, and distinguish a missing instruction from a deliberate improvement. A revised method should be authorised before it replaces the current one. Training should use the actual attachment, material presentation and inspection reference intended for production. An operator should be able to explain both the sequence and the condition that requires stopping. The sheet is useful when it supports that judgement under ordinary conditions.

The proposed event record should be short enough to complete during production but detailed enough to reconcile later. Link the order, operation-bulletin revision and equipment identity to the readiness, stop, acceptance and stable-handover events. Preserve the reason for any missing timestamp instead of silently reconstructing it as measured fact. GFT recommends separating operator entry from supervisory correction and retaining the original value when a correction is justified. This chapter specifies the decision meaning of those fields; data governance and platform architecture belong elsewhere in the paper library. A manual record remains suitable for the trial if it supports the same traceable boundary.

Exceptions need controlled treatment. A missing spare, a changed fabric response or an absent qualified operator may make the planned method infeasible. GFT proposes recording the exception, its temporary approval and the order affected, then revising the next transition estimate if the condition persists. Concealing exceptions inside a shortened average would weaken the schedule. Equally, an isolated abnormality should not automatically become permanent allowance. Separate the repeatable method from the unresolved cause so planning can use a realistic range while engineering works on removal.

10.4

Cells make task reassignment physically possible

The Lean Enterprise Institute defines a cell through adjacent processing steps and near-continuous movement of items individually or in small batches. It explains that a U shape can reduce walking and enable different combinations of operator tasks as demand changes. These are layout mechanisms, not evidence that every U-shaped arrangement improves a garment line. [S27]

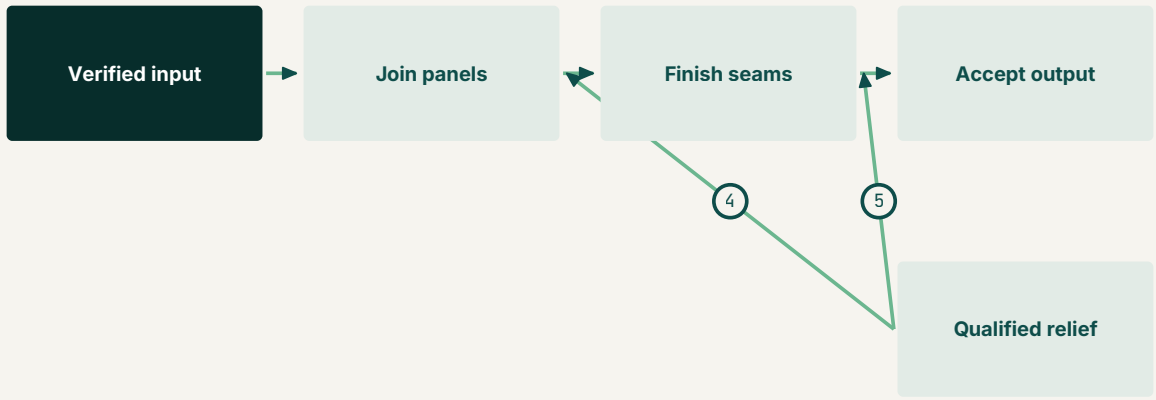
GFT recommends starting the layout review with the authorised product family and feasible operation sequence. Mark machine types, attachments, manual work, inspection points and material presentation on the existing floor arrangement. Trace the route of both components and people, including replenishment and removal of rejected work. Record crossings, reaches and returns that require observation. Only then draw alternatives. The proposed test is whether a layout permits the intended work combinations safely and at acceptable quality, with the actual utilities and access conditions present.

An alternative should preserve space for maintenance, cleaning, safe access and material replenishment. GFT recommends checking that compressed air, power leads and other services do not force people across a moving supply route. A short walking path is not sufficient if a worker must twist repeatedly to retrieve panels or cannot adjust the workstation to the task. Obtain competent local safety and ergonomic review before a physical rearrangement. No clearance dimensions are prescribed here because the relevant equipment, building and applicable requirements have not been established.

The illustrative topology in **Exhibit 48**, p. 158 shows a proposed sewing path with a qualified relief role. It is deliberately a relationship diagram rather than a scaled floor plan. A U arrangement would place entry and exit near each other, subject to the local access review. The relief links identify where a qualified person might provide cover; they do not establish simultaneous capacity or permit an operator to abandon a running task. Physical placement and staff allocation must still be trialled together.

EXHIBIT 48 / ILLUSTRATIVE PROCESS AND COVER RELATIONSHIPS

Adjacent tasks need qualified cover as well as a short route



4. Cover
5. Cover

ILLUSTRATIVE [S27] [S17] Illustrative topology, not a scaled U-shaped floor plan or validated balance. Solid sequence links show proposed material movement; links labelled cover indicate possible assistance by a separately qualified relief role. No simultaneous resource availability is assumed.

Before moving equipment permanently, GFT recommends a reversible mock-up using actual material carriers and representative garments. Have operators demonstrate the intended work sequence, replenishment, defect removal and response to a stopped neighbour. Observe the busiest credible staffing configuration as well as the leanest feasible configuration. A cell that works only when everyone is present and no material is delivered has not passed the proposed operating test. Preserve the observations and revise the arrangement before changing fixed services or making a major purchase.

GFT proposes comparing movement as time attached to an actual task sequence. Measure travel with the intended material carrier and the intended replenishment route, then include that time in the assignment under test. An empty-handed walk around an unfinished mock-up is insufficient evidence of the production route. Retain the conditions of the observation, including whether access was clear and whether another operator needed the same space. Where a proposed shared position causes conflicting access, redesign the handover or preserve separate staffing. Do not count the same walking reduction again as both extra production time and a separate reduction in paid hours unless the financial boundary supports both effects.

Layout economics should include the receiving and dispatch boundaries. Bringing machines closer while leaving kits across the building may shorten internal transfers and increase replenishment travel. GFT proposes tracing a complete order through preparation, sewing and removal before crediting a distance saving. Count recurring handling by every affected role, including material handlers and quality staff. Keep aisle stock visible in that trace. This method avoids claiming a local reduction when the same work has simply moved beyond the drawn cell boundary.

The layout decision should remain conditional on product compatibility. A dedicated machine or an operation with a different safety or environmental requirement may need a shared resource outside the cell. GFT recommends describing the external route, its authorisation signal and the permissible queue rather than forcing visual symmetry. The useful cell is the one that supports a feasible sequence with controlled handovers. Its outline can be straight, curved or interrupted if that is what the observed operations require. Appearance is not the acceptance criterion.

10.5

Skill flexibility makes the cell more than a shape

A garment-balancing study explicitly models worker capability by task and compares staff-assignment approaches. Its experiments also show that assigning workers to multiple tasks can worsen the modelled balance when skills differ substantially across those tasks. This is simulation evidence about the studied allocation problem, not proof that cross-training is ineffective. It warns against treating all nominally available workers as interchangeable capacity. [S17]

GFT proposes recording capability at the combination of person, operation, machine, material and quality requirement. Qualification should refer to observed safe execution and accepted work, with an explicit record of any supervision still required. A generic ability to sew does not identify whether somebody can adjust the relevant folder or maintain the required seam on the incoming material. The proposed skills record should therefore support the exact reassignment being considered, while limiting personal information to what the production decision needs.

In an illustrative staffing calculation, assume joining takes 0.8 minutes and seam finishing takes 0.7 minutes for a qualified operator, with 0.2 minutes of movement per completed garment. Combining the tasks gives 0.8 + 0.7 + 0.2 = 1.7 minutes per garment, or about 0.59 garments per minute. If the required cell rhythm is one garment

per minute, that combination is infeasible even though the machines are adjacent. These invented values demonstrate why available walking space cannot substitute for a time-feasible assignment.

If a different illustrative operator needs 1.2 minutes for joining and 0.9 minutes for finishing, the same movement allowance produces 2.3 minutes per garment, or about 0.43 garments per minute. Neither illustrative rate is a measured GFT result or a universal learning allowance. The difference changes the feasible staffing plan before any machine is moved. GFT recommends using task-specific observations and uncertainty ranges in the balancing model, with product and method held comparable, rather than attaching a single permanent speed factor to a person.

Training should therefore target a specific coverage gap. GFT recommends identifying an operation whose absence would stop the intended family, selecting a trainee and supervisor, and protecting time for practice outside the promised production rate. Define what evidence authorises independent execution and what causes that authorisation to be reviewed. Include settings, abnormality response and first-piece checks where the assignment requires them. Training is not complete merely because a person has watched the task or has been listed as available on a rota.

The proposed cell trial should test foreseeable disruption without creating unsafe production conditions. Use a planned, supervised absence from the assignment to check whether the nominated cover can take over correctly. Record the time needed for handover and the output or quality effect. Do not deduct that cover role from another operation while still counting its full capacity there. Where no feasible cover exists, retain the staffing constraint in the schedule. A transparent constraint is more useful than a nominally flexible cell that repeatedly breaks its delivery promise.

GFT also recommends including operators in the acceptance discussion. Reassignment can change attention, movement and responsibility even if the total standard work content appears unchanged. Ask whether the task sequence is clear, whether help is accessible and whether the pace can be maintained without bypassing checks. Record concerns as design inputs requiring resolution. The proposed objective is reliable accepted output with feasible work, not a staffing reduction inferred from a drawing. Any employment or remuneration decision requires its own authorised process and applicable advice.

10.6

Batch size is an economic consequence, not a slogan

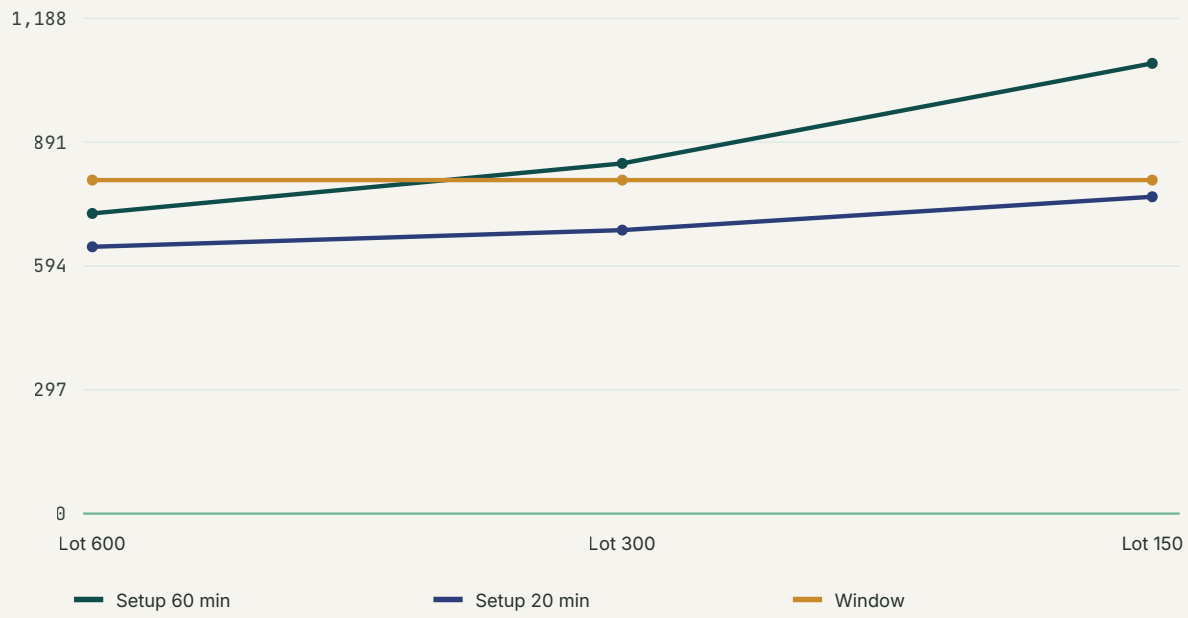
The Lean Enterprise Institute describes pull production as upstream work authorised by downstream need. Combined with the SMED distinction, that supplies a practical question: how frequently can the plant change its authorised mix without losing the delivery window? It does not prescribe a universally economic batch size. GFT's proposed comparison keeps production lot size, transfer quantity and customer order size separate, because reducing a transfer bundle need not require an additional style change. [S24] [S25]

For the illustrative comparison in **Exhibit 49**, p. 161, assume a repeat planning window requires 1,200 accepted garments at a stable effective rate of 2 accepted garments per minute. Processing therefore occupies 600 minutes. Compare production lots of 600, 300 and 150 garments. Assume every lot requires a style setup, including the initial setup within the window, no setup is carried in from a previous period, and all transitions have the same duration. These artificial conditions make the count explicit: the alternatives require 2, 4 and 8 setups.

With an illustrative baseline setup of 60 minutes, total occupied time is 600 + 2 × 60 = 720 minutes for the largest lot, 600 + 4 × 60 = 840 for the middle lot, and 600 + 8 × 60 = 1,080 for the smallest lot. With an illustrative improved setup of 20 minutes, the corresponding totals are 640, 680 and 760 minutes. An assumed available window of 800 minutes admits the smallest lot only under the improved method. This is a conditional feasibility result, not proof of profit.

EXHIBIT 49 / ILLUSTRATIVE OCCUPIED MINUTES PER PLANNING WINDOW

Shorter setup makes the smallest illustrative lot fit the window



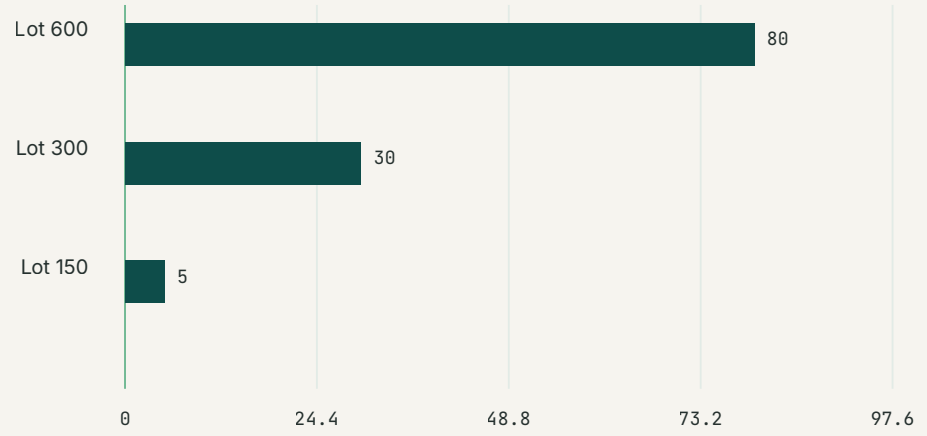
ILLUSTRATIVE [S25] All numerical inputs are illustrative: demand 1200 accepted garments, effective rate 2 good garments/minute, processing 600 minutes, lots 600/300/150 and setup counts 2/4/8 including initial setup. Occupied time = 600 + setup count x setup duration. Baseline setup 60 minutes; improved setup 20 minutes; available window 800 minutes. No overlapping setups or additional restart losses assumed. Points compare discrete lot choices, not a fitted continuous curve.

The illustrative setup shares make the trade-off visible. For lots of 600, 300 and 150 garments, the baseline shares are 120/720, 240/840 and 480/1,080, approximately 16.7, 28.6 and 44.4 per cent. With improved setup they become 40/640, 80/680 and 160/760, approximately 6.3, 11.8 and 21.1 per cent. Smaller lots still carry a higher setup burden. The improvement changes what is feasible; it does not eliminate the penalty. Round only for presentation and retain full precision in the planning calculation.

The illustrative spare-time test in **Exhibit 50**, p. 162 reveals a further condition. Under the improved setup, the largest lot leaves 800 - 640 = 160 spare minutes, or 80 additional minutes per setup. The middle lot leaves 120 spare minutes, or 30 per setup. The smallest leaves 40 spare minutes, or only 5 per setup. These are maximum evenly distributed extra allowances in the constructed window, not recommended restart durations. If the smallest-lot option adds more than that allowance on average, it no longer fits without another change to the assumptions.

EXHIBIT 50 / ILLUSTRATIVE EXTRA MINUTES AVAILABLE PER SETUP

The smallest lot leaves little room for extra restart loss



ILLUSTRATIVE [S25] All inputs illustrative, from the preceding batch-window case. Spare time per setup = (800-minute available window - occupied time after improvement) / setup count. Lots 600/300/150 use occupied times 640/680/760 and setup counts 2/4/8, giving 80/30/5 minutes. This allowance applies only to losses not already counted in setup or effective running rate.

GFT recommends treating the numerical case as a deliberately simplified screening model. A real transition matrix may depend on colour, attachment, fabric and previous product. Different styles may have different effective rates, and material readiness may force gaps. Recalculate with the actual sequence rather than divide total demand by an average lot size. Preserve the initial and final states so setups do not disappear at the period boundary. Add separate restart loss only where it is not already contained in the effective production rate or measured setup interval.

To test whether a feasible small-lot schedule pays, compare its incremental cost with the avoidable cost or additional contribution it creates. In an illustrative extension, compare the improved lots of 150 and 600 garments. The smaller choice occupies 760 - 640 = 120 extra minutes. Assume an avoidable incremental operating cost of XAF 200 per extra minute, solely as an invented evaluation-date input. The hurdle is 120 × 200 = XAF 24,000 per planning window, before any extra kit preparation, transport, training or defect expense.

If that illustrative smaller-lot choice avoids XAF 30,000 of otherwise expected holding and markdown cost in the same window, the net benefit is XAF 30,000 - XAF 24,000 = XAF 6,000 before the excluded costs. Those assumed values are neither market prices nor a GFT financial forecast. A higher benefit, a lower cost or a different order

mix changes the answer. Do not count inventory value released as recurring profit; show cash timing separately. This operating decision framework is not investment, legal or tax advice.

> **GFT NOTE**
>
> Start with a reversible comparison on an authorised product family. Preserve the order mix, acceptance rules, paid-hours boundary and delivery promise. Record preparation effort, stopped time, recovery, good output, stock movement and any change in operator workload. Approve a smaller production lot only when its schedule is feasible and its incremental economic case survives the observed losses. Keep a larger-lot option available while the new method remains provisional.

The decision record should end with an owner, a permitted operating range and a review trigger. GFT recommends stating which product families the method covers, which staffing combinations have been demonstrated and which conditions require replanning. Feed those conditions into the line-balancing studio and ramp-planning specification as requirements, not as claimed deployed capability. Leave detailed inventory policy and on-demand manufacturing technology to their respective papers. The specific contribution here is the connection from preparation and physical work design to an economically defensible lot decision.

A smaller batch earns its place when the next good order arrives sooner at a cost the factory can defend.

CHAPTER SOURCE NOTES

S25 Lean Enterprise Institute. 2020-07-02.

S1001 Elsevier, Procedia Manufacturing; author publication hosted by Polytechnic of Porto. 2018.

S26 Lean Enterprise Institute. 2020-07-02.

S27 Lean Enterprise Institute. 2020-06-12.

S17 Atlantis Press, International Journal of Computational Intelligence Systems. 2021-04-26.

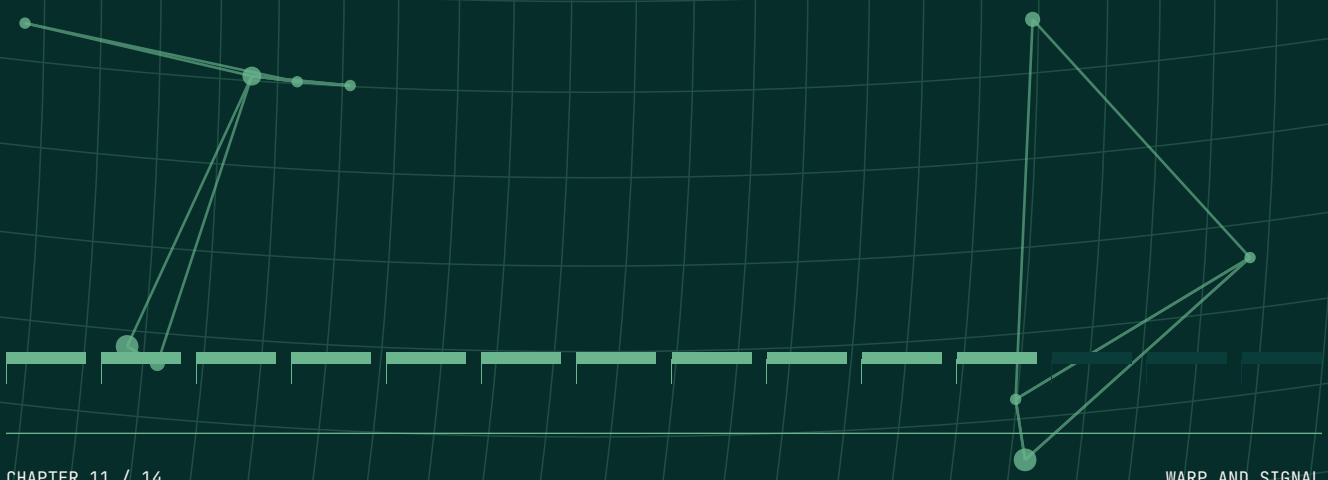
S24 Lean Enterprise Institute. 2020-07-02.

11

PART III: DESIGN FLOW INSTEAD OF LOCAL BUSYNESS / NO VOLUME WITHOUT GOOD OUTPUT

Quality at source protects both utilisation and flow

Defects consume capacity twice, first through lost good output and then through rework, queues and repeated interruption.



CHAPTER 11
DECISION TEST

Defects consume capacity twice, first through lost good output and then through rework, queues and repeated interruption.

