TRAINING MODULE

C2C Variation & Buffer

Why the average cycle time lies to you

A working module for engineers with 1–2 years on the floor. By the end you will be able to calculate cycle-to-cycle variation by hand, size the buffer it forces, and diagnose why a station won't repeat consistently.

Grounded in Six Sigma variation thinking (Shewhart, Wheeler) and Goldratt's statistical-fluctuation chapter in The Goal

BEFORE WE START

What You Will Be Able to Do After This Module

1. Explain why two stations with the SAME average cycle time can behave completely differently on the floor.
2. Calculate C2C variation %, cycle range, and max/min cycle time from raw readings, by hand.
3. Size the WIP buffer a station needs to protect the line, using the same formula the software uses.
4. Run a structured investigation into WHY a station's cycle time won't repeat — not just flag that it doesn't.
5. Recognize the two most common mistakes junior IEs make when they only look at the average.

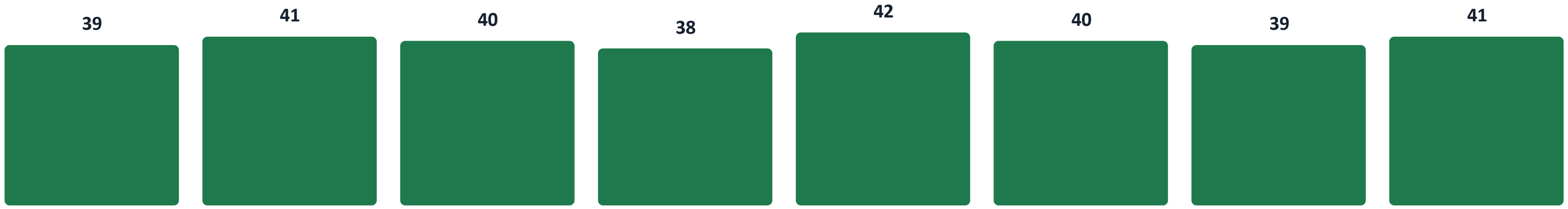
Two Stations, Same Average, Very Different Lines

Both stations below average exactly 40 seconds. Watch what a stopwatch actually records, cycle by cycle:

STATION A

Avg = 40s

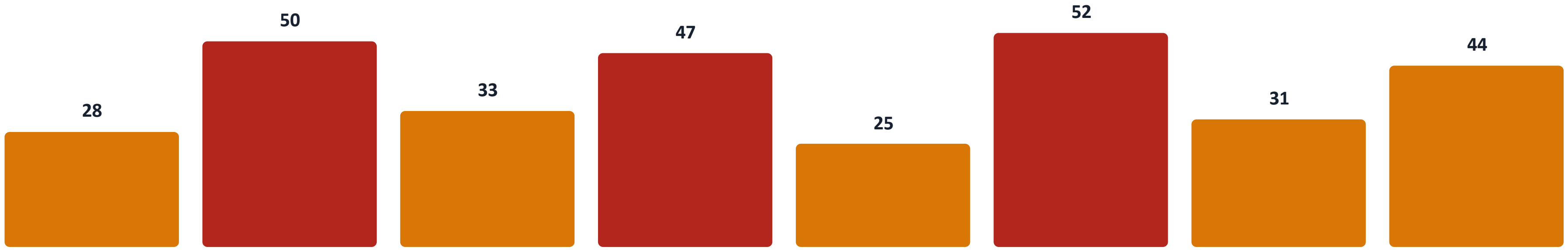
Predictable



STATION B

Avg = 40s

Wildly unstable



The Time & Motion sheet reports “40s” for both. A time study built only on the average would call these two stations identical — they are not remotely the same problem.

THE METRIC

C2C Variation — Definition and Formula

C2C Variation % = (Max Cycle − Min Cycle) ÷ Average Cycle × 100

PLAIN ENGLISH

It measures how far the WORST cycle strayed from the TYPICAL cycle — as a percentage of that typical cycle. A 0% station is a metronome. A 60% station is a coin flip.

