📐 VSM Calculation Guide — KAIZEN ACADEMY™

A complete reference of every calculation and formula from *Learning to See* by Mike Rother & John Shook, organized logically with worked examples from the Acme Stamping and TWI Industries case studies.

Part 1 — Foundation: Demand & Tempo

These calculations establish the fundamental rhythm of production. Everything else builds on them.

1.1 Available Working Time

```
Available Time = Total Shift Time − Breaks − Other Non-Working Time
```

Acme Stamping Example *(pp. 58–59)*

Input	Value
Total shift time	8 hours = 28,800 sec
Breaks (2 × 10 min)	1,200 sec
Available time per shift	**28,800 − 1,200 = 27,600 sec**

TWI Industries Example *(p. 46)*

Input	Value
Total shift time	8 hours = 28,800 sec
Breaks (2 × 15 min)	1,800 sec
Available time per shift	**28,800 − 1,800 = 27,000 sec**

1.2 Customer Demand Rate

```
Daily Demand = Monthly Demand ÷ Working Days per Month
```

```
Demand per Shift = Daily Demand ÷ Number of Shifts
```

Acme Stamping Example *(pp. 58–59)*

Step	Calculation	Result
Monthly demand	12,000 LH + 6,400 RH	18,400 pcs/month
Working days		20 days/month
Daily demand	18,400 ÷ 20	**920 pcs/day**
Shifts per day		2

Step	Calculation	Result
Demand per shift	920 ÷ 2	**460 pcs/shift**

TWI Industries *(p. 45)*

Step	Calculation	Result
Monthly demand		24,000 pcs/month
Daily demand	24,000 ÷ 20	**1,200 pcs/day**
Demand per shift	1,200 ÷ 2	**600 pcs/shift**

1.3 Takt Time

```
Takt Time = Available Working Time per Shift ÷ Customer Demand per Shift
```

Takt time synchronizes the pace of production to the pace of sales *(p. 44)*.

Generic Example *(p. 44)*

```
Takt = 27,000 sec ÷ 455 pcs = 59.3 seconds
```

Acme Stamping *(p. 59)*

```
Takt = 27,600 sec ÷ 460 pcs = 60 seconds
```

This means Acme must produce one steering bracket every 60 seconds to match customer demand. This number "includes no time for equipment downtime, changeovers... or for producing scrap" *(p. 59)*.

TWI Industries *(implied, pp. 107–108)*

```
Takt = 27,000 sec ÷ 600 pcs = 45 seconds
```

Part 2 — Current State Analysis

These calculations describe how the value stream performs today.

2.1 Process Data Boxes

Each process on the map records key metrics in a data box *(pp. 21–22)*:

Metric	Abbreviation	What It Means
Cycle Time	C/T	Time between one part and the next coming off the process
Changeover Time	C/O	Time to switch from one product variant to another
Uptime	%	On-demand machine availability
EPE	Every Part Every ___	Measure of production batch size
Number of Operators		People required to run the process
Available Time	sec	Working time per shift minus breaks
Scrap Rate	%	Percentage of defective output

Acme Stamping — All Process Data *(pp. 33–35, 119)*

Process	C/T	C/O	Uptime	Operators	EPE
Stamping (200T press)	1 sec	1 hour	85%	1	2 weeks

Process	C/T	C/O	Uptime	Operators	EPE
Spot Weld #1	39 sec	10 min	100%	1	—
Spot Weld #2	46 sec	10 min	80%	1	—
Assembly #1	62 sec	0	100%	1	—
Assembly #2	40 sec	0	100%	1	—

2.2 Process Capacity

```
Capacity = (Available Time ÷ Cycle Time) × Uptime %
```

This is implicit on p. 22: "available work time divided by cycle time multiplied by uptime percent is a measure of current process capacity, if no changeovers are made."