Quality at source is a capacity control before it is an inspection routine. A sewing line that measures its speed by gross pieces sewn while pushing defective seams into downstream repair is not achieving high utilisation; it is paying twice for the same garment. The first payment occurs when a station spends scheduled time, needle strokes, thread and operator attention producing a unit that cannot pass to the customer. The second payment occurs when that defective piece re-enters the line, interrupts a productive station, consumes additional standard minutes for unpicking and re-sewing, and inflates work in progress (WIP) while upstream bundles wait. [S04] [S13] [S22] In Green Future Tech Limited's (GFT's) Cameroon textile programme, prepared on 31 January 2024 with source refreshes retained in 2026, hourly tracking of defects alongside output and downtime is built into the first shift. Where Cameroon's cotton-to-garment sector seeks to move from an inherited baseline of roughly 95 per cent raw cotton fibre export and 5 per cent local processing towards a 50 per cent target by 2030, and where reported incumbent plant utilisation stood between 10.83 and 48.9 per cent in July 2023, factories cannot forfeit scarce effective capacity to hidden repair loops. [R06] [R07] [R12]

Treating quality as an end-of-line filter separates the people who create defects from the signal that a defect has occurred. When an inline seam fault waits in a progressive bundle until final inspection, the line continues to consume cut components and machine hours under the same faulty tension, worn needle or misunderstood method. [S02] [S21] [S32] Even at the final table, manual checking is an imperfect barrier: industry inspection literature records manual fabric and defect inspection at 60 to 70 per cent accuracy, missing 20 to 30 per cent of defects. [R29] This chapter shows why effective output must exclude reworked pieces until their repair burden is counted, how Total Productive Maintenance (TPM) links machine condition to seam integrity, why smaller transfer batches compress the time between defect creation and containment, how root-cause inquiry prevents repeat stoppages, why raw piece-rate incentives undermine first-pass yield, and how integrated garment programmes lower WIP and defects together. [S02] [S04] [S12] [S28] [S29] [S32] Automated visual inspection hardware and computer-vision deployment remain with wp03. [R29]

11.1

Quality is part of effective output, not a later correction

In the Overall Equipment Effectiveness (OEE) framework, quality is a multiplicative determinant of effective capacity, not a post-production deduction on a shipping report. Availability measures downtime losses from breakdowns or adjustments, performance captures speed losses from minor stoppages and slow cycles, and quality measures defect losses caused by process faults and reduced yield. [S04] Because the three ratios multiply together, a line operating at 85 per cent availability and 80 per cent performance in an illustrative calculation stands at 68 per cent before quality is considered; if only 85 per cent of completed garments pass right first time, effective output drops to 57.8 per cent of planned production time. [S04] Counting gross units off the last sewing machine as saleable output conceals that 10.2 percentage point capacity loss. [S01] [S04]

11.2 GROSS PIECE COUNTS HIDE THE SECOND CAPACITY TAX OF REWORK

Garment lines are vulnerable to false volume reporting because most sewing defects are repairable rather than total scrap. When a lockstitch seam skips, a collar point puckers, or oil stains a cotton panel, a helper or inline checker unpicks the stitches and returns the panel to the operator for repair. [S09] If the line board records only total pieces passing the finishing table at shift end, a repaired garment looks identical to a garment sewn right first time. Yet the repaired garment consumed the standard minute value (SMV) of the operation during initial assembly, consumed unrecorded labour minutes during unpicking, and returned to consume machine and operator time a second time during re-sewing. [S04] [S13]

Because garment SMV is the sum of the SMVs of each required step, and line efficiency compares earned standard minutes of good output with attended labour minutes, a garment that passes through an operation twice earns its standard minute credit only once. [S13] Every minute spent unpicking and re-stitching reduces productive time for new garments while adding zero earned standard minutes. [S04] [S13] Under Theory of Constraints principles and apparel bottleneck diagnostics, any rework time stolen from the highest-utilisation station or the station with the largest upstream WIP buffer permanently reduces finished throughput for the whole line. [S20] [S30]

METHOD

Boundary protocol for sewing-line quality and rework accounting

ISO 22400-2 requires key performance indicators to state their formula, elements, time behaviour and unit. [S01] On a sewing line, GFT separates four counts every hour:

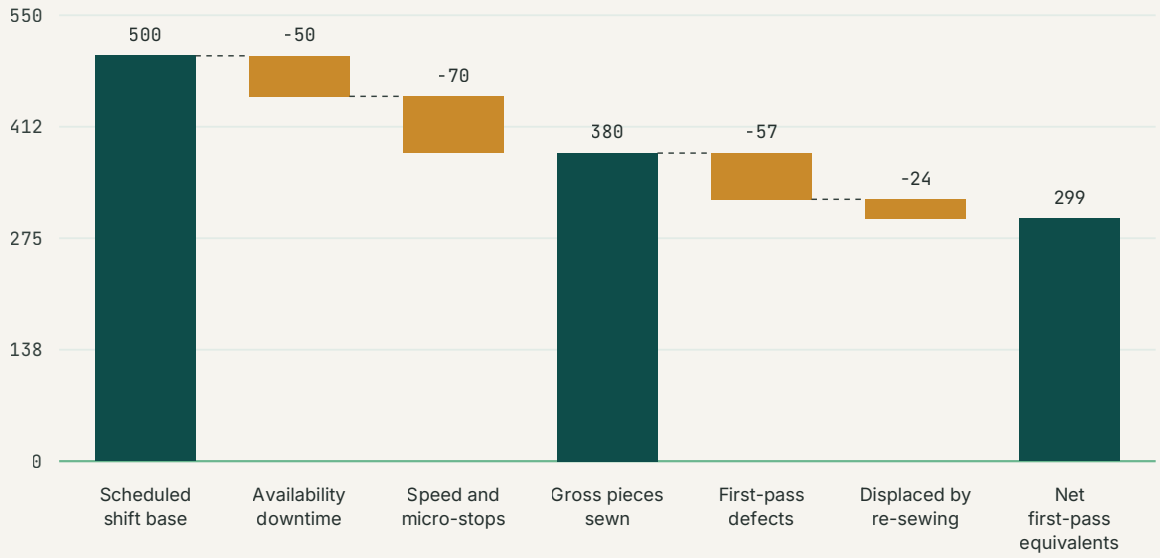
1. **Line starts (`N_start`):** Cut bundles or unit sets released into the first operation under pull authorisation. [S24]
2. **First-pass good output (`N_fpy`):** Garments passing inline and end-of-line verification on first presentation without unpicking, re-sewing or spot cleaning. [S04]
3. **Reworked units (`N_rwk`):** Garments rejected and routed back for stitch repair or stain removal, even if they later pass re-inspection. [S04] [S09]
4. **Scrapped or second-grade rejects (`N_scr`):** Garments with irreversible damage or permanent stains. [S04]

First-Pass Yield (FPY) is `FPY = N_fpy / (N_fpy + N_rwk + N_scr)`. [S04] **Defects Per Hundred Units (DHU)** counts total defect occurrences (`D_total`) across inspected garments (`N_insp`) as `DHU = (D_total / N_insp) x 100`. [S12] For the OEE quality component (`Q_OEE`), GFT uses first-pass good units in the numerator and logs repair minutes (`T_rwk`) explicitly. [S01] [S04]

Exhibit 51, p. 167 shows how this accounting boundary exposes the gap between gross production and net first-pass capacity in a derived shift reconciliation.

EXHIBIT 51 / GOOD-GARMENT EQUIVALENTS PER SHIFT

Rework taxes capacity twice by removing good output and consuming repair minutes



DERIVED [S04] [S13] Derived with illustrative inputs using the OEE loss structure in S04 and SMV accounting in S13: 500 scheduled shift garment equivalents less 50 availability loss and 70 speed loss leaves 380 gross pieces completed; 57 defective pieces (15 per cent first-pass defect share) reduce first-pass good output to 323 pieces, while inline re-sewing of 48 repairable pieces at 0.5 garment-equivalent cycle each displaces 24 additional new-garment equivalents of station capacity, leaving 299 net first-pass equivalents.

In **Exhibit 51**, p. 167, a shift that appears on a gross tally sheet to have sewn 380 pieces (or 371 shipped pieces after 48 of the 57 defective garments are repaired and 9 are scrapped in this illustrative derivation) has generated only 323 first-pass good garments and sacrificed 24 new-garment equivalents of station time to re-sewing. [S04] [S13] The exhibit is a derived illustration of the accounting mechanism rather than an empirical measurement of a Cameroon plant, and it requires shift-level observation of actual repair durations.

WORKED EXAMPLE: THE HIDDEN STANDARD-MINUTE COST OF INLINE SEAM REPAIR

Consider an illustrative sewing line in Cameroon assembling a cotton work shirt with a garment SMV of 12.0 standard minutes across 20 operators working a 480-minute shift (9,600 attended operator-minutes). [S13] [S33] Suppose the line completes 400 gross shirts, of which 340 pass inspection on the first pass, 50 require unpicking and re-sewing of collar or cuff lockstitch seams, and 10 are rejected as second-grade due to oil stains. [S04] [S09]

Each of the 50 repaired shirts requires an illustrative 3.6 minutes of helper unpicking and 2.4 minutes of operator re-sewing, consuming `50 x 6.0 = 300` labour minutes of rework. The 2.4 minutes of machine re-sewing per shirt (`50 x 2.4 = 120` machine-minutes) occurs on lockstitch stations where average operation work content is 1.2 minutes, displacing `120 / 1.2 = 100` station-operations that could have advanced new shirts. [S13] [S30]

- **Unadjusted gross reporting (misleading):** Credits 390 shipped shirts (340 first-pass plus 50 repaired) at 12.0 SMV = 4,680 earned standard minutes (`48.75` per cent efficiency) and reports only `2.5` per cent scrap. [S13]
- **First-pass good reporting (diagnostic):** Credits only the 340 first-pass shirts = `340 x 12.0 = 4,080` earned standard minutes (`42.50` per cent first-pass efficiency), with `85.0` per cent FPY and a visible 300-minute rework tax. [S04] [S13]
- **Constraint opportunity cost:** If the collar topstitch station is the line constraint at 0.80 minutes per shirt, and 30 repairs require re-stitching that collar seam, the constraint loses `30 x 0.80 = 24` minutes, permanently forfeiting `24 / 0.80 = 30` finished shirts for the whole line (360 standard minutes lost). [S13] [S30]

This illustrative arithmetic is not a forecast; it shows why GFT requires starts, first-pass good units, rework counts and constraint repair minutes to appear together on the hourly board. [S01] [S04]

11.3

TPM links equipment condition to defect prevention

Treating sewing defects as purely human errors ignores stitch mechanics. In NIST's analysis of advanced maintenance, Total Productive Maintenance (TPM) aims for zero breakdowns and zero defects by eliminating six major losses: equipment breakdown, setup and adjustment slowdowns, idling and short-term stoppages, reduced capacity, quality-related losses, and startup or restart losses. [S02] In a sewing room, the boundary between an availability loss, a micro-stoppage and a quality defect is thin. A bent needle, an uncleaned rotary hook, an improperly set bobbin spring, or a misaligned folder first causes stitch tension irregularity or puckering, then triggers thread breakage, and finally forces a mechanical adjustment or needle change. [S02] [S09]

11.4 EMPIRICAL DEFECT PARETO DISTRIBUTIONS POINT BACK TO MACHINE CARE AND OPERATION DESIGN

Apparel monitoring confirms that a few machine- and handling-related categories dominate sewing quality losses. In the Wiley *Engineering Reports* study of Company X, Pareto analysis of recorded sewing defects showed that two categories, Lock Stitch Repair and Stain, accounted for 54.77 per cent of all product defects, while the top

five categories accounted for 87.56 per cent of total defects. [S09] In the same factory, downtime monitoring recorded 4,923 minutes lost to technical malfunction, 3,694 minutes to machine adjustment, 2,432 minutes to faulty needles, and 1,427 minutes to thread breakage. [S09]

Exhibit 52, p. 169 summarises the concentration of defect categories reported in that apparel case study.

EXHIBIT 52 / PER CENT OF RECORDED DEFECTS (COMPANY X)

A small set of repair categories can dominate sewing quality loss

54.77%	87.56%	12.44%
Lock stitch repair + stain	**Top five defect categories**	**Remaining defect types**
Top two defect categories combined in Company X (S09)	Cumulative share of the five main fault categories (S09)	All other recorded defect categories combined (derived from S09)

SOURCED [S09] Sourced from the Pareto defect analysis of apparel manufacturer Company X in S09. Single-company empirical scope; specific defect shares depend on garment construction, machine fleet and fabric type.

The concentration shown in **Exhibit 52**, p. 169 carries a direct operational lesson, even though Company X's percentages reflect one factory rather than a universal benchmark. [S09] Neither "Lock Stitch Repair" nor "Stain" can be eliminated by telling operators to be more careful. Oil and grease stains originate from over-lubricated needle bars, leaking head gaskets, oil-saturated lint beneath the throat plate, or dirty work surfaces, which are direct targets of TPM autonomous cleaning and seal inspection. [S02] [S09] Similarly, lockstitch faults arise from the mechanical interaction of needle geometry, hook timing, presser-foot pressure, feed-dog height, and thread-to-fabric selection. [S09] [S1102]

11.5 SEAM MECHANICS AND TASK COMPLEXITY GOVERN DEFECT CREATION AT THE NEEDLE

Materials and industrial-engineering research shows why defect prevention must start in technical setup and work design before the first bundle enters the line. Experimental testing of woven fabrics sewn with polyester threads of varying linear densities demonstrates that seam yielding force and ultimate seam strength increase with sewing thread strength and fabric compactness, and that structural degradation inside a seam begins at an identifiable Seam Yielding Point before complete rupture. [S1102] If an operation bulletin specifies an incompatible thread linear density, excessive dynamic tension, or a needle point that damages compact warp yarns, the seam is compromised at stitching even if it passes a casual glance. [S13] [S1102]

An empirical study of 96 sewing operations in a garment workshop published in *Heliyon* evaluated physical action complexity, posture-keeping complexity and cognitive complexity against operation time variance and defect rates. [S1101] Action complexity and cognitive complexity were significantly correlated with both sewing operation time fluctuation and the rate of sewing defects. [S1101] Complex manual manipulation or high cognitive load without visual fixtures creates wider cycle-time swings, destabilising line balance while raising defect rates. [S15] [S17] [S1101]

A practical TPM and industrial-engineering programme therefore attacks quality losses at source through four pre-emptive controls:

- **Start-of-shift autonomous checks:** Operators spend three scheduled minutes wiping the needle bar, presser foot, throat plate and oil pan, checking tension on a production swatch, and sewing a test strip before bundle release. [S02] [S26]
- **Preventive needle and hook discipline:** Mechanics log needle changes by operating hours and fabric weight rather than waiting for a burred needle to snag yarns or snap thread, addressing the 2,432 minutes of faulty-needle downtime and 1,427 minutes of thread-breakage downtime observed in Company X. [S02] [S09]
- **Mechanical error-proofing (poka-yoke):** Industrial engineers replace freehand alignment with edge guides, compensating presser feet, folders and cutting notches, lowering action and cognitive complexity. [S26] [S1101]
- **Restart verification:** Because TPM recognises startup and restart losses alongside setup adjustments, the first piece sewn after any changeover, thread change, repair or outage is verified at the station before normal rhythm resumes. [S02] [S25]

11.6

Smaller flow units shorten defect feedback

Even with sound maintenance, abnormalities occur during a shift: a bobbin runs low, a thread cone hits a knot, a folder screw loosens, or a shade mismatch enters the line. What determines whether that abnormality ruins one garment or forty garments is the size of the transfer batch and the volume of WIP between adjacent operations. [S21] [S28] [S32]

11.7 PROGRESSIVE BUNDLES ACT AS DEFECT INCUBATORS

In a progressive bundle system, cut parts move between stations in tied bundles of 20 to 50 pieces buffered by racks or carts. [S21] Each operator unties a bundle, performs one sewing step on all pieces, reties it, clips a ticket, and pushes the bundle into the downstream queue. [S21] Suppose an attachment slips at Operation 4 so the seam margin narrows beyond tolerance, preventing Operation 7 (three stations downstream) from catching the inner ply. Under progressive bundle flow with an illustrative two-bundle buffer (60 pieces) between stations, Operation 4 can complete up to 180 defective pieces across intermediate queues before Operation 7 unties the first affected bundle and spots the fault. [S21] [S22]

In strict single-piece flow, there is no WIP between adjacent operators, and in small-lot pull cells, transfer batches are constrained to a single garment or two to five pieces authorised by a kanban limit. [S21] [S24] When Operation 4 hands a garment directly to Operation 5, or into a three-piece buffer, the downstream operator handles the seam

within minutes. Lean Enterprise Institute analysis emphasises that small-lot flow supports quality because abnormalities are exposed immediately rather than buried in inventory, and protective excess capacity at non-constraints is normal and beneficial because it gives operators time to detect, stop and resolve problems without starving the constraint. [S28] [S30]

11.8 LITTLE'S LAW GOVERNS DETECTION LATENCY ACROSS THE LINE

For long-run averages in a stable system that is not starting, stopping or surging, Little's Law states that average WIP equals throughput rate multiplied by throughput time (`WIP = TH x TT`). [S22] Across the line segment between defect creation (`i`) and detection (`j`), throughput time is the **defect detection latency** (`T_detect`), and intermediate WIP (`WIP_ij`) equals the maximum number of defective garments in transit before the alarm is raised (`T_detect = WIP_ij / TH`). [S22]

In an Ethiopian garment factory case study published in the *Journal of Textile and Apparel, Technology and Management*, replacing large-buffer push flow with kanban pull and single-piece flow reduced WIP by 48.5 per cent and throughput time by 80.3 per cent. [S31] Although those figures come from one factory and are not a Cameroon forecast, cutting inter-station queues and transfer time by half to four-fifths compresses the maximum population of hidden in-process defects by the same proportion. [S22] [S31]

MIT's capacity analysis notes that the relationship between waiting time and capacity utilisation is strongly nonlinear. [S23] Flooding every non-constraint station to full occupancy swells queues nonlinearly, stretches detection latency from minutes to hours, and pressures operators to pass marginal work forward. [S23] [S28] [S32] Pull-capped WIP and protective capacity at non-constraints keep queues short so every handoff acts as an immediate seam check. [S24] [S28]

11.9

Root-cause analysis must outlast the immediate repair

Shortening detection latency improves utilisation only if detection triggers permanent prevention rather than faster re-sewing. In many garment plants, inline quality control stops at containment: a roaming checker spots a puckered placket or a skipped chainstitch, marks it with chalk, and hands the piece back to the operator, who repairs it in thirty seconds. Because no root-cause inquiry takes place, the fault recurs fifteen minutes later, creating a chronic drain on OEE performance and quality components. [S04] [S29]

11.10 FIVE WHYS MOVES INQUIRY FROM OPERATOR BLAME TO PROCESS MECHANISM

To break chronic rework cycles, Lean practice pairs containment with the **Five Whys**, the practice of asking "why" repeatedly whenever a problem is encountered in order to move beyond obvious symptoms to discover the root cause. [S29] In a sewing room, a Five Whys inquiry must take place at the workstation while the defective piece, thread, needle and attachment are still in place, and it must never stop at "operator carelessness", which describes a human state rather than a controllable process mechanism. [S26] [S29] [S1101]

Consider a trace on a garment line experiencing repeated skipped stitches on a trouser side-seam overlock operation:

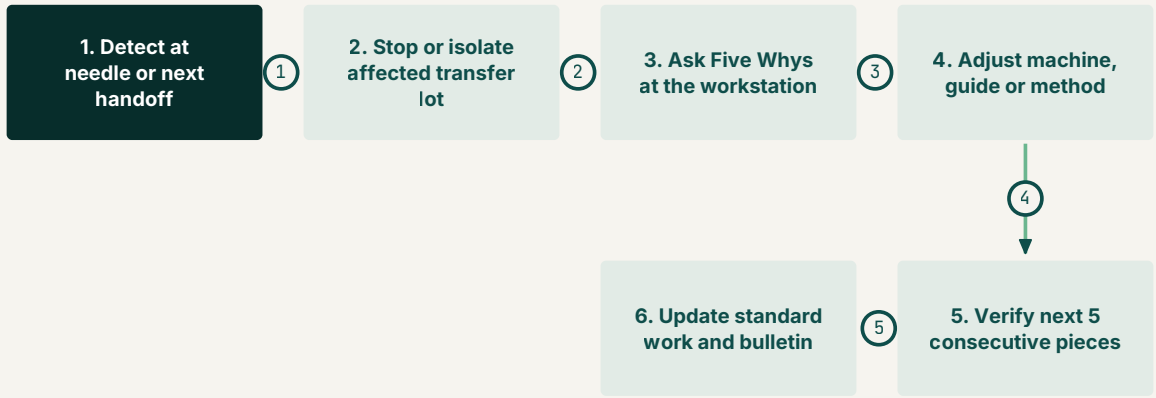
1. **Why is the garment rejected at inline check?** The five-thread overlock seam has a two-centimetre gap of unlinked looper stitches across the pocket bag junction (symptom). [S04]
2. **Why did the looper miss the needle thread loop?** The needle deflected as it penetrated the step from two plies to six plies of cotton twill at the pocket corner. [S1102]
3. **Why did the needle deflect across the six-ply step?** The station retains a fine needle from the previous light poplin style, and the presser foot lacks a hinged compensating toe. [S02] [S25]
4. **Why was the fine needle and rigid foot retained?** The operation bulletin for the twill trouser listed only the machine class ("5-thread overlock") without specifying needle gauge or presser-foot code. [S13] [S26]
5. **Why did the changeover proceed without verifying needle and foot specification?** The style-change checklist had no mechanic sign-off gate for first-piece seam-step inspection before bundle release (system root cause). [S02] [S25] [S26]

Fixing only Step 1 saves one trouser while leaving the line certain to produce more skipped seams. Fixing Step 3 stops defects on the current line today. Fixing Steps 4 and 5 (updating the operation bulletin and adding first-piece mechanic verification to the SMED changeover checklist) prevents the defect class across all lines and future runs. [S13] [S25] [S26]

Exhibit 53, p. 173 maps the six-step closed loop that connects inline abnormality detection to updated standard work.

EXHIBIT 53 /

Quality at source shortens the path from abnormality to prevention



1. Andon / flag
2. Supervisor + operator
3. Root mechanism
4. First-piece gate
5. Zero recurrence

ILLUSTRATIVE [S26] [S28] [S29] Illustrative operational decision flow synthesising one-piece flow abnormality exposure (S28), Five Whys root-cause inquiry (S29) and standardised work baseline updates (S26). Not a record of an executed factory trial.