WORKED EXAMPLE — STATION B FROM THE LAST SLIDE

Cycles Recorded	Average Cycle	Max Cycle	Min Cycle
28, 50, 33, 47, 25, 52, 31, 44	40.0 s	52 s	25 s

C2C = (52 − 25) ÷ 40 × 100 = 67.5%
Over the tool's own 50% flag threshold for “high C2C” — this station gets investigated, even though its average looks perfectly fine against a 45s Takt.

WHY IT MATTERS

Variation Steals Capacity — Even When the Average Is Fine

In The Goal, Goldratt runs a dice game through a line of stations to prove a point statisticians already knew: random, independent fluctuation at one station does not average out downstream — it accumulates as lost throughput. A 52-second cycle at your Station B doesn't get “cancelled” by the 28-second cycle that follows it; the downstream station still sat idle waiting, or the line still missed Takt for that one unit.

This is the Six Sigma insight too: a process is only “in control” when it's both centered AND stable. Average alone tells you nothing about stability.

THE GOAL

Eliyahu M. Goldratt — the dice-game chapter

THE CONSEQUENCE

Instability Gets Paid for in WIP Buffer

A downstream station can't know, cycle to cycle, whether Station B will hand it work in 25 seconds or 52. The plant's only defense is a buffer of parts sitting in front of it.

Unstable Cycle

Station B swings 25–52s around a 40s average.

→

Downstream Risk

The next station can starve on a slow cycle, or queue up on a fast one.

→

Buffer Absorbs It

A small WIP cushion sized to the swing keeps the next station fed either way.

This buffer is real cost — space, WIP inventory, cash tied up on the floor — sitting there ONLY because the process isn't repeatable. Fix the instability and the buffer requirement shrinks with it. Buffer is a symptom treatment, not a cure.

1

CALCULATION 1

Cycle Range, Max & Min

Once you know Observed CT and C2C%, you can predict the full swing WITHOUT re-timing every cycle.

This is exactly what the software pre-computes for every station in your Production Study.

THE FORMULAS

Cycle Range = Observed CT × (C2C% ÷ 100)

Max Cycle = Observed CT × (1 + C2C% ÷ 200)

Min Cycle = Observed CT × (1 − C2C% ÷ 200)

WORKED EXAMPLE — OBSERVED CT = 40s, C2C = 60%

Metric	Formula Applied	Result
Cycle Range	40 × (60 ÷ 100)	24.0 s
Max Cycle	40 × (1 + 60 ÷ 200)	52.0 s
Min Cycle	40 × (1 − 60 ÷ 200)	28.0 s

45s Takt sits BETWEEN this station's Min (28s) and Max (52s) — meaning some cycles beat Takt comfortably, and some blow past it by 7 full seconds.

2

CALCULATION 2

Buffer Sizing

How many pieces of WIP does this instability actually force you to carry, at minimum?

The software floors this at 3 pieces even for a stable station — a small standing cushion is normal line design, not a red flag on its own.

THE FORMULA

Buffer (pcs) = MAX(3, INT(Cycle Range ÷ Takt) + 1)

WORKED EXAMPLE — CYCLE RANGE = 24s, TAKT = 45s

1. Cycle Range ÷ Takt = 24 ÷ 45 = 0.53
2. INT(0.53) = 0
3. 0 + 1 = 1
4. **MAX(3, 1) = 3 pieces ← the floor wins here**

WHY THE FLOOR OF 3 MATTERS

Even a near-perfectly stable station needs a couple of pieces of cushion in real production — material handling, micro-stoppages, and normal line noise. The floor keeps the formula honest at the low end; it's the HIGH end (large C2C ranges) where buffer size actually becomes a signal worth acting on.