Acme Stamping Examples:

Process	Available	C/T	Uptime	Capacity
Stamping	27,600 sec	1 sec	85%	`(27,600 ÷ 1) × 0.85 = 23,460 pcs`
Weld #1	27,600 sec	39 sec	100%	`(27,600 ÷ 39) × 1.00 = 708 pcs`
Weld #2	27,600 sec	46 sec	80%	`(27,600 ÷ 46) × 0.80 = 480 pcs`
Assembly #1	27,600 sec	62 sec	100%	`(27,600 ÷ 62) × 1.00 = 445 pcs`
Assembly #2	27,600 sec	40 sec	100%	`(27,600 ÷ 40) × 1.00 = 690 pcs`

Assembly #1 is the bottleneck at 445 pcs/shift vs. 460 demand — a gap that must be addressed.

2.3 Inventory Conversion: Pieces to Days

```
Inventory (days) = Inventory Quantity ÷ Daily Customer Demand
```

"Lead times (in days) for each inventory triangle are calculated as follows: inventory quantity divided by the daily customer requirement" *(p. 35)*.

Acme Stamping — All Inventory Points *(pp. 33–35)*

Daily customer requirement = **920 pcs/day**

Location	LH Pcs	RH Pcs	Total	Calculation	Days
Raw coils	—	—	—	(observed)	**5.0**
After Stamping	4,600	2,400	7,000	7,000 ÷ 920	**7.6**
After Weld #1	1,100	600	1,700	1,700 ÷ 920	**1.8**
After Weld #2	1,600	850	2,450	2,450 ÷ 920	**2.7**
After Assembly #1	1,200	640	1,840	1,840 ÷ 920	**2.0**
Finished Goods	2,700	1,440	4,140	4,140 ÷ 920	**4.5**

2.4 Production Lead Time

```
Production Lead Time = Sum of all inventory days across the value stream
```

Acme Current State Timeline *(p. 35)*

Coils	Stamped	Post-W1	Post-W2	Post-A1	FG	**Total**
5.0	7.6	1.8	2.7	2.0	4.5	**23.6 days**

2.5 Total Value-Added Time

```
VA Time = Sum of all process cycle times
```

Acme: `1 + 39 + 46 + 62 + 40 = 188 seconds`

2.6 VA % and NVA % — The "Shock" Ratio

```
VA % = Total Processing Time ÷ (Production Lead Time × 86,400 sec/day)
```

```
NVA % = 1 − VA %
```

This is the central insight of the value stream map — how little of the total lead time is actual processing.

Acme Current State:

`VA% = 188 sec ÷ (23.6 days × 86,400 sec/day) = 188 ÷ 2,038,400 = 0.0092%`

~99.99% of the time is non-value-added. The part sits waiting for 23.6 days but is only being worked on for 188 seconds.

Part 3 — Future State Design

These calculations drive the redesign of the value stream.

3.1 Operators Needed for a Cell

```
Operators Needed = Total Work Content ÷ Takt Time
```

"Dividing the total welding and assembly work content by the takt time" *(p. 63)*.

Acme Weld/Assembly Cell *(pp. 63–64)*

Step	Cycle Time
Weld #1	39 sec
Weld #2	46 sec
Assembly #1	62 sec
Assembly #2	40 sec
Total Work Content	**187 sec**

`Operators = 187 sec ÷ 60 sec takt = 3.12 → 4 operators (round up)`

Four operators would be underutilized. The kaizen target:

```
Max Work per Operator = Takt Time − Buffer (e.g., 4 sec)
```

```
Target Total Work = Operators × Max Work
```

Item	Calculation	Result
Target operators		3
Max work per operator	60 − 4 sec buffer	56 sec
Target total work	3 × 56	**168 sec**
Waste to eliminate	187 − 168	**19 seconds**

TWI Assembly Cell *(p. 108)*

`Operators = 195 sec ÷ 45 sec takt = 4.33 → 5 operators`

3.2 Cycle Time vs. Takt — When C/T Must Be Faster

When a process requires changeovers, it must cycle faster than takt to leave time for setups.

```
Time Remaining = Available Time − (Demand × Actual C/T)
```

```
Changeovers per Shift = Time Remaining ÷ C/O Duration
```