As shown in **Exhibit 53**, p. 173, the loop closes only when the verified physical fix is written into standardised work, which the Lean Enterprise Institute defines as the documented current process for all shifts that reduces variability, eases training, reduces strain, and establishes the baseline for improvement. [S26] Because **Exhibit 53**, p. 173 is an illustrative design, a factory must set local escalation rules: an operator adjusts thread tension immediately, whereas a fault affecting three consecutive pieces triggers a flag requiring the supervisor and mechanic within five minutes.

WARNING

Three failure modes that turn root-cause logs into administrative theatre

1. **Stopping at human-blame codes:** Closing corrective actions with labels such as "operator error" leaves the mechanical, material or task-complexity cause ([^S02], [^S1101]) untouched.
2. **Logging symptoms without operation and machine IDs:** Recording "broken stitch" without naming the operation number and machine serial prevents Pareto analysis ([^S09]) from separating a single maladjusted machine from a thread batch issue ([^S1102]).
3. **Closing actions without recurrence verification:** A root-cause action is verified only when the next three shifts run that operation without recurrence ([^S26], [^S29]).

11.11

Piece-rate pressure can work against quality and flow

A quality-at-source protocol will fail if the compensation system rewards operators for violating it. Across garment manufacturing, managers often rely on individual piece-rate incentives or gross-bundle targets in the belief that paying per piece sewn maximises labour effort and utilisation. [S14] [S32] In practice, unadjusted piece-rate pressure interacts with progressive bundles to degrade both first-pass quality and flow.

11.12 EVIDENCE ON PIECE-RATE AND LARGE-BATCH DISTORTIONS

Empirical research from the National Bureau of Economic Research (NBER) on international differences in lean production, productivity and employee attitudes shows how piece-rate and batch systems undermine performance. [S32] Examining component production prior to lean transformation, the NBER study notes that piece-rate payment combined with large batches led to long lead times and low quality, both because workers had an incentive to work as fast as possible and because large batches meant that many bad products could be made before inspectors caught them. [S32]

Although the NBER study examined automotive components rather than apparel and serves as an analogy to test rather than a direct garment statistic, its causal chain operates inside a bundle sewing room: [S21] [S32]

- **Reluctance to stop for machine drift:** Under an individual piece rate, every minute an operator pauses to clean lint, re-thread tension discs, change a blunted needle, or call a mechanic reduces personal piece earnings, encouraging operators to pass marginal seams downstream. [S02] [S32]
- **Buffer hoarding:** Operators paid by individual ticket count build a personal pile of bundles beside their machine so they are never starved of work, inflating WIP and throughput time under Little's Law. [S22] [S32]
- **Resistance to rebalancing and cross-training:** A balanced line requires multi-skilled operators to move temporarily to relieve a shifting bottleneck or cover an absence. [S17] [S20] Because moving to a less familiar operation lowers speed along the learning curve, pure piece-rate workers lose pay when they help the constraint. [S17] [S18]
- **Compounding fatigue during extended hours:** Better Work's review of working-time evidence concludes that extending working hours does not in general yield proportionate increases in total output, and may reduce total output in the long run. [S41] Fatigued operators working overtime under piece-rate pressure commit more cognitive and handling errors, generating rework the next morning. [S41] [S1101]

11.13 ALIGNING INCENTIVES AND SUPERVISION WITH FIRST-PASS LINE OUTPUT

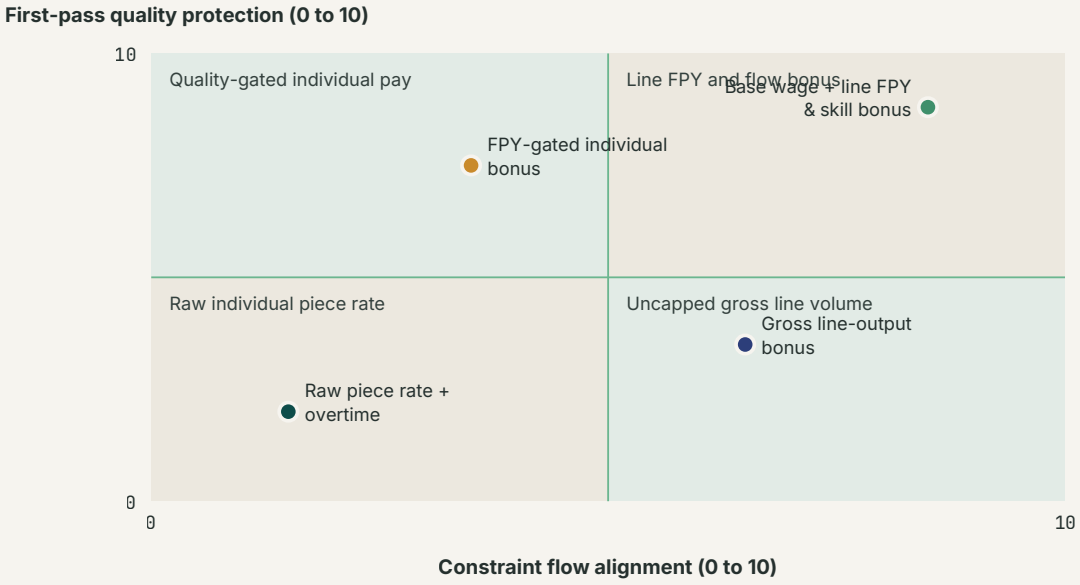
Protecting quality at source requires shifting incentives and supervisor evaluations from individual gross speed to right-first-time system flow. Better Work Ethiopia's 2023 annual report (covering 2022 data) records that factories reported improved

productivity, quality and workplace organisation, alongside reduced absenteeism, in lines led by newly trained supervisors. [S40] Those outcomes confirm that supervisory skill (coaching standard methods, responding to flags, and balancing stations hourly) drives joint quality and productivity gains. [S12] [S40]

Exhibit 54, p. 175 compares four compensation architectures across constraint flow alignment and first-pass quality protection.

EXHIBIT 54 / ILLUSTRATIVE DESIGN SCORE (0 TO 10)

Incentives must protect line output and first-pass quality



ILLUSTRATIVE [S32] [S41] Illustrative 0-to-10 design comparison of garment incentive models based on the piece-rate and batch quality risks in S32 and overtime productivity limits in S41. Scores are analytical design ratings, not empirical factory measurements.

In **Exhibit 54**, p. 175, the four points represent management choices rather than empirical measurements:

- **Raw piece rate plus overtime (lower-left):** Encourages fast stitching and large buffers while penalising stops for tension or bottleneck relief, generating rework and long lead times. [S32] [S41]
- **Gross line-output bonus (lower-right):** Rewards collective volume so operators cooperate on flow, but counting gross pieces before first-pass deduction still pushes defective seams forward. [S04] [S32]
- **FPY-gated individual bonus (upper-left):** Deducts defects from personal piece counts, improving station care, but leaves operators reluctant to leave their primary machine to rebalance a moving constraint or share cell tasks. [S17] [S27]
- **Stable base wage plus line First-Pass Yield, earned-minute and skill-versatility bonus (upper-right):** Guarantees lawful base pay within statutory hours, pays the team bonus only on first-pass good garments within the WIP cap, and rewards operators qualified to cover bottleneck operations. [S13] [S17] [S32] [S33]

Detailed wage structures and KPI cascades belong to wp02 and wp09; this analysis is engineering guidance, not legal, tax or employment-law advice. [S33]

11.14

Garment improvement programmes join defects to WIP and output

Multi-factory evidence from the International Labour Organization (ILO) shows that when quality at source, work-study balancing and WIP control are implemented as one system, line output rises while both WIP and defect rates fall. [S12] [S37]

11.15 EMPIRICAL RESULTS FROM ILO GARMENT FACTORY INTERVENTIONS

In its final report on the Factory Improvement Toolset (FIT) in the Asian garment sector, the ILO combined operation bulletins, SMV measurement, line planning, hourly balancing, bottleneck management, workplace organisation and inline quality tracking. [S12] Across participating sewing rooms, line achievement improved by 9.49 per cent, while work in progress and defects per hundred units (DHU) both fell by 22 per cent. [S12]

Exhibit 55, p. 176 presents these three simultaneous programme outcomes.

EXHIBIT 55 / PER CENT CHANGE IN PARTICIPATING ASIAN GARMENT SEWING ROOMS

The ILO garment programme improved output while reducing WIP and defects

+9.49%	-22%	-22%
Sewing-room line achievement	**Work in progress (WIP)**	**Defects per hundred units**
Increase in line achievement across programme sewing rooms (S12)	Reduction in sewing-room work in progress (S12)	Reduction in garment DHU alongside lower WIP (S12)

SOURCED [S12] Sourced from the ILO final report on the Factory Improvement Toolset in the Asian garment sector (S12). Programme-level aggregate results across participating factories; outcomes reflect combined balancing, WIP and quality interventions and are not a standalone forecast for Cameroon.

Why did line achievement rise by 9.49 per cent while WIP and DHU each dropped by 22 per cent in **Exhibit 55**, p. 176? [S12] First, cutting in-process bundles by 22 per cent meant stitch and alignment faults were caught after a few garments rather than after full racks had been sewn, driving the 22 per cent drop in DHU. [S12] [S22] [S28] Second, a 22 per cent drop in DHU freed operators and bottleneck machines from unpicking and re-stitching, converting rework time into first-pass good garments.

[S04] [S12] Third, with fewer stalled rework bundles clogging the racks, supervisors could see true station queues and rebalance work hourly around the constraint, lifting line achievement by 9.49 per cent. [S12] [S20]

Complementary ILO evidence from Africa confirms that these mechanisms translate to emerging garment hubs when adapted to local skill baselines. Under the ILO SCORE and SIRAYE programme in Ethiopia, workplace cooperation combined with line balancing and quality improvement enabled Edget Garment to raise line-balance efficiency from 24 per cent to 75 per cent and increase daily line output from 50 to 120 pieces. [S37] These figures establish what integrated industrial engineering can achieve under specific factory conditions; they must not be copied into a Cameroon financial model without local baseline measurement and a line trial. [S12] [S31] [S37]

11.16 IMPLEMENTING QUALITY AT SOURCE FROM THE FIRST SHIFT IN CAMEROON

For a garment operation in Cameroon, whether a turnaround addressing the 10.83 to 48.9 per cent capacity utilisation gap recorded for incumbent plants in July 2023 or a new line processing domestic cotton fibre locally, quality at source must be engineered as a manual discipline before digital software is purchased. [R06] [R12] [S09] Clean station tally cards and disciplined supervisor huddles create the data hygiene that later digital tools require. [S07] [S09]

The following table summarises the four-tier control structure that GFT specifies to link sewing quality at source with OEE, line balancing and lean flow. [S01] [S04] [S28]

Control tier	Boundary and cadence	Primary signal captured	Immediate operational action	System link to OEE and flow
Tier 1: Needle self-check	Every bundle; 3-minute shift-start swatch test	Tension, stitch density, oil-free surface ([^S02], [^S1102])	Wipe oil/lint, adjust tension or swap needle before bundle ([^S02], [^S09])	Blocks micro-stops and defect creation at source ([^S04])
Tier 2: Operator handoff	Small transfer batch (1 to 5 pieces) under WIP cap ([^S21], [^S24])	Incoming seam completeness and margin ([^S28])	Return faulty piece; flag if 3 consecutive pieces fail ([^S28], [^S29])	Compresses detection latency (T_{detect}) ([^S22])
Tier 3: Roving traffic-light	Every 2 hours at complex and constraint stations ([^S20], [^S1101])	5-piece sample scored green (0), amber (1), red (2+ defects) ([^S09])	Red station triggers immediate Five Whys ([^S29])	Protects constraint ([^S30]) and complex tasks ([^S1101])
Tier 4: Hourly FPY board	Hourly tally; daily 10-minute shift huddle ([^S01], [^S12])	N_{start}, N_{fpy}, N_{rwk}, N_{scr}, top 3 DHU codes ([^S04], [^S12])	Assign standard-work or SMED update ([^S25], [^S26])	Feeds honest Q_{OEE} and earned SMV ([^S04], [^S13])

GFT NOTE

Practical recommendation for GFT's Cameroon textile programme

In GFT's three-part Cameroon textile programme, performance management and digital strategy are staged so that measurement precedes automation. [S01] [S09] For sewing lines, GFT recommends four concrete rules from the first shift of operations:

1. **Ban unrecorded rework on the sewing floor:** No garment may be returned for unpicking or re-sewing without passing across the station's tally card. Recording a defect is never punished; re-sewing off the clock is treated as a breach of line control. [S04] [S32]
2. **Protect the constraint with an upstream quality gate:** Place an inline inspection and buffer check immediately upstream of the bottleneck workstation ([^S20], [^S30]) so defective panels never consume constraint cycle time.
3. **Couple TPM needle/lubrication logs with the top-three defect Pareto:** Review the top three DHU categories alongside machine downtime codes every Friday ([^S02], [^S09]). If lockstitch skips or oil stains exceed an illustrative threshold of 2.0 DHU, require a joint mechanic and engineering sign-off on hook timing, thread specification and oil guards before Monday shift start ([^S09], [^S1102]).
4. **Gate digital monitoring and computer vision on manual FPY stability:** Deploy electronic Production Monitoring Devices (wp18) and automated vision inspection (wp03, [^R29]) only after the line has operated the manual four-tier system for four consecutive weeks with stable definitions ([^S01], [^S09]).

When a factory governs quality at source through these four rules, OEE, line balancing and lean flow work as one system: good maintenance stabilises stitch formation, feasible balancing and guides lower task complexity, pull-capped buffers expose abnormalities rapidly, and first-pass accounting ensures that every earned standard minute represents a saleable garment. [S02] [S04] [S13] [S24] [S1101] The next chapter turns to the human and infrastructure envelope (lawful hours, supervision, retention, ergonomics and electrical power) that sets the attainable ceiling on this operating system. [S33] [S35] [S38] [S39] [S40]

A line that counts defective pieces as progress is only measuring how fast it creates tomorrow's repair queue.

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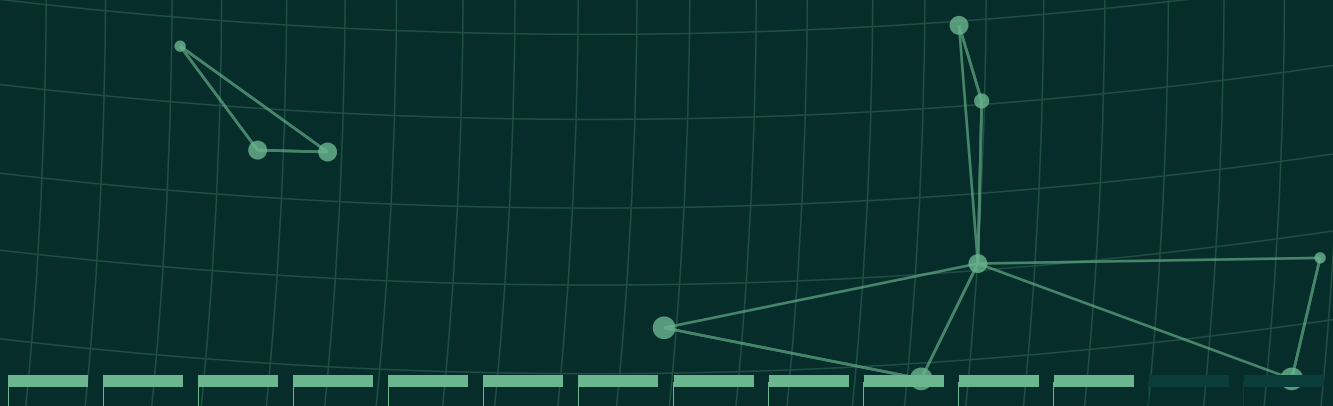
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12

People and power set the attainable utilisation ceiling

A technically balanced line still fails when learned operators are absent, hours are unsustainable or electricity interrupts production.



CHAPTER 12
DECISION TEST

A technically balanced line still fails when learned operators are absent, hours are unsustainable or electricity interrupts production.

A garment factory cannot sustain a line balance that violates its human and infrastructure envelope. [S14] Even when engineers establish clean standard minute values, sequence tasks accurately, limit work in progress and contain defects at source, the real ceiling on Overall Equipment Effectiveness (OEE) and good throughput is set by the people who staff the workstations and the electrical system that powers the machines. [S04] In labour-intensive sewing operations, overall performance depends primarily on employee performance and attendance rather than autonomous machine speed. [S14] Equally, sewing machines, cutting tables, fusing presses and air compressors cannot convert operator skill into good garments when grid electricity fails. [S35] Treating workforce stability and power reliability as background assumptions produces capacity plans that look achievable in a spreadsheet and fail on the floor. [S36]

In Cameroon, where national policy targets raising local cotton processing from roughly 5 per cent of raw fibre output to 50 per cent by 2030, reported capacity utilisation across incumbent textile plants ranged from 10.83 per cent to 48.9 per cent in July 2023. [R06] [R07] [R12] Closing that utilisation gap requires bringing statutory working hours, overtime fatigue, frontline supervision, operator turnover, workstation ergonomics, electrical outages and buyer order planning inside the formal capacity model. [S33] [S36] [S39] This chapter defines how human and electrical constraints govern the line and shows how GFT's Cameroon textile programme derates nominal capacity into a deliverable schedule. [S04]

12.1

Lawful hours bound the capacity plan

Every valid calculation of available production time begins with the legal and physiological limits of the working week. [S33] In OEE accounting and standard-minute planning, the denominator starts with scheduled shift hours before subtracting planned breaks, maintenance and unplanned downtime. [S01] [S04] If a schedule assumes an unlawful or unsustainable time base, every downstream indicator of availability, efficiency and unit cost is distorted. [S01] Capacity planning must anchor its baseline roster in statutory ordinary hours and treat any extension as a constrained, separately costed exception. [S33]

In Cameroon, Law No. 92/007 of 14 August 1992 establishing the Labour Code states that statutory hours of work in all public and private non-agricultural establishments may not exceed 40 hours per week. [S33] Shared labour-market records for Cameroon likewise note the standard 40-hour working week alongside a 48-hour maximum ceiling and an overtime wage premium of 1.2 times the ordinary hourly rate, within a labour market where informal employment accounts for roughly 90 per cent of total employment. [R16] Where an eight-hour daily shift across five working days provides 2,400 gross scheduled minutes per week per operator, planned non-production intervals such as meal breaks, ergonomic recovery pauses, daily huddles and routine machine cleaning must be deducted explicitly to establish planned production time. [S01] [S26]

Separating statutory ordinary time from authorised overtime is equally important for unit-cost governance. [R14] [R16] Cameroon's statutory minimum wage (SMIG) rose from XAF 41,875 per month in 2023 to XAF 43,969 per month from 23 February

2024, roughly US$76 per month (a 5 per cent rise), whereas average monthly earnings across formal sectors sit near US$359 and the 2024 garment-sector minimum wage benchmark in Cambodia stood at US$204 per month. [R14] [R15] [R17] Effective labour cost per good garment is governed by earned standard minutes produced during paid hours. [S13] [R14] If a plant relies on overtime hours paid at a 1.2 times premium while fatigued operators produce fewer earned minutes per hour, labour cost per good garment rises from both sides of the fraction. [R16] [S41] This analysis is an engineering framework for capacity planning and is not legal, tax or investment advice; sponsors must obtain local legal review when structuring rosters and overtime authorisations under Cameroonian law. [S33]

12.2 SHIFT ROSTERS REQUIRE EXPLICIT DEDUCTIONS FOR RECOVERY AND LINE CADENCE

Multiplying 40 weekly hours by 60 minutes and assuming 2,400 productive minutes per operator per week forces routine human and operational needs to appear as unexplained losses. [S01] [S04] Operators cannot maintain a constant sewing rhythm across eight hours without physiological recovery, needle and bobbin changes, bundle handling and supervisory alignment. [S13] [S26]

In GFT's Cameroon textile programme, an eight-hour day (480 rostered minutes) deducts rest periods, a ten-minute shift huddle, five minutes of autonomous machine care and ergonomic micro-pauses. [S02] [S26] Declaring an illustrative net planned window of 430 to 445 minutes per shift as the availability base aligns the takt denominator with safe sewing time. [S04] [S26] Any requirement exceeding those net ordinary minutes must trigger a review of line balance, constraint staffing or order release rather than an informal instruction to work late. [S30] [S41]

12.3

Overtime is not a proportional output multiplier

Factory planners under delivery pressure often treat overtime as a linear capacity buffer. [S41] Extending an eight-hour shift by two hours appears in a naive spreadsheet to add 25 per cent to daily availability and output, using this illustrative ratio as a direct multiplier. Empirical evidence refutes that assumption. [S41] Extended hours alter physiology, concentration and attendance, eroding the hourly production rate and increasing defects during both the extra hours and subsequent regular shifts. [S41]

Research published by the International Labour Organization and International Finance Corporation Better Work programme on excessive overtime, workers and productivity concludes that extending working hours does not in general yield proportionate increases in total output, and may even lead to an absolute reduction in total output in the long run. [S41] As weekly hours climb beyond the 40-hour statutory baseline, coordination slows, micro-stoppages lengthen and seam errors increase. [S04] [S33] [S41] In OEE terms, an apparent increase in scheduled time is offset by declines in performance and quality rates. [S04]

Chronic overtime also corrupts floor pacing. [S41] When operators expect regular late working, daytime pacing adjusts downward so workers conserve energy for the extended shift and secure the overtime premium. [R16] [S41] What looks like an after-

noon bottleneck requiring two hours of evening overtime is often a cycle in which fatigue slows morning paces, slower paces create midday starvations, and evening overtime produces tired workers who arrive late or absent the next day. [S20] [S41]

12.4 FATIGUE DEGRADES FIRST-PASS YIELD AND INFLATES REWORK QUEUES

A sewing defect created during the ninth or tenth hour of a shift wastes more than the standard minutes of the station that stitched the faulty seam. [S04] [S13] [S21] In apparel OEE monitoring at Company X, lock-stitch repairs and stains accounted for 54.77 per cent of all defects and the top five repair categories represented 87.56 per cent of total quality losses, requiring garments to be unpicked, re-sewn, re-inspected and re-pressed. [S09] Unpicking a lock-stitch seam without damaging fabric takes two to three times longer than the original illustrative operation SMV, pulling skilled operators away from primary flow. [S09] [S13]