FROM SYMPTOM TO CAUSE

Ten Places High C2C Variation Comes From

A high C2C% is a symptom. The investigation always asks one question: “Why is this method not repeating consistently, cycle to cycle?”

1. SOP exists?
2. SOP followed?
3. Operator variation
4. Shift variation
5. Material variation
6. Tool / fixture variation
7. Machine variation
8. Environment / interruption
9. Waiting / rework
10. Searching / walking / batch effect

HOW TO ACTUALLY INVESTIGATE ONE

The Investigation, Step by Step

1	**FLAG**	Any element with Var% over the 15% stability threshold gets pulled into the investigation — not the whole station, the specific element.
2	**ASK**	Work the root-cause question bank against that element: SOP, operator, material, tool, environment, waiting, searching — in that order.
3	**SOURCE**	State the Source of Variation in one sentence an operator would recognize — not a category label.
4	**CONTROL**	Recommend the Standardization Opportunity and the specific Control that removes it — an SOP line, a fixture, a kitting change.
5	**EXPECT**	State the Expected C2C Reduction — a number to check against, next time this station is re-timed.

Diagnosing Station B — Our 67.5% C2C Station

FLAGGED: 67.5% C2C, cycles ranging 25–52s against a 40s average — element under investigation: "Retrieve fastener from bin."

▲ SOURCE	**SOP followed?**	No — operator free-picks from a mixed bin instead of the kitted sequence the SOP describes.
▲ SOURCE	**Material variation?**	Bin contains 3 fastener sizes mixed together — operator visually sorts before grabbing.
ruled out	**Tool / fixture?**	No dedicated fixture at this station — not the driver here.
ruled out	**Operator variation?**	Same operator across all 8 cycles — rules out shift/operator swap as the cause.

CONTROL: Kit fasteners into single-size, single-cycle pouches upstream. EXPECTED REDUCTION: C2C from 67.5% down toward the plant's normal 10–15% band for a manual pick.

Five Mistakes That Give Junior IEs Away

- ✗ Signing off a station as “fine” because its average CT beats Takt — without ever checking C2C%.
- ✗ Recommending MORE buffer as the fix, instead of investigating why the variation exists in the first place.
- ✗ Stopping at “the operator is inconsistent” — a conclusion, not an investigated root cause.
- ✗ Flagging the whole station instead of the specific element actually driving the swing.
- ✗ Ignoring a high-C2C station that sits comfortably under Takt on average — it can still starve or block its neighbors.

FROM PENCIL-AND-PAPER TO THE SOFTWARE

What the C2C Tools Do For You

Two tools cover this ground — one shows you WHERE the problem is, the other tells you WHY.

C2C Variation & Buffer Analysis

Every station's C2C%, Max/Min/Range, and required buffer — calculated automatically, flagged the moment C2C exceeds 50%, with total buffer WIP and Takt-breach count summarized for the whole line.

C2C Stability Investigation Engine

For every ELEMENT over the 15% threshold, runs the full root-cause question bank — SOP, operator, material, tool, environment — and outputs Source of Variation, Standardization Opportunity, Recommended Control, and Expected C2C Reduction, one diagnostic card per element.

KEY TAKEAWAYS

Recap — Say This Back In Your Own Words

- The average cycle time tells you almost nothing about whether a station is stable.
- C2C% = (Max − Min) ÷ Average × 100. Above 50% is the tool's own flag for "investigate this."
- Instability is paid for in buffer — real WIP, real space, real cash. Buffer treats the symptom, not the cause.
- The investigation targets the SPECIFIC element and asks a structured "why," never stops at "operator inconsistency."

TALK IT THROUGH — 3 QUESTIONS FOR YOUR NEXT LINE WALK

1. Pick a station you'd normally call "fine" because its average beats Takt — what's its actual C2C%?
2. For your highest-C2C station, which ONE element is really driving the swing — not the whole station?
3. If you removed the buffer sitting in front of that station today, what would break first?