TWI Weld/Deflash *(pp. 107–108)* — Why C/T = 39 sec, not 45 sec takt:

Step	Calculation	Result
Demand per shift		600 pcs
If C/T = Takt (45 sec)	600 × 45	27,000 sec = ALL available time
No time left for changeovers!		
Actual C/T chosen		39 sec
Run time at 39 sec	600 × 39	23,400 sec
Time remaining	27,000 − 23,400	**3,600 sec (1 hour)**
C/O target		300 sec (5 min)
Changeovers per shift	3,600 ÷ 300	**12 changeovers**

Part 4 — Pull Systems & Supermarkets

4.1 Kanban Sizing

```
Kanban per Shift = Demand per Shift ÷ Container Quantity
```

Acme Finished Goods *(p. 61)*

`Kanban/shift = 460 pcs ÷ 20 pcs/tray = 23 kanban per shift`

4.2 Container Size as Time

```
Time per Container = Container Quantity × Takt Time
```

Acme Stamped-Parts Bins *(p. 67)*

`Time per bin = 60 pcs × 60 sec = 3,600 sec = 60 minutes`

The book describes this as "about one hour of current steering bracket assembly."

4.3 Supermarket Sizing

```
Supermarket Size = EPE Demand + Safety Buffer
```

Acme Stamped-Parts Supermarket *(pp. 67–68)*

Item	Value	Notes
EPE target	1 day	
LH daily demand	600 pcs	

Item	Value	Notes
RH daily demand	320 pcs	
Buffer	+0.5 day	For replenishment delay and stamping problems
Total supermarket	**1.5 days**	
LH stock	600 × 1.5 = 900 pcs	
RH stock	320 × 1.5 = 480 pcs	

4.4 Signal Kanban Trigger

When bin-for-bin pull is impractical (due to long changeovers), a signal kanban triggers a batch.

```
Feasibility: C/O-to-Run % = C/O Time ÷ (C/O Time + Run Time)
```

Acme Stamping — Why Bin-for-Bin Fails *(p. 68)*

Item	Value
Bin size	60 pcs
Run time for 1 bin	60 × 1 sec = 60 sec
Changeover time	3,600 sec (1 hour)
C/O as % of total	`3,600 ÷ (3,600 + 60) = 98.4%`

Setup time completely dominates — producing 60-piece bins one at a time is impractical. The signal kanban triggers a full daily batch instead (600 LH or 320 RH).

Part 5 — Scheduling & Leveling

5.1 Pitch

```
Pitch = Takt Time × Pack-Out Quantity
```

Pitch is "the basic unit of your production schedule for a product family" *(p. 51)*.

Generic Example *(p. 51)*

`Pitch = 30 sec × 20 pcs = 600 sec = 10 minutes`

Acme Stamping *(p. 76)*

`Pitch = 60 sec × 20 pcs/tray = 1,200 sec = 20 minutes`

TWI Industries *(p. 108)*

`Pitch = 39 sec × 50 pcs (avg order) + 300 sec C/O ≈ 30 minutes`

5.2 Load-Leveling Box

```
Columns in Leveling Box = Available Time per Shift ÷ Pitch
```

Acme Stamping:

`Columns = 27,600 sec ÷ 1,200 sec = 23 columns`

Rows = number of product variants (2 for Acme: LH and RH).

5.3 Mix Leveling Pattern

```
Mix Ratio = LH Quantity ÷ RH Quantity → Repeating Pattern
```

Acme Stamping *(pp. 73–74)*

Item	Value
LH trays per day	600 ÷ 20 = 30 trays
RH trays per day	320 ÷ 20 = 16 trays
LH:RH ratio	`30 ÷ 16 = 1.875 : 1`
Simplified pattern	**R L L R L L R L L …**

Instead of batching (30 LH then 16 RH), alternate in a repeating pattern. Every 3 trays: 2 LH + 1 RH.