In an illustrative comparison where a line operating for two overtime hours pays 1.2 times the normal wage while achieving 70 per cent of standard hourly pace and double its normal rework rate, labour cost per good garment during those extra hours rises by more than 70 per cent above the ordinary-hour baseline, before counting extra electricity and overhead. [R16] [S34] [S41] GFT therefore treats recurring overtime as a symptom of an unresolved balance, quality or scheduling failure. [S30] [S41]

12.5

Supervisors convert standards into daily performance

A sewing line does not balance itself once the operation bulletin is posted. [S12] [S13] Between the engineered standard and the finished garment stands the line supervisor. [S40] In every shift, the supervisor verifies attendance, reallocates tasks when a machinist is absent, checks folders and tension guides, spots upstream queues before they starve the constraint, coaches operators and resolves quality holds. [S12] [S20] [S26] Where supervision is weak or coercive, standards decay within days into informal workarounds. [S26] [S40]

Empirical evidence shows that frontline supervisory skill is a quantifiable determinant of productivity, quality and retention. [S40] [S1201] Assessments by Tufts University researchers on the ILO and IFC Better Work Supervisory Skills Training programme found that when female supervisors completed the three-day training in communication, time management, work allocation and professional conduct, line productivity increased by 22 per cent compared with lines led by untrained supervisors. [S1201] Across seven countries where more than 5,850 supervisors participated over two years, training replaced shouting with clear instruction and bottleneck resolution. [S1201]

Programme evidence from East Africa and Asia reinforces these findings. [S12] [S40] In its 2023 report covering 2022 data, Better Work Ethiopia documented improved productivity, higher quality, better workplace organisation and reduced absenteeism on lines led by newly trained supervisors. [S40] Similarly, the ILO SCORE and SIRAYE intervention at Edget Garment in Ethiopia paired workplace cooperation and coaching with line balancing, lifting balance efficiency from 24 per cent to 75 per cent and raising daily output from 50 to 120 pieces. [S37] Across Asian garment plants, the ILO

Factory Improvement Toolset combined operation bulletins, SMV measurement, hourly balancing and bottleneck management to lift line achievement by 9.49 per cent while reducing work in progress and defects per hundred units by 22 per cent. [S12]

12.6 FRONTLINE LEADERSHIP STABILISES ATTENDANCE AND HOURLY FLOW CONTROL

Unscheduled absence is an immediate shock to precedence and cycle balance. [S15] [S17] If a 30-operator line loses three machinists at roll call, an untrained supervisor often reacts by shouting or assigning an unverified novice to a complex operation such as collar attachment. [S17] [S19] The novice struggles, builds an upstream pile and starves downstream stations, causing throughput to drop by 30 to 40 per cent in an illustrative cascade triggered by a 10 per cent attendance loss. [S20] [S30]

A trained supervisor manages the shock through a structured protocol. [S12] [S40] Supportive leadership lowers stress-induced absenteeism, reducing missing operators at shift start. [S40] When an absence occurs, the supervisor consults the skill matrix to redeploy a cross-trained utility operator to the constraint while combining or splitting non-constraint operations so no station exceeds pitch or takt time. [S16] [S17] During hourly checks, the supervisor investigates variances using root-cause inquiry rather than blame, keeping operators engaged in reporting thread breakages or cutting flaws early. [S09] [S29] [S40] In GFT's Cameroon textile programme, supervisor preparation is budgeted as core capacity alongside machines, with workforce pipelines detailed in white paper wp09. [S40] [S1201]

12.7

Turnover makes learned capacity perishable

Even well-supervised lines face a structural capacity leak when trained operators leave. [S39] Unlike an automated spinning frame whose cycle time remains fixed, a sewing operator acquires speed and consistency through weeks of sensorimotor learning on specific fabrics, seams and attachments. [S18] [S19] High attrition destroys a factory's stock of standard-minute capability and forces the line back onto the low-output portion of the learning curve. [S18] [S39]

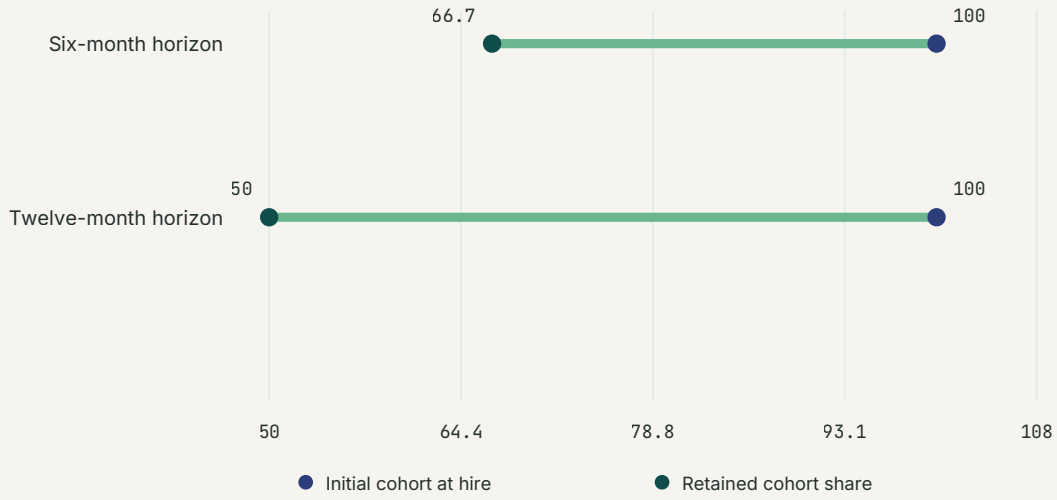
A panel study published by the United Nations University World Institute for Development Economics Research (UNU-WIDER) examining labour turnover and workers' well-being in the Ethiopian manufacturing industry, predominantly in textiles and garments, found that almost one-third of studied workers left before completing their first six months and half left within the first year. [S39] Losing roughly 33 per cent of a cohort within six months and 50 per cent within twelve months means a plant must continuously recruit replacements merely to keep seats occupied. [S39]

To see how turnover depresses the utilisation ceiling, attrition rates must be combined with learning curves. [S18] [S39] In an experimental study of manual sewing-machine operators in apparel manufacturing, average capacity attainment of the manual-machine group rose from 60.6 per cent to 79.4 per cent over six weeks, a gain of 18.8 percentage points (nearly 20 per cent) without any change in hardware or layout. [S18] Whenever an experienced operator working near 80 per cent capacity is replaced by a recruit starting near 60 per cent capacity, the station loses roughly one-quarter of its effective rate for six weeks. [S17] [S18]

The cohort erosion pattern documented in the UNU-WIDER panel is shown in **Exhibit 56**, p. 185. [S39]

EXHIBIT 56 / PERCENT OF COHORT

Turnover can reset capacity during the first year



SOURCED [S39] Sourced from UNU-WIDER panel study of Ethiopian manufacturing workers, mainly in textiles and garments (S39). Almost one-third left before six months (plotted as 33.3% departed vs 66.7% retained from a 100% starting cohort) and half left within one year (50.0% departed). This is empirical sector evidence from Ethiopia, not a Cameroon forecast.

As **Exhibit 56**, p. 185 shows, losing one-third of a cohort within six months and half within twelve months turns line balancing into a continuous replacement struggle. [S39] While the UNU-WIDER study reflects Ethiopian conditions rather than a measured Cameroon baseline, it warns greenfield programmes in Cameroon, where announced projects such as Camtext SA envision roughly 12,000 jobs at Dibamba and 3,000 at Garoua and formal training incidence across surveyed firms stands at 24.0 per cent. [R10] [S1202] What **Exhibit 56**, p. 185 cannot establish is the exact attrition rate a Cameroonian plant will experience; that depends on local wages relative to the XAF 43,969 monthly SMIG and informal alternatives, transport, supervision and onboarding. [R14] [R16] [S40]

12.8 SKILL MATRICES AND RETENTION GATES PROTECT CONSTRAINT STATIONS

Because sewing lines are serially dependent systems governed by their slowest station, turnover damage depends on where departure occurs. [S15] [S30] Garment balancing research rates worker performance by task from 0 (no skill at all) to 1.5 (fully skilled), while remote power-monitoring research identifies task level of difficulty (LD) and operator level of skill (LS) as the primary variables governing line design and staffing. [S17] [S19] If attrition removes the sole fully skilled operator (rated near 1.5) at a high-difficulty constraint operation, line output collapses to the replacement's learning-curve pace. [S17] [S18] [S30]

Workforce planning must therefore integrate three operational controls:

- **Cohort retention tracking by difficulty**: Track 30-day, 90-day, 180-day and 365-day retention separately for trainees, standard machinists and high-skill constraint operators, linking exits to supervision and commute burden. [S19] [S39] [S40]
- **Cross-training buffers around bottlenecks**: For every operation classified as high difficulty or operating above 85 per cent illustrative station utilisation, maintain at least two additional qualified operators on the same shift who practice weekly. [S17] [S18] [S20]
- **Staged onboarding outside the constraint flow**: Train new recruits on off-line rigs or feeder subassemblies during their six-week ramp from 60.6 per cent toward 79.4 per cent capacity before assigning full takt responsibility. [S18] [S26]

12.9

Ergonomics constrains sustainable speed

Time-study engineers sometimes mistake the fastest cycle an operator demonstrates during a five-minute stopwatch observation for a sustainable eight-hour standard. [S15] [S26] The human body is a biomechanical system subject to cumulative muscular fatigue, postural strain and repetitive-motion injury. [S26] [S38] When a workstation forces an operator to hunch over an angled needle plate, reach excessively for bundles, twist the spine or stand on bare concrete all shift, cycle time degrades and health risks accumulate. [S26] [S38]

A 2025 comparative analysis of sitting and standing workstations in Ethiopian garment manufacturing published in the *International Journal of Human Factors and Ergonomics* highlights that sewing operator safety is vital in the clothing industry and that poor workstation ergonomics cause long-term health risks. [S38] Whether a line uses seated tables or standing cells, mismatches between operator anthropometry, table height, pedal placement and material chutes generate musculoskeletal disorders in the neck, shoulders, wrists and back. [S38] Standardised work in lean manufacturing explicitly includes documenting the process to reduce injuries and strain alongside variability. [S26]

Ergonomic strain enters the utilisation equation through all three OEE components and turnover. [S04] [S38] [S39] Discomfort causes micro-pauses as operators stretch or shift posture, depressing afternoon performance. [S04] [S38] Muscular tremor and visual fatigue from poor lighting increase seam wander, lowering first-pass quality. [S04] [S09] Chronic pain drives sickness absence and early resignations, accelerating turnover. [S38] [S39]

12.10 WORKSTATION GEOMETRY AND RECOVERY ALLOWANCES VALIDATE THE SMV

An engineered Standard Minute Value is valid only when its method description and relaxation allowances reflect an ergonomically safe workstation. [S13] [S26] [S38] When calculating garment SMV as the sum of operation SMVs, engineers add basic time to allowances for personal needs, fatigue recovery and unavoidable delay. [S13] Copying synthetic time standards while providing non-adjustable stools and poorly positioned racks leaves the fatigue allowance too small for actual recovery. [S13] [S38]

Before locking an operation bulletin, engineers should verify four parameters at every station:

1. **Height alignment**: Chairs and tables must let forearms rest near horizontal at the needle plate without elevating shoulders or flexing the neck. [S26] [S38]
2. **Primary reach zone**: Pickup and drop chutes must sit within easy reach so operators do not twist their torso on every cycle. [S26] [S38]
3. **Pedal and lighting calibration**: Foot pedals and knee lifters must respond smoothly, with glare-free task lighting at the needle point. [S09] [S38]
4. **Verified fatigue allowances**: Heavy fabric handling or standing pressing requires higher documented recovery allowances inside the SMV than light seaming. [S13] [S38]

12.11

Power reliability belongs in line design and maintenance

Even with a trained, ergonomically supported and well-supervised workforce within lawful hours, a garment line cannot produce good garments without reliable electricity. [S35] [S36] In Cameroon, assuming uninterrupted grid power is fatal to schedule accuracy and unit-cost forecasting. [S35] [S1202]

Institutional diagnostics and firm surveys establish that electrical instability is a binding constraint on Cameroonian manufacturing. [S35] [S1202] The International Finance Corporation's Country Private Sector Diagnostic for Cameroon states directly that regarding access to electricity, energy supply is limited and unreliable. [S35] Data from the World Bank Enterprise Surveys *Cameroon 2024 Country Profile* quantify this disruption: 93.3 per cent of surveyed firms in Cameroon report experiencing electrical outages, compared with 69.7 per cent across Sub-Saharan Africa and 55.0 per cent across lower-middle-income economies. [S1202] Surveyed Cameroonian establishments experience an average of 10.4 electrical outages in a typical month (10.6 for small firms, 9.4 for medium firms and 11.8 for large firms with 100 or more employees), nearly double the lower-middle-income average of 5.3 outages per month. [S1202] Moreover, 25.3 per cent of large firms in Cameroon identify electricity as their single biggest obstacle, ahead of political instability (19.7 per cent) and access to finance (11.3 per cent). [S1202]

World Bank Development Research Group analysis across 84 countries from 2006 to 2019 shows that power outages negatively and significantly affect revenue-based total factor productivity, with outage-exposed manufacturing firms exhibiting a 9 per cent lower unconditional average productivity than non-exposed firms. [S36] As the World Bank's Cameroon 2024 profile notes, inadequate electricity provision can increase costs, disrupt production and reduce profitability. [S1202]

The indicators connecting electrical unreliability to productivity and Cameroonian operating conditions are summarised in **Exhibit 57**, p. 188 and **Exhibit 58**, p. 189. [S36] [S1202]

EXHIBIT 57 / REPORTED SURVEY AND ECONOMETRIC INDICATORS

Outages can destroy productivity before a sewing line starts

-9%

Productivity penalty

Lower average revenue-based TFP for outage-exposed firms across 84 countries (S36)

93.3%

Cameroon outage incidence

Share of Cameroon firms facing electrical outages vs 69.7% in Sub-Saharan Africa (S1202)

10.4

Monthly outage frequency

Electrical outages in a typical month in Cameroon; 11.8 for large firms (S1202)

25.3%

Large-firm top obstacle

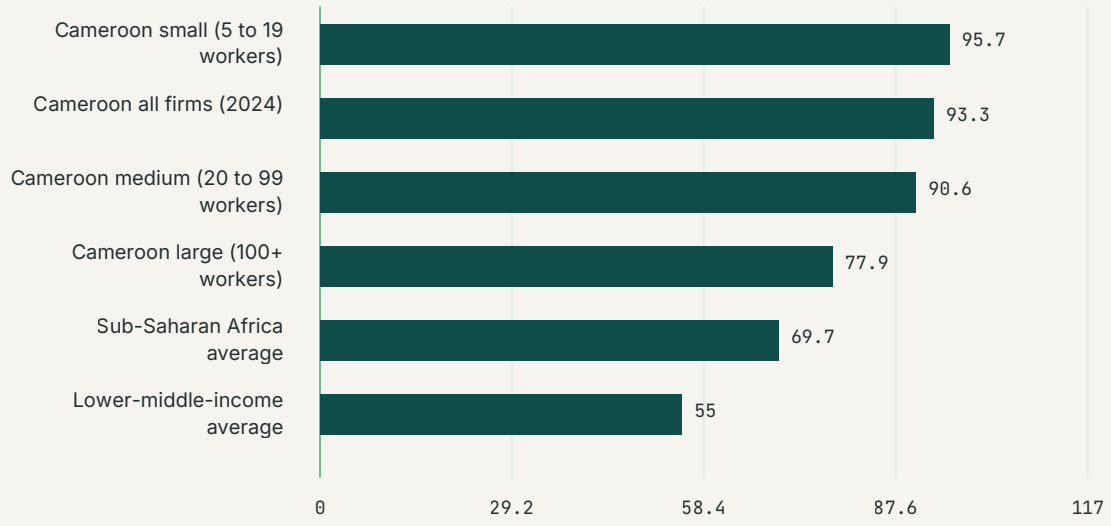
Share of large Cameroon firms naming electricity as their biggest obstacle (S1202)

SOURCED [S36] [S1202] Sourced from World Bank 84-country manufacturing study 2006 to 2019 (S36) and World Bank Enterprise Surveys Cameroon 2024 Country Profile published 2025 (S1202). The 9% TFP gap is a multi-country average across 84 developing economies, not a Cameroon-only econometric estimate.

To place Cameroon's electrical exposure in comparative perspective, **Exhibit 58**, p. 189 ranks the share of firms experiencing electrical outages by firm size tier in Cameroon against regional and income-group benchmarks from the same World Bank survey. [S1202]

EXHIBIT 58 / PERCENT OF SURVEYED FIRMS

Electrical outages affect nearly every surveyed firm tier in Cameroon



SOURCED [S1202] Sourced from World Bank Enterprise Surveys Cameroon 2024 Country Profile Appendix (S1202). Covers formal non-agricultural private firms with 5 or more employees.

Together, **Exhibit 57**, p. 188 and **Exhibit 58**, p. 189 show why a Cameroonian garment plant cannot treat electricity as an external utility issue. [S36] [S1202] Even among large establishments with 100 or more workers, 77.9 per cent experience outages at an average of 11.8 outages per typical month. [S1202] However, these survey aggregates do not specify the exact duration or voltage-sag profile at a specific feeder in Douala, Dibamba or Garoua; each factory must log its own feeder events at the shift boundary. [R10] [S1202]

12.12 OUTAGES IMPOSE BLACKOUT, RESTART AND VOLTAGE-DAMAGE LOSSES

In an apparel OEE loss tree, an electrical outage is more than the raw minutes during which the feeder is dead. [S02] [S04] Total Productive Maintenance (TPM) identifies startup and restart losses alongside breakdowns, setup slowdowns, short stoppages and quality defects inside the six big losses. [S02] When grid power drops on a running floor, three losses occur:

1. **Blackout or switchover downtime**: Even with an automatic transfer switch and backup generation, the interval between grid loss, generator spin-up, synchronisation and line restart consumes planned time. [S02] [S04] Where backup generation is absent, the floor sits idle while attended wages accrue. [R16] [S35]
2. **Restart and thermal-recovery losses**: Garment assembly relies on fusing presses, steam boilers, vacuum tables and air compressors. [S02] When power cuts out, fusing belts must emergency-clear to avoid scorching panels, and thermal setpoints take 10 to 25 illustrative minutes after restoration to stabilise. [S02]
3. **Quality and equipment damage**: Mid-seam power drops leave needles in fabric, create thread tangles, cause burn stains in fusing presses and subject servo-motor boards to voltage transients on restoration. [S02] [S09]

IEEE analysis of OEE emphasises separating equipment-independent external conditions from internal machine reliability. [S06] A sewing line's downtime log must assign distinct codes to `GRID-OUTAGE`, `GEN-SWITCH`, `THERMAL-RESTART` and `SURGE-FAULT`. [S02] [S06]

12.13 TARIFF STRUCTURE AND EFFICIENCY SHAPE BACKUP POWER DESIGN

Mitigating interruptions intersects with Cameroon's electricity tariff structure and efficiency discipline. [S34] [S43] Under Decision No. 00000427 of 12 December 2022 issued by Cameroon's electricity regulator (ARSEL) fixing medium-voltage (MT) tariffs for ENEO customers, billing combines two additive terms: a fixed monthly charge per kilowatt of subscribed demand and a variable charge per kilowatt-hour across time-of-day bands. [S34] Because the fixed demand charge accrues regardless of output, low utilisation and power stoppages raise the fixed electricity cost absorbed by each good garment. [S34] [S44]

UNIDO's industrial energy case study at Lotus Garments in Egypt establishes that a garment plant must optimise its energy management system through efficiency measures before investing in renewable or backup power applications. [S43] Sizing solar, battery storage or backup generators around an inefficient load wastes capital on compressed-air leaks, uninsulated steam pipes and idling motors. [S43] [S44] Eliminating base-load waste, fitting servo motors and isolating critical bottleneck circuits on uninterruptible power supplies shrinks the backup capacity required to keep the constraint moving. [S30] [S43] Detailed microgrid sizing remains with white paper wp07 and GFT's solar-storage tool, while unit-cost accounting is expanded in Chapter 13. [S34] [S43]

12.14

Buyer planning can reduce avoidable peaks

A plant's ability to maintain a 40-hour roster, protect ergonomics, avoid chronic overtime and schedule energy-intensive tasks outside peak grid-vulnerability windows depends on how customer orders enter the system. [S33] [S41] [S42] When commercial teams accept volatile orders with compressed lead times and uncoordinated peaks, they inject surges into the sewing room that no internal balancing algorithm can absorb smoothly. [S22] [S42]

International Labour Office research on purchasing practices in global garment supply chains documents that erratic buyer ordering and last-minute changes drive excessive overtime and compliance failures, while noting that some companies plan their orders, lead times and production peaks in advance with their suppliers. [S42] Sharing capacity forecasts, locking specifications before the cut date and smoothing order peaks allow the factory to stabilise takt time and run steady shifts. [S15] [S42]

MIT operations teaching highlights that Little's Law strictly applies to long-term averages of stable systems that are not starting, stopping or surging, and that waiting time rises nonlinearly as capacity utilisation approaches saturation. [S22] [S23] Accepting an order peak that pushes required weekly hours past the plant's derated ceiling causes queues to explode, work in progress to age and defect rates to climb. [S20] [S23] [S41]

12.15 COMMERCIAL ORDER GATES MUST CHECK DERATED CAPACITY BEFORE COMMITMENT

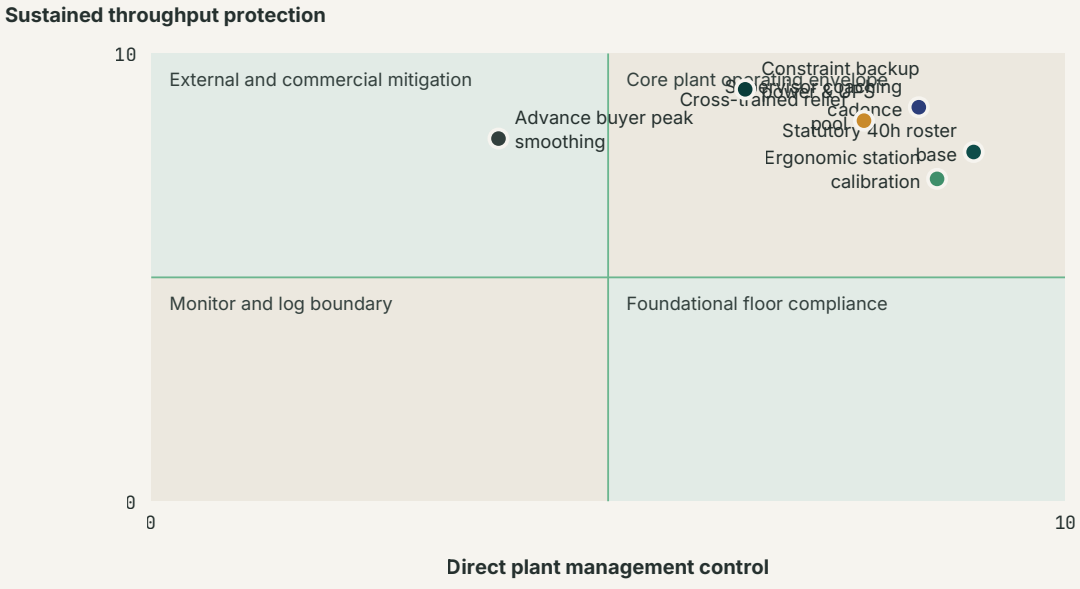
Sales and operations planning (S&OP) must evaluate every proposed order release against *attainable derated capacity* rather than nameplate capacity. [S04] [S42] Before confirming a delivery date, planners should verify four gates:

- **Net ordinary-hour feasibility**: Required standard minutes must fit within net planned minutes of the 40-hour statutory week across qualified operators. [S13] [S33] [S41]
- **Skill-adjusted ramp allowance**: Orders with new constructions or recent hires must apply six-week learning-curve ramps (such as the 60.6 per cent to 79.4 per cent manual-machine progression) rather than steady-state efficiency. [S17] [S18]
- **Outage and changeover derating**: Available hours must deduct changeover duration and expected feeder outage or transfer losses from the rolling 90-day power log. [S02] [S25] [S1202]
- **Material readiness gate**: Fabric, thread, trims and approved samples must be verified on site before release, preventing starvation stops that mimic machine downtime. [S06] [S26]

The planning framework integrating statutory hours, human capability, ergonomic safety and electrical reliability is mapped in **Exhibit 59**, p. 191. [S33] [S35] [S38] [S39]

EXHIBIT 59 / ILLUSTRATIVE PLANNING SCORE (0 TO 10)

The attainable schedule combines legal, human and power constraints



ILLUSTRATIVE [S33] [S35] [S38] [S39] Illustrative GFT planning matrix scoring six operational envelope controls by degree of direct in-plant management control (x-axis, 0 to 10) and protective impact on sustained good throughput (y-axis, 0 to 10). Conceptual basis drawn from statutory hours (S33), power reliability (S35), ergonomics (S38) and turnover dynamics (S39). Scores are illustrative design judgments, not measured factory outcomes.

As **Exhibit 59**, p. 191 shows, five of the six controls sit under direct plant control: enforcing the 40-hour statutory roster, coaching supervisors, maintaining a cross-trained relief pool, calibrating ergonomics and protecting constraints with backup

power. [S33] [S35] [S38] [S39] Advance buyer peak smoothing sits in the upper-left quadrant because it requires commercial negotiation, yet its high vertical position reflects how strongly order smoothing protects internal flow. [S41] [S42] Because **Exhibit 59**, p. 191 is an illustrative model, its coordinates guide prioritisation rather than asserting universal elasticities.

CAPACITY DERATING BOUNDARY AND MULTIPLICATIVE RECONCILIATION

GFT derates nominal shift capacity (`N_nom`, in pieces per shift at standard minute values) through three sequential factors from rolling shift logs: [S04]

1. **Power availability factor (`F_pwr = 1 - L_pwr`)**: Planned time remaining after blackouts, transfer intervals and thermal restarts (`L_pwr`), logged separately from mechanical breakdowns. [S02] [S35] [S36]
2. **Human capability factor (`F_hum = 1 - L_hum`)**: Combined effect of absence, turnover-induced learning-curve gaps and ergonomic recovery (`L_hum`) across the constraint path. [S18] [S38] [S39]
3. **First-pass quality factor (`F_qual = 1 - L_qual`)**: Share of started units passing quality checks without rework or rejection (`L_qual`). [S04] [S09]

Deliverable good-unit capacity (`N_good`) is `N_good = N_nom x F_pwr x F_hum x F_qual`, with each step deducting from the surviving balance. [S04]

WORKED EXAMPLE: DERATING A 1,000-PIECE NOMINAL SHIFT PLAN

Consider an illustrative garment line whose operation bulletin yields a nominal capacity of `1,000` pieces per eight-hour shift under uninterrupted power, full skilled attendance and zero defects. [S04] [S13] Before signing a delivery schedule, the engineer applies three illustrative derating assumptions informed by sector risk categories: [S36] [S39]

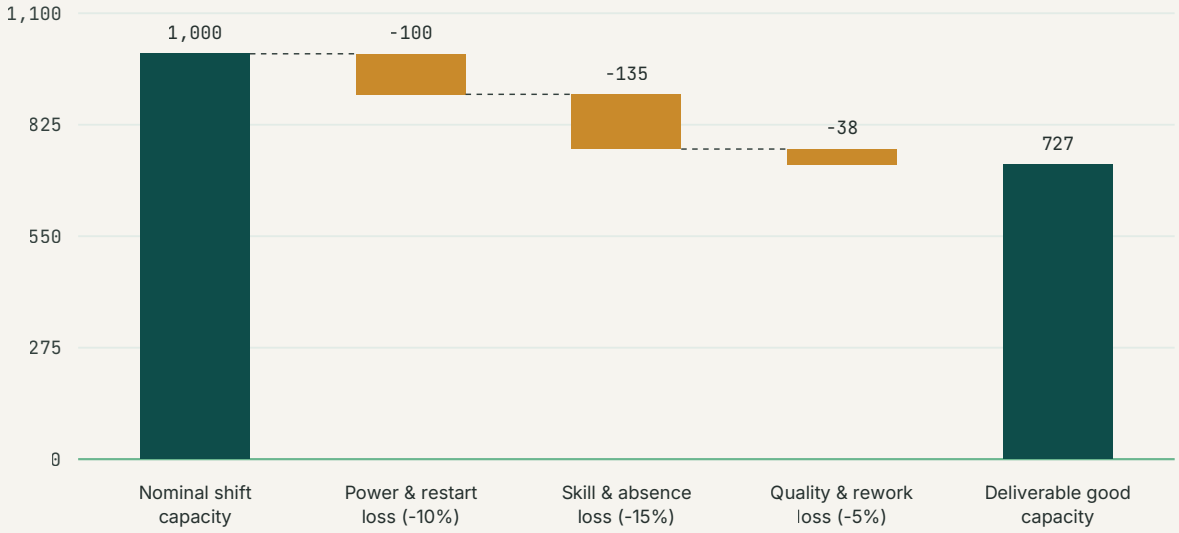
- **Step 1 (Power loss, 10 per cent)**: Blackouts, switchover pauses and thermal recovery reduce operating time by an illustrative `10` per cent (`F_pwr = 0.90`), deducting `100` unit-equivalents to leave `900` pieces. [S02] [S04] [S36]
- **Step 2 (Skill and absence loss, 15 per cent)**: Absenteeism and replacements ramping along the six-week learning curve place human performance `15` per cent below standard pace (`F_hum = 0.85`), deducting `135` unit-equivalents from `900` to leave `765` pieces. [S04] [S18] [S39]
- **Step 3 (Quality loss, 5 per cent)**: An illustrative `5` per cent defect deduction (`F_qual = 0.95`) on `765` units removes `38.25` pieces (rounded to `38` in integer reporting), leaving `1,000 x 0.90 x 0.85 x 0.95 = 726.75` good-unit equivalents, or `727` deliverable good garments per shift. [S04]

Promising `950` pieces per day on nameplate assumptions would create a `223`-piece daily shortfall and trigger chronic overtime. [S41] Committing up to the `727`-unit ceiling while attacking the `100`, `135` and `38` lost units protects delivery and unit economics. [S04] [S40] This worked example uses illustrative percentages solely to demonstrate the method.

The sequential derating bridge from the worked example is presented in **Exhibit 60**, p. 193. [S04] [S36] [S39]

EXHIBIT 60 / GOOD-UNIT EQUIVALENTS PER SHIFT

Nominal shift capacity must be derated for real constraints



DERIVED [S04] [S36] [S39] Derived with illustrative inputs using the multiplicative OEE loss structure (S04) and risk categories from power constraints (S36) and labour turnover (S39). Opening nominal capacity = 1,000 pieces; less 10% power loss (-100, leaving 900); less 15% skill and absence loss on remaining (-135, leaving 765); less 5% quality loss on remaining (-38.25, rounded to -38), giving 1,000 × 0.90 × 0.85 × 0.95 = 726.75, rounded to 727 good-unit equivalents.

As **Exhibit 60**, p. 193 makes clear, three moderate constraints (10 per cent power loss, 15 per cent skill and absence loss and 5 per cent quality loss) compound multiplicatively to remove 273 pieces per 1,000 nominal units, reducing deliverable output by 27.3 per cent. [S04] A live factory must replace these illustrative percentages with measured shift averages before setting order caps. [S01] [S04]

GFT NOTE: BUILD THE PEOPLE AND POWER LEDGER FROM THE FIRST SHIFT

In GFT's Cameroon textile programme, a sewing line is never commissioned with an unconstrained nameplate target. [R12] [S04] GFT pairs the hourly board with a four-part protocol linked to the `supervisor-pipeline`, `ramp-planner` and `solar-storage` tools: [S04] [S40]

1. **Enforce a 40-hour ordinary baseline**: Set takt, pitch and order acceptance on Cameroon's 40-hour statutory week, requiring plant-manager sign-off whenever weekly overtime exceeds four illustrative hours per operator. [S33] [S41]
2. **Train and audit supervisors**: Require supervisors to complete coaching in communication, hourly balancing and skill-matrix redeployment prior to launch, tracking absenteeism and 90-day retention on the scorecard. [S39] [S40] [S1201]
3. **Meter and isolate electrical losses**: Separate blackouts, switchovers and thermal restarts from mechanical breakdowns, and prioritise efficiency retrofits and backup power on cutting, fusing and bottleneck sewing stations. [S02] [S30] [S43] [S1202]
4. **Gate orders on derated capacity**: Apply rolling 30-day measured `F_pwr`, `F_hum` and `F_qual` factors before accepting delivery dates, negotiating peak smoothing rather than absorbing surges as overtime. [S04] [S42]

LEGAL, TARIFF AND SITE-SPECIFIC VALIDATION BOUNDARY

Working-time rules, overtime tiers, health standards and medium-voltage tariffs are governed by Cameroonian law and regulatory decisions, including Law No. 92/007 and ARSEL Decision No. 00000427. [S33] [S34] Cited studies from Ethiopia, Bangladesh, Egypt and multi-country World Bank panels establish mechanisms but do not substitute for site data in Douala, Dibamba or Garoua. [R10] [S13] [S36] [S39] [S43] Nothing in this chapter is legal, tax, financial or investment advice; sponsors must validate contracts with Cameroonian counsel and verify feeder reliability through site metering before capital commitment. [S33] [S34]

A line balance is only as durable as the people who run it and the current that drives it.

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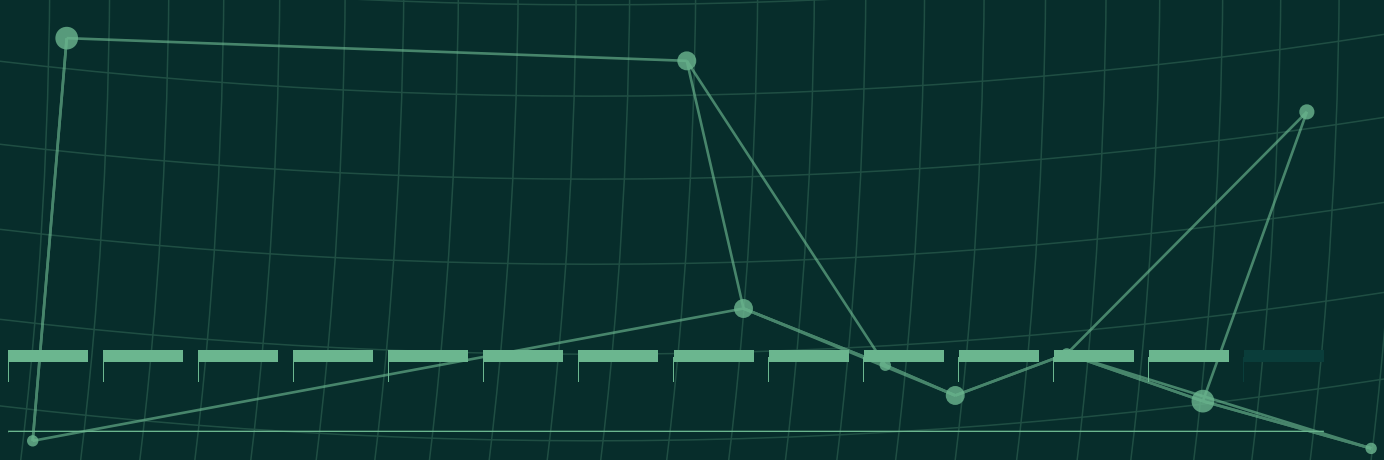
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13

Unit economics improve only when losses close

The financial benefit is not a higher dashboard score; it is more good garments at acceptable labour, energy, capital and working-capital cost.



CHAPTER 13
DECISION TEST

The financial benefit is not a higher dashboard score; it is more good garments at acceptable labour, energy, capital and working-capital cost.

A garment factory does not bank an overall equipment effectiveness percentage or a theoretical line-balance ratio. It banks the margin between the revenue of shipped, first-quality garments and the total cost of the labour, electricity, materials, working capital and machinery required to produce them. [S04] [S13] Across the preceding chapters, this paper has treated availability, speed, quality, standard minutes, constraint balancing and pull-based flow as one connected operating system. This chapter translates that operating system into unit economics. Its core argument is that unit cost falls sustainably only when real losses close at the system constraint without reappearing as rework, excess work in progress, exhausting overtime or oversized energy infrastructure. [S04] [S30] [S41] [S44] In Cameroon, where reported capacity utilisation at incumbent textile plants stood between 10.83 and 48.9 per cent in July 2023 and underutilisation alone was reported to cost about CFAF 2 billion in 2020, the financial viability of domestic cotton-to-garment processing depends on how reliably installed lines convert attended hours into saleable output. [R06] [R12]

13.1

Fixed cost is absorbed by good output

13.2 NAMEPLATE CAPACITY CREATES AN ACCOUNTING OBLIGATION BEFORE IT CREATES REVENUE

Every industrial garment programme commits to fixed and semi-fixed period costs before the first bundle leaves the cutting room. Building lease or depreciation charges, sewing and pressing machinery amortisation, core supervisory and administrative salaries, security, insurance, software licences and contracted demand charges for electricity accrue by the calendar month rather than by the finished piece. [S01] [S34] When a sponsor evaluates a factory on its nameplate machine count, those period costs are divided in the business plan by an assumed volume that reflects continuous operation at nominal speed. On the floor, however, period costs can only be absorbed by good output: units that pass final inspection and meet the customer's delivery specification. [S04] Every availability stop, speed loss, balancing delay and rejected garment shrinks the denominator of good units while leaving fixed period obligations unchanged. [S02] [S04]

The economic distance between installed capacity and absorbed cost is visible in Cameroon's textile record. While roughly 95 per cent of national cotton fibre is exported raw and about 5 per cent is processed locally against a national target of 50 per cent by 2030, existing industrial assets have struggled to convert physical plant into sustained output. [R06] [R07] In the July 2023 account of incumbent manufacturer CICAM, capacity utilisation was reported at 33.7 per cent at Garoua, 48.9 per cent at CICAM 1 and 10.83 per cent at CICAM 2, with prior underutilisation reported to have cost roughly CFAF 2 billion in 2020. [R12] Restructuring cost estimates for the incumbent ranged from CFAF 30.7 billion to CFAF 48.2 billion, with one relaunch plan cited at CFAF 70.2 billion, whereas the Camtext SA project announced on 12 November 2025 carries a capital commitment of US$300 million (180 billion XAF) to process 12,000 tonnes a year, with a projected return on investment near 11 years and optimal capacity around 2033. [R09] [R10] [R13] Whether restructuring legacy lines or commissioning greenfield capacity, capital recovery is governed by the volume of good output crossing the finishing boundary each shift. [R10] [R12]

13.3 GOOD THROUGHPUT AT THE CONSTRAINT GOVERNS OVERHEAD ABSORPTION

GFT's Cameroon textile programme treats capacity utilisation and effective labour cost as the primary swing variables in factory unit economics. In a dependent sewing line, fixed-cost absorption is governed by the rate of good garments emerging from the constraint operation, not by average station busyness. [S30] If an upstream station runs fast while the bottleneck is starved, blocked or stopped for adjustment, the factory accumulates work in progress (WIP) rather than finished goods. [S09] [S20] [S30] Under Little's Law, for a stable system in long-term average conditions, extra WIP without a rise in constraint throughput simply lengthens throughput time, tying up working capital in cut fabric and delaying defect detection. [S22] [S31] [S32]

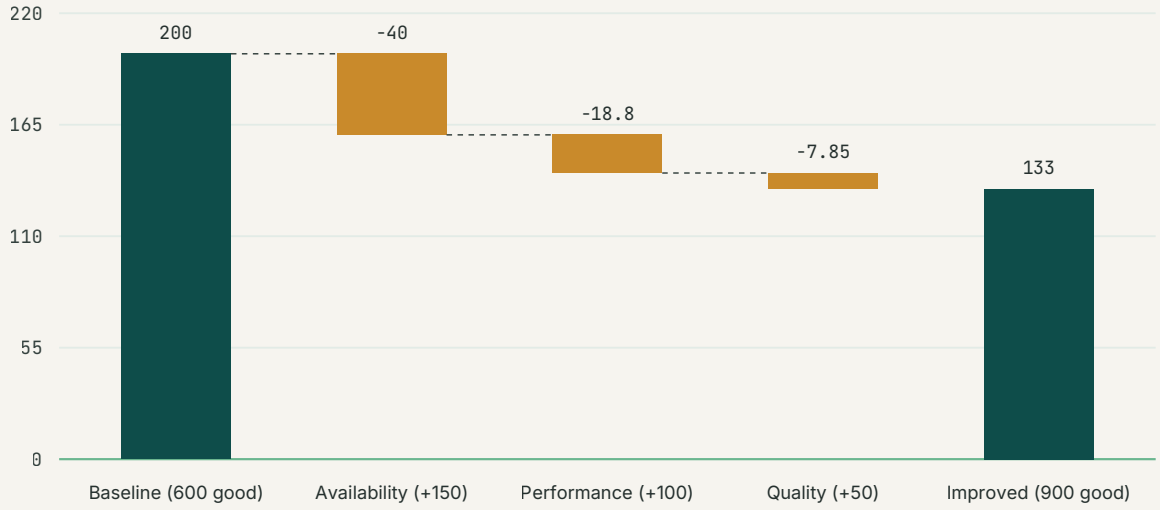
To keep unit economics grounded in physical reality, GFT separates five cost channels before claiming any financial gain from a productivity initiative:

- **Fixed production overhead per good unit:** period depreciation, facility, management and fixed utility charges divided strictly by first-pass and acceptably repaired garments delivered in the period, an illustrative boundary grounded in OEE quality rules. [S04] [S34]
- **Direct and indirect labour per good unit:** attended operator, helper, mechanic and supervisor wages, social charges and lawful overtime premiums divided by good output, reflecting earned standard minutes rather than nominal headcount. [R16] [S13] [S1301]
- **Quality and rework cost:** direct labour minutes, thread, trim and machine time consumed in unpicking and re-sewing defective seams, plus material scrap and margin loss on seconds or rejects. [S04] [S09] [S12]
- **Energy and utility cost per good unit:** fixed subscribed-demand charges, variable grid kilowatt-hours across tariff schedules and backup generator fuel divided by good output. [S34] [S35] [S44]
- **Working-capital holding cost:** financing cost, storage footprint and obsolescence risk of raw materials and bundles waiting between cutting, sewing and packing. [S22] [S23] [S31]

The effect of closing multiplicative OEE losses on fixed-cost absorption is shown in **Exhibit 61**, p. 199. In this derived model using illustrative inputs, a sewing line carries XAF 120,000 of fixed production cost per shift. When availability, performance and quality losses hold output to 600 good garments per shift, each garment absorbs XAF 200.00 of fixed cost. [S04] Recovering 150 good garments through availability, 100 through performance and 50 through first-pass quality raises shift output to 900 good garments and lowers fixed cost to XAF 133.33 per garment, a 33.33 per cent unit reduction achieved without adding machines. [S02] [S04]

EXHIBIT 61 / XAF FIXED COST PER GOOD GARMENT

Good output lowers fixed cost per garment



DERIVED [R12] [S04] Derived with illustrative inputs: XAF 120,000 fixed shift production cost divided by 600 baseline good garments equals XAF 200.00 per garment. Sequential recovery of 150 availability-equivalent units (to 750 units, XAF 160.00), 100 performance-equivalent units (to 850 units, XAF 141.18) and 50 quality-equivalent units (to 900 units, XAF 133.33) reduces fixed cost per garment by XAF 66.67 (33.33 per cent). Multiplicative loss categories follow S04; underutilisation context follows R12.