- **Batched:** `LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLRRRRRRRRRRRRRRRR`
- **Leveled:** `RLLRLLRLLRLLRLLRLLRLLRLLRLLRLLRLLRLLRLLRLLRLLR`

Part 6 — Batch Sizing & EPE

6.1 Current Batch Size from EPE

```
Batch Size = EPE Interval (days) × Daily Demand
```

Acme Current State — EPE = 2 weeks:

Variant	EPE	Daily Demand	Batch Size
LH	10 days	600 pcs	**6,000 pcs**
RH	10 days	320 pcs	**3,200 pcs**

6.2 Target Batch Size (EPE = 1 day)

Acme Future State — Intermediate *(p. 68)*

Variant	Batch Size
LH	600 pcs (1 day)
RH	320 pcs (1 day)

6.3 Target Batch Size (EPE = 1 shift)

Acme Future State — Final *(p. 77)*

Variant	Batch Size
LH	300 pcs (1 shift)
RH	160 pcs (1 shift)

6.4 Inventory Reduction from Smaller Batches

```
Reduction % = 1 − (New Batch ÷ Old Batch)
```

`Reduction = 1 − (300 ÷ 6,000) = 1 − 0.05 = 95%`

The book states "about 85 percent" *(p. 77)* — the difference accounts for the supermarket buffer held beyond the batch itself.

6.5 Changeover Budget Method

```
Time for C/O = Available Time − Time to Run Daily Demand
```

```
Max Changeovers = Time for C/O ÷ C/O Duration per Setup
```

"A typical target is approximately 10% of available time to be used for changeovers" *(p. 54)*.

Generic Example *(p. 54)*

Step	Calculation	Result
Available time/day		16 hours
Time to run daily demand		14.5 hours
Time left for C/O	16 − 14.5	**1.5 hours**
C/O duration per setup		15 min (0.25 hr)
Max changeovers	1.5 ÷ 0.25	**6 per day**

Part 7 — Supplier Integration

7.1 Delivery Frequency Improvement

```
Inventory Reduction = 1 − (New Inventory Days ÷ Old Inventory Days)
```

Acme Coil Supply *(p. 69)*

Item	Current	Future
Delivery frequency	2× per week (Tue/Thu)	Daily (milk run)
Coil inventory	5 days	1.5 days
Reduction		`1 − (1.5 ÷ 5) = 70%`

The book notes: "Simply moving to daily delivery eliminates 80% of the inventory at Acme" *(p. 69)*. The difference is because ideal daily delivery would need only 1 day of stock.

7.2 Scrap Adjustment to Demand

Scrap rate is listed as a data box metric *(p. 21)* and shown as "2% Scrap" in the icon examples *(p. 108)*. Acme does not apply it, but the implicit formula is:

`Gross Demand = Net Demand ÷ (1 − Scrap Rate)`

`Gross Demand = 460 pcs ÷ (1 − 0.02) = 469.4 pcs/shift`

You must produce more than the customer needs to account for scrap.

Part 8 — Performance Metrics & Comparison

8.1 Three-State Lead Time Comparison

Acme Stamping *(pp. 69–70, 80–81)*

State	Coils	Stamped	WIP	FG	Lead Time
Current	5.0 d	7.6 d	6.5 d	4.5 d	**23.6 days**
Flow & Pull	2.0 d	1.5 d	0 d	4.5 d	**8.0 days**
With Leveling	1.5 d	1.0 d	0 d	2.0 d	**4.5 days**

8.2 Inventory Turns

`Inventory Turns ≈ Working Days per Year ÷ Production Lead Time (days)`

State	Lead Time	Turns
Current	23.6 days	`240 ÷ 23.6 ≈ 10`
Flow & Pull	8.0 days	`240 ÷ 8.0 = 30`
With Leveling	4.5 days	`240 ÷ 4.5 ≈ 53`

8.3 Lead Time Reduction

`Reduction % = (Current − Future) ÷ Current`

`Reduction = (23.6 − 4.5) ÷ 23.6 = 80.9%`

8.4 VA % Improvement

State	VA Time	Lead Time	VA %
Current	188 sec	23.6 days	0.0092%
Future	169 sec	4.5 days	0.0435%

VA % improves by ~4.7x — but remains extremely small, showing that even the future state has further to go.