As **Exhibit 61**, p. 199 demonstrates, the unit-cost reduction is largest on the initial recovery of good volume because fixed cost per unit follows a reciprocal curve against output. [S04] However, **Exhibit 61**, p. 199 cannot establish that those 300 additional garments have a buyer or that material supply is available to feed the line. Producing 900 garments against a confirmed order of 600 without an authorised downstream pull signal merely converts cash into unsold stock. [S24] [S28] Overhead absorption improves unit economics only when recovered capacity produces ordered, defect-free garments that convert into cash. [S04] [S24]

13.4

Low nominal wages do not remove the productivity problem

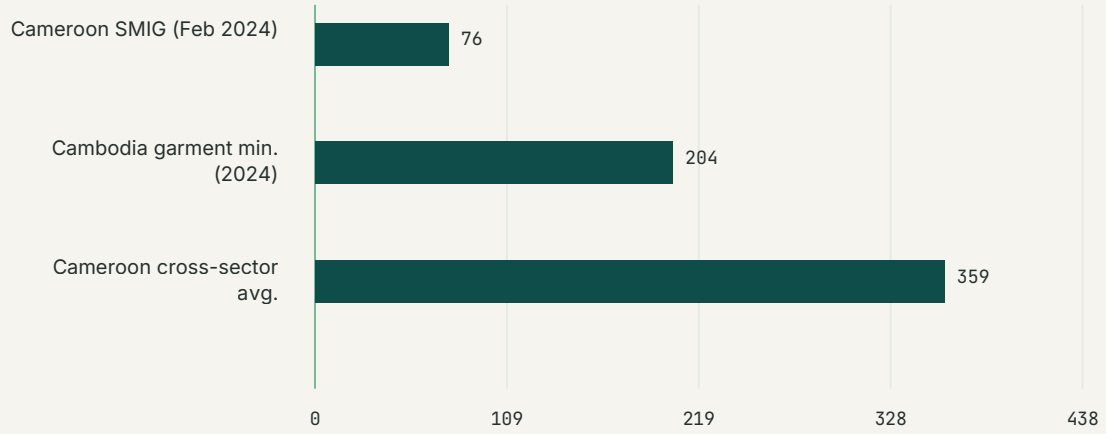
13.5 MONTHLY WAGE COMPARISONS MISLEAD WHEN DIVORCED FROM STANDARD MINUTES

A persistent error in industrial feasibility studies for emerging textile economies is to equate a low statutory minimum wage with a low unit labour cost. In the shared evidence register, Cameroon's statutory minimum wage (SMIG) stood at XAF 41,875 a month in 2023 and was raised to XAF 43,969 a month from 23 February 2024, equivalent to about US$76 a month and representing a 5 per cent increase. [R14] By comparison, the register records an average salary across sectors in Cameroon of about US$359 a month, and a Cambodia garment-sector minimum wage benchmark of US$204 a month for 2024 (with currency conversions treated as estimates against a CFA franc peg of 655.957 per euro and reference ranges near 590 to 610 per US

dollar in 2023 and 563 to 577 more recently). [R15] [R17] [R32] Looked at solely as monthly payroll figures in **Exhibit 62**, p. 200, the statutory floor in Cameroon appears far below the Asian garment benchmark. [R14] [R17]

EXHIBIT 62 / US$ PER MONTH (APPROXIMATE)

Nominal monthly wage benchmarks do not measure unit labour cost



SOURCED [R14] [R15] [R17] [R32] Sourced from the shared register: Cameroon SMIG raised to XAF 43,969 per month from 23 February 2024 (about US$76, R14); Cambodia garment minimum wage US$204 per month for 2024 (R17); Cameroon cross-sector average salary about US$359 per month (R15). Currency conversions are approximate estimates (R32). Monthly wages do not adjust for earned standard minutes, skill or quality.

The comparison in **Exhibit 62**, p. 200 is incomplete for three operational reasons. First, a factory sells standard minutes of garment work content embedded in finished pieces, not attended months. [S13] [S1301] Cut and Make (CM) labour cost per piece equals the garment's Standard Minute Value (SMV) multiplied by direct labour cost per attended minute, divided by achieved line efficiency. [S13] [S1301] When line efficiency falls because of poor balancing, waiting for bundles, breakdowns or learning gaps, labour cost per earned minute rises in inverse proportion. [S09] [S15] [S1301] Second, factories require mechanics, inspectors, cutters, supervisors and planners paid well above the statutory minimum wage, moving blended payroll toward higher formal-sector brackets. [R14] [R15] [S40] Third, statutory working hours in Cameroon are bounded by the 40-hour non-agricultural week in the Labour Code, with a 48-hour maximum and overtime paid at 1.2 times the base rate. [R16] [S33] Relying on chronic overtime to offset low daytime efficiency raises hourly wage rates while inducing fatigue that depresses output over the long run. [R16] [S41]

13.6 LEARNING, TURNOVER AND REWORK MULTIPLY EFFECTIVE LABOUR COST

Human proficiency and retention directly alter the denominator of earned minutes. In the apparel manual-skill study cited earlier, manual-machine operators increased their average capacity from 60.6 per cent to 79.4 per cent over six weeks. [S18] In the ILO SCORE case at Edget Garment in Ethiopia, line-balance efficiency rose from 24 per cent to 75 per cent and daily output increased from 50 to 120 pieces when work was rebalanced and workplace cooperation was introduced. [S37] Moreover, learned capability is perishable: in the UNU-WIDER panel study of Ethiopian manufacturing workers, almost one-third left before six months and half left within the first year. [S39] While that turnover rate is an Ethiopian observation rather than a Cameroon forecast,

it demonstrates the cost mechanism: when an experienced operator leaves a critical station, the line returns to the lower end of the learning curve, training costs recur and downstream stations wait. [S18] [S39]

Quality losses compound the labour penalty. When a garment fails inspection and requires unpicking and re-sewing, operator minutes consumed per unit rise while earned standard minutes remain fixed. [S04] [S13] Individual piece-rate incentives that reward raw speed without a quality gate encourage operators to push defective bundles forward, creating long lead times and low quality as documented in NBER evidence. [S32] Conversely, the ILO Factory Improvement Toolset programme across Asian garment factories showed that structured industrial engineering raised sewing-room line achievement by 9.49 per cent while reducing both WIP and defects per hundred units by 22 per cent. [S12] Better Work Ethiopia similarly reported that lines led by newly trained supervisors achieved higher productivity and quality alongside reduced absenteeism. [S40]

WORKED EXAMPLE: ILLUSTRATIVE CM LABOUR COST UNDER LOW AND STABILISED LINE PERFORMANCE

To see why nominal wage differentials cannot substitute for line discipline, consider an illustrative comparison for a woven shirt with an SMV of 16.0 standard minutes. [S13] This worked example uses disclosed illustrative assumptions solely to demonstrate the costing arithmetic; it is not an observed GFT result or a margin forecast. [S1301]

Assume a 24-operator sewing line works 40 statutory hours per week across 4.33 weeks per month, giving $40 \times 4.33 \times 60 = 10,392$ attended minutes per operator, or $24 \times 10,392 = 249,408$ attended line minutes per month. [R16] [S33] Suppose the fully loaded monthly cost of each direct operator (above the XAF 43,969 statutory minimum) is an illustrative XAF 75,000, and line supervision plus mechanic support adds an illustrative XAF 300,000 per month. [R14] Monthly line payroll is $(24 \times 75,000) + 300,000 = \text{XAF } 2,100,000$, giving a cost per attended minute (CPM) of $\text{XAF } 2,100,000 / 249,408 = \text{XAF } 8.42$. [S1301]

1. **Unbalanced baseline (State A):** Gross SMV efficiency is 32 per cent and first-pass quality yield is 90 per cent, giving a net effective efficiency in good garments of $0.32 \times 0.90 = 28.8$ per cent. [S04] [S13] [S1301] Monthly earned standard minutes in good output are $249,408 \times 0.288 = 71,829.5$, yielding $71,829.5 / 16.0 = 4,489$ good shirts. Direct labour cost is $\text{XAF } 2,100,000 / 4,489 = \text{XAF } 467.81$ per good shirt. [S1301]
2. **Stabilised operation (State B):** Through feasible balancing, maintenance and supervisor coaching, gross efficiency reaches 60 per cent and quality yield reaches 96 per cent, giving a net effective efficiency of $0.60 \times 0.96 = 57.6$ per cent. [S09] [S12] [S40] Even if the plant raises operator pay by 20 per cent to an illustrative XAF 90,000 per month (lifting monthly line payroll to $\text{XAF } 2,460,000$ and attended CPM to $\text{XAF } 9.86$), monthly output doubles to $249,408 \times 0.576 / 16.0 = 8,979$ good shirts. Direct labour cost falls to $\text{XAF } 2,460,000 / 8,979 = \text{XAF } 273.97$ per shirt, a 41.4 per cent unit-cost reduction alongside a 20 per cent wage increase. [S1301]

This arithmetic explains why GFT's labour-cost tool evaluates wages, learning curves, turnover, absenteeism and SMV efficiency together rather than quoting statutory minimum wages in isolation. [R14] [S13] [S18] [S39]

13.7

Maintenance value should be read through lost capacity

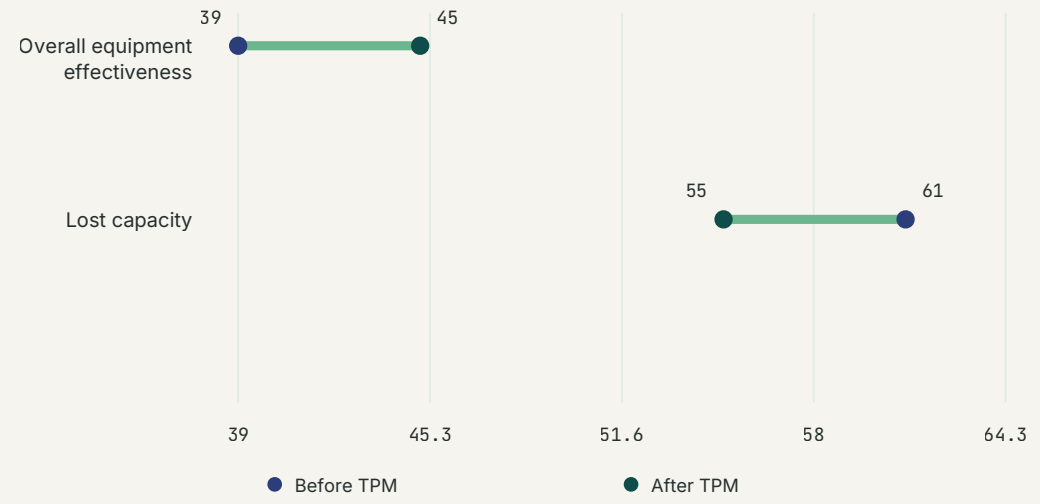
13.8 EQUIPMENT BREAKDOWNS COST WHAT THE CONSTRAINT LOSES

Total Productive Maintenance (TPM) targets zero breakdowns and zero defects by eliminating six losses: equipment breakdown, setup and adjustment slowdowns, idling and short-term stoppages, reduced capacity, quality-related losses and startup or restart losses. [S02] Treating preventive maintenance as a deferrable discretionary expense misreads the cost of lost capacity. In the apparel monitoring study of Company X, cumulative downtime logs showed 4,923 minutes lost to technical malfunction, 3,694 minutes to machine adjustment, 2,432 minutes to faulty needles and 1,427 minutes to thread breakage, disrupting downstream flow and generating stitch defects. [S06] [S09]

Empirical evidence from the NIST Manufacturing Extension Partnership (MEP) illustrates how structured maintenance translates into recovered capacity and avoided capital expenditure. [S08] In a documented NIST MEP case at a manufacturing cell experiencing recurring lathe breakdowns, implementing TPM reduced downtime, lifted cell productivity by about 22 per cent, raised OEE from 39 per cent to 45 per cent and cut lost capacity from 61 per cent to 55 per cent, as plotted in **Exhibit 63**, p. 202. [S08] By recovering six percentage points of effective capacity on its bottleneck equipment and adding visual inspection cues, the plant avoided US$250,000 in new machine purchases. [S08]

EXHIBIT 63 / PER CENT OF CELL CAPACITY

Maintenance improved OEE and reduced lost capacity in one NIST case



SOURCED [S08] Sourced from the NIST MEP case study (2022-10-04): after Total Productive Maintenance was implemented on a bottleneck machining cell, OEE increased from 39 to 45 per cent and lost capacity fell from 61 to 55 per cent. Single-case non-apparel limitation applies; demonstrates the capacity-recovery mechanism.

While **Exhibit 63**, p. 202 records a single non-apparel case and is not a fixed forecast for a sewing room, its economic mechanism applies directly to garment assembly. [S08] [S09] Before buying extra lockstitch or overlock machines to meet an order target, management should check whether existing machines are losing 40 to 60 per cent of planned time to avoidable breakdowns, needle faults and adjustments. [S08] [S09] Buying machines to mask unmaintained equipment inflates capital outlay, floor congestion and electrical load without fixing underlying failure modes. [S02] [S08]

13.9 MAINTENANCE RETURN DEPENDS ON STATION POSITION IN THE FLOW

Not every minute of recovered machine availability carries the same financial value. Workstation OEE is affected by equipment-independent conditions such as input starvation. [S06] Conversely, Theory of Constraints establishes that an hour lost at the bottleneck is an hour lost for the whole line, whereas an hour lost at an unconstrained station with protective capacity may have zero effect on daily finished output. [S23] [S30] GFT therefore evaluates maintenance economics across three operational tiers:

1. **Constraint and single-point-of-failure equipment:** spreaders, cutters, fusing presses, steam systems and the highest-utilisation sewing stations identified by sustained upstream queues. [S20] [S30] Breakdowns here directly reduce shippable garments once buffers empty, so preventive maintenance and critical spares earn the full contribution and overhead-absorption value of recovered line throughput. [S02] [S20] [S30]
2. **Quality-critical sewing and finishing stations:** collar, cuff, placket, buttonhole, bartack and pressing stations where tension or temperature drift causes defects. [S02] [S09] In Company X, Lock Stitch Repair and Stain accounted for 54.77 per cent of defects and the top five categories for 87.56 per cent. [S09] Maintenance here pays back by preventing rework labour, seconds discounts and scrap. [S04] [S09]
3. **Non-constraint stations with protective capacity:** basic seam operations whose cycle time sits well below line pitch time. [S16] [S28] Operator autonomous maintenance (cleaning, lint removal, needle checks and lubrication) keeps downtime within the protective margin without costly sensors. [S02] [S09]

13.10

Electricity cost contains fixed and variable elements

13.11 TWO-PART INDUSTRIAL TARIFFS PENALISE LOW UTILISATION AND PEAK SPIKES

In garment manufacturing, electricity powers sewing motors, cutting tables, air compressors, lighting, ventilation and electric steam or finishing loads. [S16] [S43] In Cameroon, electricity regulator ARSEL issued Decision 00000427 on 12 December 2022 fixing untaxed electricity sale tariffs for medium-voltage (MT) customers served by utility ENEO. [S34] The regulatory text specifies two additive terms: a fixed monthly charge per kilowatt of subscribed demand and a variable charge per kilowatt-hour consumed, differentiated by operating hours and consumption schedules. [S34] Following a tariff freeze since 2012, the regulatory framework initiated pro-

gressive annual increases from 1 January 2023 through 2026 of 5 per cent per year for medium-voltage consumption between 0 and 3 MW and 10 per cent per year between 3 and 10 MW. [S1302]

This two-part, rising tariff architecture links production discipline directly to unit energy cost:

- **Subscribed-demand dilution:** Because the fixed demand charge (XAF per subscribed kW per month) is billed regardless of output, low utilisation leaves a fixed capacity charge sitting on a small garment volume, while uncoordinated simultaneous equipment starts force a higher subscribed kW tier. [S34] [S44]
- **Time-of-use and overtime penalties:** When daytime losses force evening overtime shifts to meet delivery dates, production shifts into higher-cost peak tariff windows while incurring the 1.2 times statutory overtime wage rate. [R16] [S34] [S41]
- **Outage and backup-generation premiums:** IFC documents that Cameroon's grid supply is limited and unreliable. [S35] In the World Bank's study across 84 developing countries from 2006 to 2019, outage-exposed manufacturers showed a 9 per cent lower unconditional average revenue-based total factor productivity. [S36] Outages either halt output while wages and fixed demand charges continue or force diesel backup generation at a much higher cost per kWh. [S34] [S36] [S1302]

TWO-PART AND BACKUP ELECTRICITY COST PER GOOD GARMENT

Within GFT's unit-economics framework, monthly electrical expenditure C_{elec} is decomposed into four measurable components across a billing period of G finished good garments: [S34] [S44]

$$C_{\text{elec}} = \left(P_{\text{sub}} \cdot r_{\text{fixed}} \right) + \left(E_{\text{grid,off}} \cdot r_{\text{off}} \right) + \left(E_{\text{grid,peak}} \cdot r_{\text{peak}} \right) + \left(E_{\text{gen}} \cdot r_{\text{gen}} \right)$$

Dividing by good output G yields unit electrical cost $c_{\text{elec}} = C_{\text{elec}} / G$, where:

1. P_{sub} is contracted medium-voltage subscribed power in kilowatts and r_{fixed} is the monthly fixed charge in XAF per kW under the ARSEL schedule. [S34]
2. $E_{\text{grid,off}}$ and $E_{\text{grid,peak}}$ are metered grid kilowatt-hours in off-peak and peak periods, multiplied by tariff rates r_{off} and r_{peak} under the 2023 to 2026 revision schedule. [S34] [S1302]
3. E_{gen} is kilowatt-hours supplied by backup generation or solar-plus-storage during outages at verified unit cost r_{gen}, while restart and scrap losses are logged in the OEE availability and quality trees. [S02] [S04] [S35]

13.12

Energy per garment can improve through the denominator alone

13.13 BASE LOAD CREATES A FALSE EFFICIENCY SIGNAL WHEN VOLUME RISES

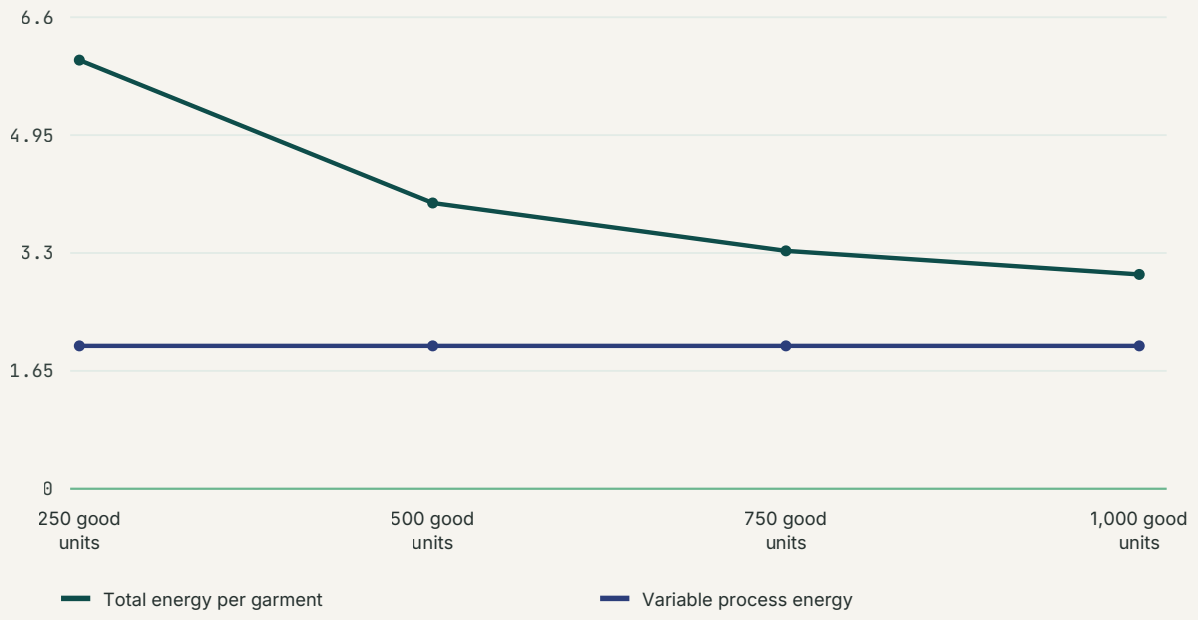
Sustainability scorecards and energy audits track specific energy consumption (SEC), defined as kilowatt-hours of electricity or megajoules of thermal energy per garment. [S44] UNIDO's *Practical Guide for Implementing an Energy Management System* warns that when a facility has a large fixed base load, production volume strongly distorts energy per unit. [S44] When volume rises, total energy is divided by more units, so the ratio falls and appears to show an improvement in energy performance even when no physical efficiency measure has occurred. [S44]

In a garment factory, base load is substantial: hall and compound lighting, IT servers, central ventilation, compressor pressure maintenance against pipe leaks, and steam-boiler standing losses draw energy whenever the building is open, while clutch motors or idle control boards draw standby power between sewing bursts. [S16] [S19] [S43] [S44]

The separation between a denominator effect and a process-efficiency gain is illustrated in **Exhibit 64**, p. 206. Using the derived illustrative inputs from the paper outline, suppose a plant section consumes a fixed base load of 1,000 kWh per shift plus 2.0 kWh of variable process energy per good garment. [S44] At 250 good garments per shift, total energy is $1,000 + (250 \times 2.0) = 1,500\text{ kWh}$, or 6.00 kWh per garment. At 500 good garments, intensity drops to 4.00 kWh per garment; at 750 good garments, it is 3.33 kWh per garment; and at 1,000 good garments, total energy is $3,000\text{ kWh}$, or 3.00 kWh per garment. [S44]

EXHIBIT 64 / KWH PER GOOD GARMENT

Base load changes energy per garment without an efficiency gain



DERIVED [S44] Derived with illustrative inputs using the UNIDO base-load mechanism (S44): fixed shift base load of 1,000 kWh plus variable process energy of 2.0 kWh per good garment. Across 250, 500, 750 and 1,000 good garments, total energy intensity falls from 6.00 to 4.00, 3.33 and 3.00 kWh per garment purely from spreading the fixed 1,000 kWh base load, while variable process energy remains flat at 2.00 kWh per garment.

As **Exhibit 64**, p. 206 shows, moving from 500 to 1,000 good garments per shift cuts total energy per garment by 25 per cent (from 4.00 to 3.00 kWh) without changing a motor, insulating a pipe or sealing an air leak. [S44] Diluting the 1,000 kWh base load over 1,000 garments saves 1.00 kWh of electricity cost and carbon emissions per garment relative to running two separate shifts at 500 garments each. [S16] [S44] Yet mistaking volume dilution for technical efficiency causes management to overlook the separate savings available from lowering the 1,000 kWh base load or the 2.00 kWh variable draw. [S43] [S44]

13.14 LINEAR REGRESSION SEPARATES UTILISATION GAINS FROM TECHNICAL EFFICIENCY

To prevent denominator confusion in monthly reviews, GFT applies the linear energy-volume model from UNIDO practice: [S44]

$$E_{\text{total}} = E_{\text{base}} + b \cdot G_{\text{std}}$$

Here, E_{total} is metered energy consumption, E_{base} is fixed non-process base load, b is marginal energy per unit, and G_{std} is good output normalised by style work content (earned standard hours). [S13] [S16] [S44] Tracking E_{base}, b and G_{std} separately assigns ownership to production supervision (diluting E_{base} over higher daytime G_{std}), facilities maintenance (cutting E_{base} by isolating idle compressor loops, zoning lighting and insulating steam headers) and process engineering (reducing b through servo drives, condensate recovery and fewer rework passes). [S02] [S04] [S16] [S43] [S44]

13.15

Efficiency should precede additional energy capacity

13.16 OVERSIZING RENEWABLE AND BACKUP SYSTEMS LOCKS IN OPERATIONAL WASTE

Where grid outages disrupt production and medium-voltage tariffs are rising, sponsors look to solar photovoltaics, battery storage and backup generators to protect availability. [S34] [S35] [S1302] However, sizing a solar array, battery bank or generator directly from the utility bills of an unoptimised plant is a costly error. UNIDO's industrial decarbonisation case study of Lotus Garments in Egypt states the rule directly: a plant must optimise its energy-management system through efficiency measures before investing in renewable applications. [S43]

Every kilowatt of avoidable base load (unsealed air mains, uninsulated steam pipes, or twenty lines running at 35 per cent efficiency when twelve balanced lines at 60 per cent could deliver the same good output) inflates peak demand and daily consumption. [S15] [S43] [S44] Sizing a solar-plus-storage microgrid before closing those operational and thermal losses forces the investor to buy solar panels, inverters and batteries simply to power air leaks, idle motors and rework loops. [S04] [S43] [S44] Closing production and energy losses first reshapes infrastructure sizing in four ways:

1. **Lower peak demand reduces inverter and generator ratings:** Balancing lines and staggering start-ups trims peak kW draw, shrinking generator and inverter kVA ratings and monthly subscribed demand. [S34] [S43]
2. **Higher daytime throughput aligns load with solar generation:** Closing OEE losses during the eight-hour daytime shift avoids evening overtime, allowing rooftop solar photovoltaics to serve the load directly without cycling batteries or buying peak-tariff grid power. [R16] [S04] [S34] [S41] [S43]
3. **Reduced base load shrinks battery autonomy requirements:** Isolating non-essential base loads and consolidating work onto balanced lines reduces the battery storage needed to ride through a two-hour outage. [S30] [S35] [S44]
4. **First-pass quality eliminates double-energy garments:** Raising first-pass yield removes the extra mechanical and thermal energy consumed by unpicking, re-sewing and re-pressing defective pieces. [S04] [S09] [S12] [S43]

> **GFT NOTE: SEQUENCE OPERATIONAL LOSS CLOSURE BEFORE SIZING POWER HARDWARE**
>
> In GFT's Cameroon textile programme, the unit-economics, footprint and solar-storage workflows are linked by a mandatory stage gate. Project teams should not freeze capital specifications for rooftop solar, battery storage or backup generators from raw nameplate machine lists or unadjusted baseline bills. [S43] [S44] First, establish the balanced line count required to meet good demand at realistic efficiency; second, separate essential sewing and cutting loads from reducible base loads; third, execute housekeeping and maintenance fixes on compressed air, lighting and steam; and only then size the hybrid power system around the verified daytime load profile. [S02] [S35] [S43] [S44]

13.17

Investment cases require measured baselines and explicit advice limits

13.18 CASE STUDIES PROVE MECHANISMS RATHER THAN TRANSFERABLE PERCENTAGE TARGETS

Technology vendors and consultants often insert published case-study gains directly into five-year cash-flow projections. Empirical studies cited in this paper confirm that operational interventions work: Company X raised apparel OEE from 42.91 to 52.27 per cent using monitoring devices and digital balancing; process redesign raised output from 1,300 to 2,000 leggings per day with the same resources; the ILO Factory Improvement Toolset raised sewing-room line achievement by 9.49 per cent while cutting WIP and defects by 22 per cent; kanban and single-piece flow in an Ethiopian factory cut WIP by 48.5 per cent and throughput time by 80.3 per cent; Edget Garment raised balance efficiency from 24 to 75 per cent and daily output from 50 to 120 pieces; and TPM in the NIST MEP case raised OEE from 39 to 45 per cent while avoiding US$250,000 in equipment purchases. [S08] [S09] [S10] [S12] [S31] [S37]

Each result is a sourced observation of a mechanism, not a transferable financial guarantee for a line in Douala, Garoua or Dibamba. [R10] [R12] [S03] Published OEE figures do not share a uniform definition across studies, and percentage gains depend on the starting baseline: a plant at 24 per cent balance efficiency has far more recoverable capacity than a line already at 58 per cent efficiency facing fabric or grid constraints. [S03] [S35] [S37]

13.19 SIX BENEFIT STREAMS MUST RECONCILE WITHOUT DOUBLE COUNTING

To build an auditable business case, GFT requires sponsors to reconcile six physical and financial streams in a single evaluation table (**Exhibit 65**, p. 209). Counting the wage savings of headcount reduction while simultaneously counting the margin of extra garments produced by those same operators double-counts recovered labour minutes. [S13] [S1301] Similarly, counting volume-driven kWh-per-garment reductions as technical energy savings while already crediting fixed-overhead absorption on higher volume double-counts base-load dilution. [S34] [S44]

EXHIBIT 65 / VERIFICATION RULES AND COST BOUNDARIES

A utilisation investment case needs six reconciled benefits

Benefit or cost stream	Physical measure	Financial conversion basis	Double-count guard
1. Incremental good output	First-pass and approved garments per shift at constraint	Contribution margin or fixed-cost absorption per good unit	Count only if backed by confirmed buyer orders and material supply
2. Direct labour efficiency	Attended labour minutes per earned standard minute (SMV)	Verified CPM and avoided overtime premium (1.2x base)	Do not count both headcount reduction and volume expansion from same hours
3. Rework and scrap reduction	Defects per hundred units and unpicking minutes logged	Saved repair labour, thread, trim and avoided seconds discount	Exclude repair minutes already credited in net line efficiency
4. Energy and demand savings	Intercept base load (kWh), slope (kWh/SMV) and peak kW	ARSEL MT fixed kW charge, variable kWh rate and diesel avoided	Separate volume-driven base-load dilution from technical efficiency
5. Working-capital release	WIP pieces and throughput time across stable line boundary	Cost of capital on cut-fabric inventory and reduced floor space	One-off cash release on inventory reduction, not a recurring shift saving
6. Intervention and operating cost	Hardware, software, training hours, spares and technician time	Full capital outlay plus recurring licence, calibration and wage uplift	Include ramp dip during changeover and ongoing supervisor time

ILLUSTRATIVE [S08] [S09] [S34] [S44] Illustrative GFT investment-evaluation table showing the six cost and benefit streams that must be reconciled from a measured pilot before capital release. Methodological boundaries follow S08 (maintenance capacity recovery), S09 (apparel OEE monitoring), S34 (two-part medium-voltage tariff) and S44 (base-load separation).

Inspecting **Exhibit 65**, p. 209 shows why disciplined factories stage capital commitments. Stream 1 (incremental good output) dominates when the factory is capacity-constrained and turning away profitable orders, or when higher throughput lets the plant consolidate two underutilised shifts into one well-utilised daytime shift. [R12] [S04] When order volume is fixed by buyer demand, the benefit must instead be captured in Stream 2 (avoided overtime premiums), Stream 3 (lower scrap and rework), Stream 4 (shorter operating hours reducing base load) and Stream 5 (lower WIP working capital), net of Stream 6 intervention costs. [R16] [S02] [S08] [S12] [S31] [S40] [S44]

13.20 SENSITIVITY BANDS AND STAGED GATES PROTECT CAPITAL ALLOCATION

Because greenfield and turnaround lines face uncertainty in learning speed, turnover, grid stability and order mix, GFT tests every utilisation investment across three scenarios before releasing funds: [S18] [S35] [S39]

- **Conservative downside case:** assumes operator learning progresses at half the rate of published studies, first-year turnover requires continuous replacement training, grid outages match worst-quarter frequency and style changes shorten runs. [S18] [S35] [S39]

- **Measured pilot baseline case:** uses the actual availability, performance, quality, SMV efficiency and kWh-per-standard-hour coefficients recorded during a controlled four-to-eight-week trial on a single pilot line. [S04] [S09] [S13] [S44]
- **Target stabilised case:** reflects the unit cost achievable once standard work, hourly balancing, autonomous maintenance and pull release have run across multiple style changeovers without regression in first-pass yield or attendance. [S12] [S24] [S26] [S40]

SCOPE OF OPERATING ANALYSIS AND EXPLICIT ADVICE LIMITS

This white paper and the associated GFT interactive tools provide industrial-engineering and operational analysis. They do not constitute investment, financial, legal, accounting or tax advice. [R16] [S33] [S34] Statutory wage rates, overtime premiums, labour-code provisions, electricity tariff schedules, customs duties and corporate tax rules in Cameroon and other jurisdictions are subject to regulatory revision, administrative interpretation and contract-specific terms. [R14] [S33] [S34] [S1302] Every illustrative calculation and derived exhibit in this chapter demonstrates an analytical method from disclosed inputs and must be replaced with audited site data, verified supplier quotations and qualified local legal, tax and financial review before any capital commitment, employment contract or commercial pricing decision is made.

By binding financial projections to physical loss closure, the sponsor closes the loop between the sewing floor and the boardroom. Only when operational discipline reduces lost capacity at the constraint, lifts earned standard minutes per attended hour, eliminates rework loops, shrinks waiting inventory and trims wasted base-load kilowatts does unit cost genuinely fall. [S04] [S13] [S30] [S44] Chapter 14 now translates this technical and economic discipline into a four-phase implementation roadmap, defining the sequence of gates, owners and scorecard measures needed to build a learning garment line from the first shift.

A dashboard score pays neither wages nor power bills; unit cost falls only when closed losses leave the factory as good garments.

CHAPTER SOURCE NOTES

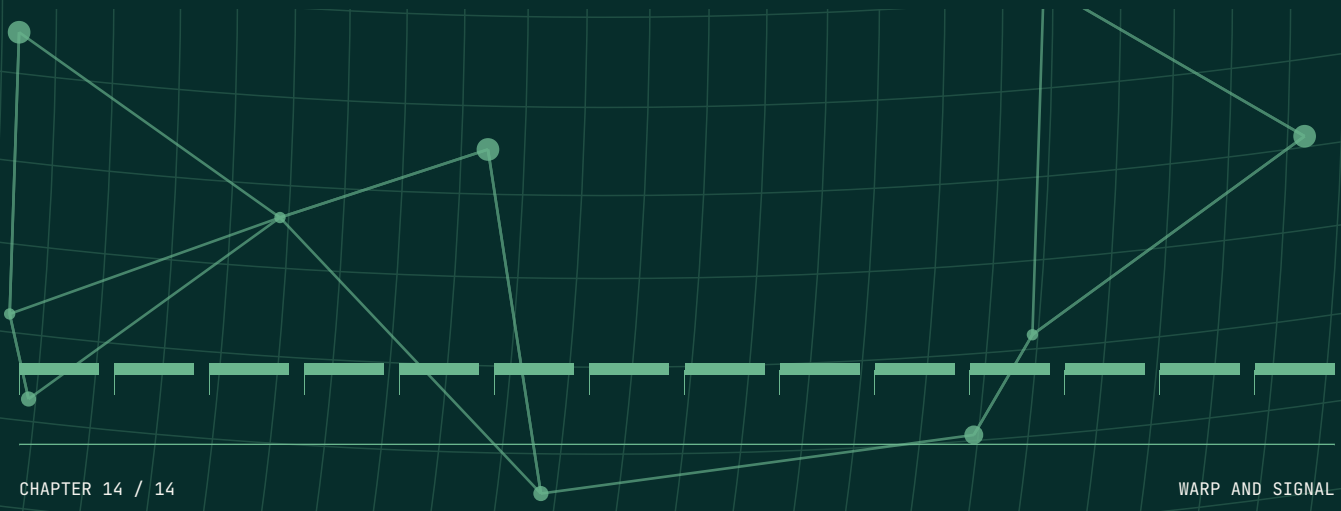
S04 MDPI, Applied Sciences. 2020-09-17.
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R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.
R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.
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R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.
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R17 just-style. Publication date unrecorded; inherited source-text check.
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S06 IEEE, IEEE Transactions on Semiconductor Manufacturing. 2005-02-28.
S08 NIST Manufacturing Extension Partnership. 2022-10-04.
S16 MDPI, Energies. 2019-07-19.
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S36 World Bank, Development Research Group. 2023.
S19 MDPI, Applied Sciences. 2020-04-29.
S10 MDPI, Engineering Proceedings. 2024-10-21.
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S26 Lean Enterprise Institute. 2020-07-02.

14

A gated roadmap turns the first line into a learning system

Release the next commitment only when a measured trial shows that good throughput, safe work and controlled flow survive ordinary operating conditions.



CHAPTER 14
DECISION TEST

Release the next commitment only when a measured trial shows that good throughput, safe work and controlled flow survive ordinary operating conditions.

GFT recommends building a learning line through evidence gates. Agree the measurement contract, stabilise work at the constraint, control release and changeover, demonstrate the people and power envelope, and then automate decisions that already have owners. Funding should follow an accepted operating result. A promising calculation, an installed device and an attractive dashboard are useful intermediate outputs, but each needs a separate acceptance test before it justifies expansion.

This chapter converts the preceding analysis into a proposed management routine. It does not report a completed GFT factory trial. The sequence, roles and acceptance rules below are recommendations for a sponsor to adapt before commissioning. Illustrative exhibits show how the routine could work; their schedules and quantities are neither commitments nor forecasts. The decision is whether the next step is justified by evidence from the line, including evidence about quality, people, energy and unfinished work.

14.1

First, freeze definitions and capture the baseline

The baseline gate should establish whether the factory can reproduce its own account of a shift. This requirement follows a real measurement problem: NIST's monitoring workshop report describes differing OEE definitions and calculations. A sponsor should therefore ask what each measure includes before accepting a comparison between lines or periods. [S03]

GFT recommends a signed measurement dictionary owned jointly by production, quality and industrial engineering. It should identify the line boundary, style, operation bulletin, reporting interval, time exclusions and responsible recorder. Define good output at an explicit acceptance point. Separate first-pass acceptance from eventual acceptance after repair. Define how reworked garments re-enter the record so they cannot earn output twice. Keep rejects, repair activity and goods awaiting judgement visible even when the headline output measure excludes them.

Declare planned production time before the shift starts. Record revisions with a reason and an approver rather than silently changing the denominator after an interruption. Distinguish the event that stopped production from the department expected to resolve it. An outage, a missing component and an equipment breakdown may all stop sewing, but the proposed response and accountable role differ. Maintain an unresolved category when the cause is unknown; a forced explanation makes the loss tree less credible.

Keep earned standard minutes separate from OEE. The Better Work assessment defines garment standard minute value as the sum of the standards for its constituent operations. GFT recommends retaining the approved standard and its version with every style record, then calculating earned minutes from accepted output under that version. A revised standard should start a visible new comparison series or a disclosed restatement, rather than manufacture an apparent gain. [S13]

Start the capture routine with an hourly line sheet and a shift reconciliation. The proposed sheet records accepted output, first-pass failures, repair movements, downtime by cause, constraint output and WIP by position. Record missing intervals explicitly. Calculate completeness from expected records and usable records, while separately tracking unresolved quantities and causes. A completed form with implausible values is not a clean baseline. The line owner should sample the physical quantities and event times against the sheet before approving the shift.

For the proposed baseline gate, define a representative observation window before collecting the trial data. Include the operating conditions the next commitment must withstand, such as ordinary staffing, replenishment and a style transition. Set acceptable completeness, reconciliation error and unresolved-loss limits in advance, using the decision's sensitivity and measurement capability. There is no universal threshold in this chapter. A missing observation that could reverse the release decision is a reason to hold, even if average completeness looks satisfactory.

The acceptance pack should contain the dictionary, raw sheets, corrections, reconciliation and unresolved questions. Production should demonstrate that another authorised reviewer can reconstruct the published result. If that fails, keep the manual routine, correct the definitions and repeat the baseline. Do not fund broader monitoring simply to accelerate an ambiguous calculation. The first learning outcome is a shared account of what happened, with enough provenance to challenge it.

GFT also recommends recording measurement resolution. A stop observed only at a periodic walk should retain its timing uncertainty rather than acquire a precise duration during transcription. Compare the uncertainty with the improvement being claimed. If plausible recording error could explain the apparent gain, improve the observation method or extend the test. This makes the baseline gate a test of decision usefulness as well as administrative completeness.

14.2

Second, stabilise standard work and the constraint

The next gate should test a feasible operating method at the point limiting good throughput. The Lean Enterprise Institute describes standardised work through takt, work sequence and required in-process inventory, and treats it as a revisable basis for improvement. Its account of constraints also prioritises the limiting link before major expansion. These support a trial sequence, not a guarantee of improvement in a particular garment line. [S26] [S30]

GFT recommends that the industrial engineer and supervisor walk the actual material route with operators and quality staff. Compare observed work with the operation bulletin, machine requirements and skill assignments. Locate persistent queues, starvation and blocking, then check whether the suspected constraint limits accepted output at the line boundary. A queue alone is not sufficient for this proposed gate: it may reflect a temporary replenishment surge, inspection hold or unsuitable release rule. Record the competing explanations before choosing an intervention.

The trial instruction should state the change, its mechanism and its limits. A proposed reallocation must preserve operation precedence, machine suitability, safe reach and demonstrated competence. Name who authorises a reassignment and who can stop it. Retain the prior layout and allocation as a recoverable configuration. Where the proposed balance depends on a specialist operator, test whether the result survives normal cover arrangements before using it as the basis for another line.

Choose the comparison method before looking at the outcome. Use matched style and staffing conditions where practical; otherwise disclose the changes in style complexity, attendance, hours, material quality and interruptions. Retain interval results as well as totals, since a strong finish may conceal an unstable start. GFT recommends recording intervention time and supervisory support separately. A pilot sustained by additional troubleshooting effort may still be promising, but that effort belongs in the scale decision and operating cost.

Set the acceptance test around good throughput sustained within agreed quality and safety conditions. Compare first-pass yield, repair workload, WIP, overtime and operator feedback alongside output. Define what deterioration would trigger a hold before the trial begins. A serious safety concern should stop the affected method immediately; it should not wait for the next commercial review. If output rises while downstream inspection accumulates, the trial has not yet demonstrated a system gain.

The proposed action register in **Exhibit 66**, p. 215 assigns accountability without inventing an organisation chart. The sponsor would appoint these roles and their deputies before the trial. Its entries are an illustrative governance design, not evidence that GFT has delivered the actions.

EXHIBIT 66 / ILLUSTRATIVE RESPONSIBILITY AND ACCEPTANCE REGISTER

Each workstream needs an owner and a hold condition

Workstream	Accountable role	Hold when
Measurement	Line owner	Shift cannot reconcile
Balance	Industrial engineer	Good flow is unstable
Flow and setup	Production manager	WIP ages or yield falls
Quality	Quality lead	Acceptance is unresolved
Maintenance	Maintenance lead	Loss closure is unproved
People	Workforce lead	Safe cover is absent
Power	Utilities lead	Restart is untested
Digital	System owner	Records cannot reconcile

ILLUSTRATIVE GFT proposed governance design. Roles are functions to assign locally, not statements about GFT staffing. Each gate needs a signed test and a documented fallback.

The register leaves approval with the sponsor and technical acceptance with the relevant leads. An owner should report a failed condition directly, with the evidence needed to repeat the test. Releasing the next commitment should require explicit closure or a narrower scope that genuinely removes the dependency. Reassigning the issue to a different department does not close it.

Before the trial, GFT recommends stating what would disprove the proposed mechanism. If reallocating work is expected to relieve the constraint, the record should show both the changed station condition and the resulting accepted line output. If the station improves while output remains unchanged, investigate the next limiting condition. That finding may justify another bounded trial, but it does not justify recognising the original forecast as an achieved benefit.

14.3

Third, reduce batch and changeover losses together

GFT recommends testing material release and setup as a connected intervention. The Lean Enterprise Institute defines pull through downstream authorisation and describes SMED through separating work that requires stopped equipment from preparation that can happen while equipment runs. These mechanisms suggest what to observe. They do not establish an appropriate batch size or a safe setup duration for the proposed line. [S24] [S25]

The production planner should begin by mapping the release signal, its permitted quantity and the point where it expires. Make clear who may authorise additional work when a downstream operation stops. Include inspection holds and repair routes in the design. Otherwise a nominal WIP limit can be met merely by moving unfinished work into an uncounted area. GFT recommends a physical route check at shift handover so the recorded boundary remains the boundary used on the floor.

Trial smaller transfer batches with an explicit protection rule for the constraint. Observe how often it waits for usable work, whether handling effort changes, and whether the quality team receives earlier information. Measure WIP age as well as quantity. A smaller queue containing very old material needs investigation even if the total looks improved. Record the time between making a defect and identifying it; this tests whether the proposed flow change actually shortens the quality feedback loop.