Part 9 — TWI Industries Summary

TWI Current State *(Appendix B, p. 111)*

Inventory Point	Days
Raw rods	20
Cut rods	5
Post-Weld #1	3
Post-Weld #2	3
Post-Deflash	5
At painter (outside)	2
Painted at TWI	6
Finished goods	4
Raw forgings	20
Machined forgings	4
Total lead time	**approx 43+ days**

TWI Future State Key Calculations *(pp. 107–108)*

Metric	Calculation	Result
Takt time	`27,000 ÷ 600`	45 sec
Weld/Deflash C/T	(faster for C/O room)	39 sec
Run time per shift	`600 × 39`	23,400 sec
Time for C/Os	`27,000 − 23,400`	3,600 sec (1 hr)
C/O target		300 sec (5 min)
C/Os per shift	`3,600 ÷ 300`	12
Assembly operators	`195 ÷ 45 → round up`	5 operators
Pitch	`50 pcs × 39 sec + 300 sec`	~30 min
Future lead time		**< 11 days**

Part 10 — Complete Formula Reference

#	Formula Name	Expression	Page
1	Available Time	`Total Shift − Breaks`	p. 59
2	Daily Demand	`Monthly Demand ÷ Working Days`	p. 58
3	Demand per Shift	`Daily Demand ÷ Shifts`	p. 58
4	Takt Time	`Available Time ÷ Demand per Shift`	p. 44
5	Process Capacity	`(Available ÷ C/T) × Uptime`	p. 22
6	Inventory Days	`Quantity ÷ Daily Demand`	p. 35
7	Production Lead Time	`Sum of all inventory days`	p. 35
8	VA Time	`Sum of process cycle times`	p. 35
9	VA %	`Processing Time ÷ Lead Time (in sec)`	p. 35
10	NVA %	`1 − VA %`	p. 35
11	Operators Needed	`Total Work Content ÷ Takt`	p. 63
12	Max Work / Operator	`Takt − Buffer`	p. 64
13	Pitch	`Takt × Pack-Out Quantity`	p. 51
14	Kanban per Shift	`Demand ÷ Container Qty`	p. 61
15	Leveling Box Columns	`Available Time ÷ Pitch`	p. 53
16	Mix Ratio	`LH Qty ÷ RH Qty`	p. 73
17	Batch Size (EPE)	`EPE Interval × Daily Demand`	p. 77
18	C/O Budget	`Available − Run Time`	p. 54
19	Max Changeovers	`C/O Budget ÷ C/O Duration`	p. 54
20	Supermarket Size	`EPE Demand + Safety Buffer`	p. 68
21	Container as Time	`Container Qty × Takt`	p. 67
22	Signal Kanban Check	`C/O ÷ (C/O + Run Time)`	p. 68
23	Inventory Turns	`Working Days/Year ÷ Lead Time`	p. 69
24	Lead Time Reduction	`(Current − Future) ÷ Current`	p. 81
25	Gross Demand (Scrap)	`Net Demand ÷ (1 − Scrap Rate)`	p. 59
26	Delivery Inv. Reduction	`1 − (New Inv ÷ Old Inv)`	p. 69
27	Cell C/T Target	`Target Work Content ÷ Operators`	p. 64
28	C/Os per Shift	`Time Remaining ÷ C/O Duration`	p. 108

Source: Learning to See — Value Stream Mapping to Add Value and Eliminate MUDA, by Mike Rother and John Shook (Lean Enterprise Institute, 1999)