For changeovers, define the clock from the last accepted garment of the outgoing style to the first accepted garment of the incoming style under the agreed checking method. Retain the subsequent stabilisation period separately, so a single successful sample does not hide a difficult restart. List preparation tasks, material checks, tooling, instructions and competence checks. Decide which tasks can move outside stopped time without transferring risk to an operator or leaving unrecorded work elsewhere.

Little's Law should be a reconciliation aid after stability has been established. MIT's lean glossary explicitly limits its direct application to long-run averages of stable systems. GFT therefore recommends pairing average WIP, average accepted throughput and average throughput time over the same boundary and compatible

period. During ramp-up or deliberate inventory clearance, use direct age and travel observations; do not present a ratio from a changing queue as a validated delivery promise. [S22]

> **WORKED EXAMPLE**
>
> An illustrative stable-boundary case assumes average WIP of 320 garments and accepted throughput of 80 garments per hour. Average throughput time is then 320 / 80 = 4 hours. A proposed trial assumes WIP falls to 240 garments while accepted throughput stays at 80 garments per hour, implying 240 / 80 = 3 hours. These are assumed inputs demonstrating the stable-system relationship, not a measured reduction or a promise for a new factory. [S22]
>
> The illustrative gate would still inspect traced garment travel times, first-pass quality, constraint starvation and missing movements. If the trial merely empties the starting queue, the shorter ratio cannot establish a repeatable operating state. The owner should continue observation under replenishment and disclose any boundary change before requesting scale.

Accept the flow intervention only when the smaller release pattern and the revised setup method work together under the intended mix. If upstream work becomes smoother while the constraint starves, revise the protection rule. If setup improves while repairs grow, reopen quality acceptance. Keep the previous release pattern available during the trial, but record each fallback activation and its cause. An intervention requiring frequent emergency overrides remains conditional even when its average output improves.

Preparation moved outside stopped time should remain in the labour record. GFT recommends showing who performs it, when it occurs and what other work is displaced. A shorter changeover clock can coexist with greater total effort or an unworkable overlap between styles. The release decision should therefore reconcile stopped time, preparation time and staffing coverage, then retain the revised preparation instruction with the approved operating method.

14.4

Fourth, build the people and power envelope

People and power are prerequisites throughout the sequence. This gate consolidates their evidence before replication; it does not postpone safe work or electrical protection until after a productivity trial. Better Work's Ethiopia report records factory-reported improvements in line performance and absenteeism following supervisor training. The scope is a programme report from Ethiopia, not a measured outcome or a transferable effect size for Cameroon. [S40]

GFT recommends treating supervisory capability as a demonstrated operating skill. Ask the supervisor to reconcile a shift, recognise abnormal WIP, obtain quality support and manage a safe restart. Observe the deputy performing the same tasks. Classroom attendance alone should not release scale. Include operator explanations in the acceptance review: the person doing the work should understand the standard, the defect criteria and the route for raising an unsafe or infeasible instruction without losing the issue in the reporting chain.

Create a coverage map for operations whose absence could stop good throughput. Record demonstrated competence, training in progress and unavailable cover separately. Trial ordinary breaks, authorised leave and expected absence patterns through planned cover arrangements. GFT recommends funding cross-training time within the operating plan rather than assuming it occurs between full production assignments. When output depends on intensive coaching, show the coaching requirement and the expected path to independent work instead of counting the current output as settled capacity.

Ergonomic acceptance needs its own evidence. The opened Ethiopian workstation study identifies health risks and assesses discomfort in sewing work; it does not establish that a proposed workstation in Cameroon is safe. GFT recommends a local review of posture, reach, task repetition, handling and recovery, informed by operator feedback and competent assessment. A trial should retain unresolved findings and their corrective owners. A faster cycle should be rejected where it relies on an unacceptable working method. [S38]

Power evidence needs an equally explicit boundary. IFC's Cameroon diagnostic describes limited and unreliable electricity supply. This dated national assessment is a reason to measure the site, not a substitute for a local outage record. GFT recommends logging interruption start, affected operations, supply recovery, safe restart and restored accepted throughput separately. A restored socket voltage and a line producing acceptable garments are distinct events, with potentially different owners and elapsed times. [S35]

Test the response to an interruption through an approved safe procedure. Account for unfinished garments, machine settings, quality checks, data capture and material release during recovery. Utilities and maintenance leads should establish the safe operating conditions; production should demonstrate the restart routine inside those conditions. The trial should never create an unsafe outage merely to complete a checklist. Where a physical test is inappropriate, document the limitation and use a reviewed simulation until an authorised test becomes possible.

The scale gate should combine skill cover, attendance stability, reasonable working arrangements, closed ergonomic findings and measured power recovery. Thresholds belong to the specific operation and must be set before acceptance. If cover remains unavailable, restrict the scope or schedule rather than claim capacity that assumes permanent exceptional effort. If power performance is unresolved, retain a conditional capacity range and fund the measurement needed to narrow it. These recommendations require local safety and labour review where applicable; they are not legal advice.

Assign these supporting actions when the first pilot budget is prepared. The workforce lead should identify paid learning time and accessible reporting routes; the utilities lead should identify the permitted recovery procedure and competent support. Their evidence may mature alongside the production trial, but the sponsor should not release an operating scope whose essential support has neither an owner nor an authorised resource allocation.

14.5

Fifth, add digital monitoring where it shortens a decision

Digital support should enter through a named operating decision. The apparel study by Koç and Eryürük reports Company X OEE increasing from 42.91 percent to 52.27 percent with monitoring devices and digital balancing. This is case evidence for investigating the mechanism. It is not a GFT result, an isolated causal estimate for software, or an acceptance target for another factory. [S09]

GFT recommends writing a decision brief before selecting a sensor or platform. Name the event to detect, the current delay, the person who responds and the action available. A useful initial case might be a constraint stop that the supervisor currently discovers too late to recover. The acceptance question is whether earlier information changes the response and improves accepted output within the quality and people limits. A screen that reports the same unresolved event more quickly has not completed that test.

Run manual and digital records in parallel for a bounded qualification window. Use shared definitions and event identifiers. Compare physical counts, stop durations, reason codes and quality dispositions at the same boundary. Distinguish event time, entry time and synchronisation time, especially when devices reconnect after an interruption. Set limits on clock error, duplicate events and unresolved disagreement from the decision's sensitivity. Investigate disagreement rather than automatically declaring the electronic record correct.

Qualification should include continuity. Demonstrate how production records events when connectivity fails, who authorises manual corrections and how the merged history avoids double counting. Retain the original entry and a correction trail. Restrict access to identifiable workforce records to authorised roles and a defined purpose. The proposed system owner should demonstrate recovery from a controlled test condition and explain what remains unavailable during recovery. If local record keeping cannot continue, the system is not ready to become the sole reporting route.

Measure the whole alert cycle: detection, acknowledgement, action and verified restoration. Define when an alert expires, escalates or closes. Acknowledgement should not be treated as repair. GFT recommends reviewing missed events and non-actionable alerts alongside average response time. An alert system that consumes supervisory attention without changing a feasible action should be simplified or withdrawn. Keep the manual fallback in the operating instructions until the sponsor has accepted both the routine operation and the recovery evidence.

The proposed tools should share approved inputs while retaining distinct decisions. Use the OEE and line tool to locate losses, the balancing tool to test feasible assignments, the ramp planner to expose learning and cover assumptions, and the maturity tool to record evidence readiness. This is a recommended integration contract, not a claim that those tools have been commissioned together. Preserve input versions and trial identifiers so the sponsor can trace a suggested action back to the relevant operating record.

Digital spending should therefore pass a separate gate even after a successful manual line trial. The sponsor should see reconciliation, demonstrated response, recovery behaviour, support effort and recurring cost. If those conditions fail, retain the proven manual method while repairing the digital use case. If they pass, extend the qualified decision to a comparable scope and repeat the boundary checks. The learning line earns automation by showing which information changes its next action.

Keep automated recommendations advisory until the receiving role has qualified the proposed action. GFT recommends requiring explicit approval for a changed release limit, task allocation or production standard during qualification. Record rejected suggestions and the reason for rejection. This gives the system owner useful evidence about missing constraints, while keeping accountability with the operating role that understands the physical consequences of the change.

14.6

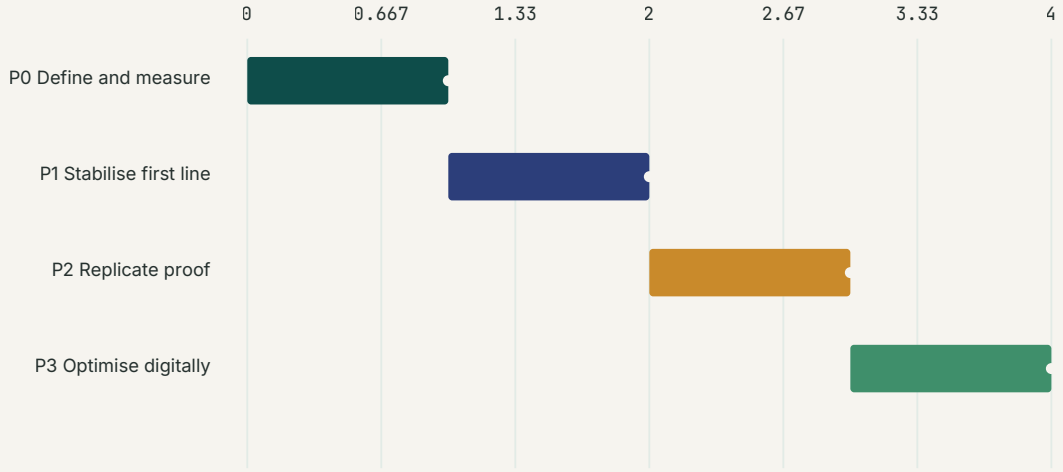
The roadmap releases spending against evidence

GFT proposes an illustrative roadmap with Phase 0 for definitions and baseline, Phase 1 for a stable first line, Phase 2 for proven replication, and Phase 3 for mature digital optimisation. The labels indicate order, not elapsed time. Manual trial monitoring belongs in the earlier phases; broader digital optimisation follows qualification. People, safety, quality and power conditions apply across the entire sequence rather than sitting in a late work package.

The roadmap in **Exhibit 67**, p. 221 uses an illustrative ordinal planning axis. Equal graphic widths do not mean equal durations. The sponsor would set dates only after reviewing the remaining dependencies, authorised resources and representative trial window. Gate evidence determines progression even where preparatory work can safely overlap.

EXHIBIT 67 / ILLUSTRATIVE ORDINAL STAGE POSITION, NOT ELAPSED TIME

Evidence gates separate baseline, first line, replication and optimisation



ILLUSTRATIVE GFT proposed sequence. Positions 0 to 4 encode order only. Equal widths imply neither equal duration nor a committed schedule. People, safety, quality and power are continuous entry conditions.

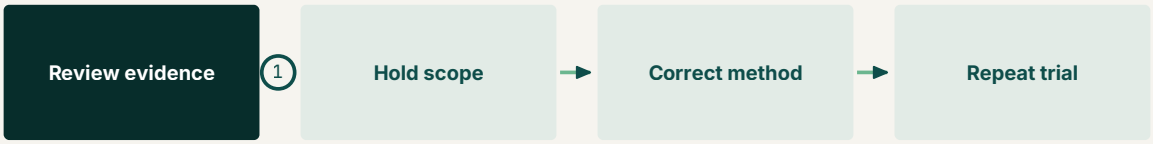
Before committing funds, the sponsor should approve a gate card describing the next scope, accountable line owner, technical acceptance leads, test conditions, release criteria and fallback. Separate expenditure already incurred from expenditure awaiting release. A supplier installation milestone may justify a contractual payment under an agreed contract, but it does not by itself establish an operating benefit. Keep contractual obligations and operational acceptance visible as distinct decisions so neither is represented as evidence of the other.

Use a proposed decision rule of release, hold or stop. Release requires sufficient evidence for the defined next scope and closure of the relevant entry conditions. Hold applies when evidence is incomplete, contradictory or unrepresentative and a bounded repeat can resolve it. Stop applies where the method is unsafe, the mechanism is disproved or the required conditions cannot be achieved within the authorised scope. Preserve the reason and the data behind each decision. A hold should not quietly become approval through inactivity.

The decision flow in **Exhibit 68**, p. 222 makes the hold and repeat route explicit. Release and stop remain separate decisions as described above. It is an illustrative control design rather than an automated approval system. Technical reviewers should retain their ability to reject an inference even when the submitted fields are complete.

EXHIBIT 68 / ILLUSTRATIVE DECISION SEQUENCE

A failed gate returns to correction before expansion



1. Incomplete

ILLUSTRATIVE Illustrative hold route only. Release and stop are separate decisions described in the chapter. A hold requires correction and a fresh test; unsafe methods stop immediately.

GFT NOTE

Fund the next answerable question. At each gate, require the line owner to explain what changed, how the record proves it, what could reverse the conclusion and how the line returns to a safe prior method. Protect the measurement and training effort needed to answer those questions. A smaller accepted operating scope is more useful than a larger commitment whose essential conditions remain unresolved.

Replication should preserve the tested mechanism while reopening local assumptions. Reuse the dictionary, trial instruction and acceptance template, then verify the receiving line's machine mix, skill cover, product requirements and utilities. Do not transfer the pilot's output target without this review. The receiving line owner should accept responsibility for the evidence rather than inherit the pilot team's sign-off. Expansion becomes a series of inspectable decisions, with a clear limit on what each accepted trial actually establishes.

Retain the evidence bundle after release. GFT recommends preserving the approved input versions, raw observations, exclusions, calculations, reviewer comments and decision record together. Record any unresolved condition with its expiry and the event that would reopen acceptance. A new style, changed staffing pattern or different power arrangement may require a fresh check. The previous approval remains evidence for its original scope, rather than becoming indefinite authority for materially different conditions.

14.7

The scorecard must prove system value and decent work

The proposed scorecard should reconcile system outcomes with their drivers. Good output and constraint throughput show whether the line delivers. OEE components and earned standard minutes explain different aspects of conversion. WIP, age and throughput time reveal whether unfinished work is accumulating. GFT recommends

keeping these measures connected in the review, while preserving their separate units and denominators. No single composite score should authorise expansion when an important underlying condition has failed.

The scorecard in **Exhibit 69**, p. 223 is an illustrative cadence proposal. Its daily review supports corrective action, its weekly review tests the operating method, and its monthly review tests persistence and the next commitment. The sponsor should adapt the cadence to the actual decision delay and reporting burden, without losing the raw evidence needed to investigate an adverse result.

EXHIBIT 69 / ILLUSTRATIVE REVIEW CADENCE AND EVIDENCE CONTRACT

The review joins output, flow, resource use and working conditions

Cadence	Evidence	Decision
Daily	Good units; earned minutes	Correct delivery loss
Daily	Constraint output; WIP age	Adjust release and cover
Daily	First-pass yield; repair	Contain quality loss
Daily	Downtime causes; restart	Assign recovery action
Weekly	OEE factors; time base	Test loss closure
Weekly	Flow time; changeover	Revise standard method
Weekly	Attendance; skill; overtime	Test attainable cover
Monthly	Cost; energy per good unit	Reconcile benefit
Monthly	Ergonomics; worker feedback	Accept or hold scale

ILLUSTRATIVE Proposed management routine, not observed factory practice. Thresholds must be agreed locally. Keep consistent boundaries and preserve style and standard versions.

Keep resource claims separate from denominator effects. UNIDO explains that greater production can reduce energy per unit under a substantial base load without an underlying efficiency improvement. GFT recommends reviewing total energy, production conditions and good output together, then attributing any normalised saving to a disclosed baseline method. A falling ratio alone should not certify either technical energy savings or reduced environmental impact. [S44]

The benefit bridge in **Exhibit 70**, p. 224 demonstrates the same discipline for production. Its illustrative inputs assume a fixed planned-time ideal capacity of 1,000 garments, initial availability of 0.80, performance of 0.90 and quality of 35/36. Initial good output is 1,000 × 0.80 × 0.90 x (35/36) = 700 garments. These assumptions demonstrate the component structure discussed by NIST, with no observed factory result implied. [S03]

In the illustrative trial, availability rises to 156/175, performance to 246/260, and quality falls to 350/369. Hold the original performance and quality constant while changing availability: output becomes 780 garments, an increment of 80. Change performance next while keeping original quality: output becomes 820, an increment

of 40. Apply final quality: output becomes 800, a loss of 20. Thus 700 + 80 + 40 - 20 = 800, and the full product is also 1,000 x (156/175) x (246/260) x (350/369) = 800. The attribution order is a declared arithmetic convention, not causal proof. [S03]

EXHIBIT 70 / ILLUSTRATIVE GOOD GARMENTS PER EQUAL PLANNED-TIME WINDOW

A reconciled output gain can still conceal a quality failure



ILLUSTRATIVE [S03] All inputs are assumed. Ideal capacity 1000; baseline A=0.80, P=0.90, Q=35/36 gives 700. Trial A=156/175, P=246/260, Q=350/369 gives 800. Sequential substitution A then P then Q produces levels 700, 780, 820, 800. Order changes attribution, not closing output. No measured benefit or investment forecast.

The illustrative bridge passes arithmetic reconciliation but would fail a pre-agreed condition prohibiting quality deterioration. The sponsor should hold scale and investigate the loss despite higher good output. In an actual trial, the finance reviewer would also check saleability, repair effort, labour time, maintenance, energy and inventory movements before recognising a commercial benefit. Production arithmetic does not establish cash generation. This chapter provides operating analysis, not investment, legal or tax advice.

The monthly review should finish with a decision record, not just a scorecard. State which gains persisted, which conditions changed, who bore additional work and which question remains unanswered. Include buyer acceptance, worker feedback and utilities evidence where they could alter the conclusion. Retain adverse observations

alongside successful intervals. The first line becomes a learning system when the next standard, allocation and commitment can be traced to that record, and when an inconvenient result is allowed to change the plan.

The next commitment should be earned by the last measured result.

CHAPTER SOURCE NOTES

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Stable definitions make comparisons useful.

Allowance

Time added to observed work for defined recovery, unavoidable delay and other policy purposes under a stated work-measurement method.

Andon

A visual or audible signal that calls attention to an abnormality and requests a defined response.

Availability

The OEE component comparing operating time with the planned production-time base after downtime losses.

Balance efficiency

A measure of how effectively assigned work content uses the stations and governing cycle of a line.

Balance loss

The share of line capacity left unused because work is unevenly allocated across stations.

Bottleneck

The operation or resource that currently limits the throughput of the whole system.

Bundle system

A production method that moves a group of garment components together between operations.

Capacity utilisation

Actual output relative to a declared capacity basis, with the time, product and quality boundaries stated.

Changeover

The work and elapsed time required to move from one product or style to another, bounded here from last good piece to first good piece.

Constraint

A limiting operation, skill, machine, material supply, power condition or policy that governs system output.

Cycle time

The time associated with completing a job or cycle at a workstation, defined consistently for the analysis.

Downtime

Planned production time lost to a recorded stop, with cause and ownership assigned.

Earned standard minutes

Good output multiplied by its standard minute value, used to compare labour productivity across work content.

First-pass yield

The proportion of units completed correctly without rework or repair at the defined inspection boundary.

Flow

The movement of work through operations with controlled release, limited queues and short feedback on abnormalities.

Good output

Units that meet the stated quality requirement and are available for the next authorised stage or delivery.

Ideal cycle time

The reference shortest cycle used in an OEE performance calculation, with its basis explicitly documented.

Industrial engineering

The discipline of designing and improving work methods, capacity, layout, allocation and production control.

Jidoka

Quality at source through detection, stopping or containment of abnormalities and response to their causes.

Kaizen

Incremental improvement carried out through repeated observation, testing and standardisation.

Kanban

A signal that authorises defined production or movement in a pull system.

Learning curve

The observed change in operator or line performance as experience accumulates.

Line balancing

The allocation of operations and resources across workstations to achieve feasible flow at the required rhythm.

Line efficiency

In this paper's labour context, earned standard minutes divided by attended labour minutes, with any alternative definition separately declared.

Little's Law

The stable-system relationship in which average WIP equals average throughput rate multiplied by average throughput time.

Micro-stop

A brief interruption that may not stop a full shift report but still reduces effective performance.

Nameplate capacity

The stated capacity of a machine or line under its design assumptions, before actual operating losses.

Operation bulletin

The ordered list of operations, methods, times, machines and skills required to make a garment.

Overall equipment effectiveness

The product of availability, performance and quality under a declared measurement protocol.

Performance

The OEE component comparing actual production rate with the declared ideal rate during operating time.

Pitch time

The governing line rhythm used in a specific balancing model, not automatically interchangeable with takt or station cycle.

Planned production time

The scheduled time intentionally allocated to production after stated non-production exclusions.

Precedence constraint

A required sequence relationship that limits where operations can be assigned or combined.

Pull production

Production controlled by downstream authorisation rather than upstream output for its own sake.

Quality rate

The OEE component representing good units relative to total units started or produced under the chosen boundary.

Right first time

Completion without defect, rework or repair at the defined process step.

Single-piece flow

Movement of one unit at a time between adjacent operations, with no inter-operator bundle inventory in the strict definition.

SMED

A changeover-reduction method that separates internal and external setup, converts work where possible and simplifies the remainder.

Standard minute value

The standard time assigned to a defined garment operation or to the sum of operations needed for a garment.

Standard work

The documented current method, sequence, timing and in-process stock used as the baseline for operation and improvement.

Takt time

Available production time divided by required good demand over the same period.

Throughput

The rate at which the whole system produces good output over a stated period.

Throughput time

Elapsed time for a unit to cross the defined production boundary, including processing and waiting.

Total productive maintenance

An organisation-wide maintenance and loss-elimination programme involving equipment condition, operation and improvement.

Work in progress

Started units or components within the production boundary that are not yet finished good output.

Yamazumi

A visual comparison of work content by station against the governing cycle or rhythm.

Follow the terms back to their context.

Page references point to occurrences in chapter prose. When a term does not occur in a chapter, its glossary definition is indexed.

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Production is the warp. Measurement is the weft.

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