Chapter 10
Standard Operations Can Attain Balanced Production with Minimum Labor

Seoul National University

Professor ILKYEONG MOON

CONTENTS

10.1 Goals and elements of standard operations

10.2 Determining the components of standard operations

10.3 Proper training and follow-up: the key to implementing a successful system

10.1 GOALS AND ELEMENTS OF STANDARD OPERATIONS

- Toyota tries to eliminate production inefficiencies to reduce costs.

- *Standard operations* are aimed at using a minimum number of workers for production.

- There are three goals of standard operations.

10.1 GOALS AND ELEMENTS OF STANDARD OPERATIONS

- The first goal is to achieve high productivity through working efficiently without any wasteful motions.

- *Standard operations routine* is important.
  - a standardized order of the various operations to be performed by each worker

10.1 GOALS AND ELEMENTS OF STANDARD OPERATIONS

- The second goal is to achieve line balancing among all processes in terms of production timing.
  - with the concept of cycle time

- The third goal is that only the minimum quantity of work-in-process will qualify as *standard quantity of work-in-process*.
  - or the minimum number of units necessary for the standard operations to be performed by workers

10.1 GOALS AND ELEMENTS OF STANDARD OPERATIONS

- Standard operations consists of the standard operations routine, cycle time, and standard quantity of work-in-process.

- Safety precautions and product quality are subgoals of Toyota's standard operations.

10.1 GOALS AND ELEMENTS OF STANDARD OPERATIONS

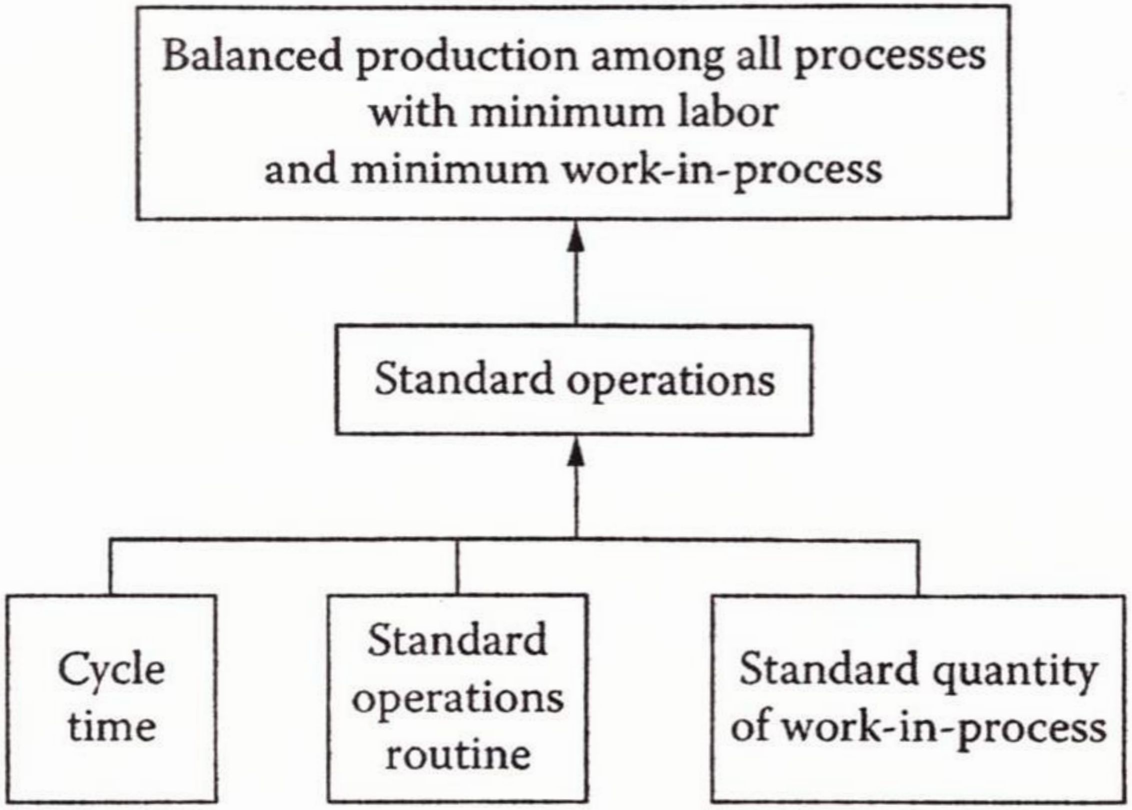


FIGURE 10.1
Elements of standard operations.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The *cycle time* or *takt time* is the time span in which one unit of a product must be produced.

$$\text{cycle time} = \frac{\text{Effective Daily Operating Time}}{\text{Required Daily Quantity of Output}}$$

- The effective daily operating time should not be reduced for any allowances due to machine breakdowns, idle time, etc.

- The required daily quantity should not be increased to allow for defective output.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The number of workers in any department at Toyota's factory can be decreased if the cycle time is relatively longer.

- Sometimes, the cycle time is determined erroneously by using the current machine capacity and labor capacity.
  - It does not give the necessary time span needed for repositioning the workers.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The completion time per unit of output has to be determined at each process and for each part.

- This time unit is always written on the *part production capacity sheet*.

  - filled out for each part

Part production capacity sheet	Item no.	Item name	Necessary quantity per day	Worker's name

Order of processes	Description of operations	Machine no.	Basic time: Manual operation time (min.)	(sec.)	Basic time: Machine processing time (min.)	(sec.)	Basic time: Completion time per unit (min.)	(sec.)	Tool's exchange: Exchange unit	Tool's exchange: Exchange time	Production capacity (960 min)	References manual operation ——— machine processing ·········
1	Center dirll	CD-300	min.	sec. 07	min. 1	sec. 20	min. 1	sec. 27	80	1'00"	Units 655	
2	Chamfer	KA-350		09	1	35	1	44	20	30"	549	
									50	30"		
3	Ream	KB-400		09	1	25	1	34	20	30"	606	
									40	30"		
4	Ream	KC-450		10	1	18	1	28	20	30"	643	
2-1	Mill	MS-100		(20)	(2	10)	(2	20)	1,000	7'00"	820	10" 10" 2'10"
2-2	Mill	MS-101		(15)	(2	10)	(2	15)	1,000	7'00"		5" 10" 2'10"
	(two stands of machines)			18								[manual operation time per unit] $= \frac{20" + 15"}{2} = 17.5" \rightarrow 18"$
3	Bore	BA-235		(08)		(50)		(58)	500	5'00"	1,947	
	(two units processing at a time)			04				29				[manual operation time per unit] $= \frac{8"}{2} = 4"$
4	Gauge (1/5)			(18)								
	(one unit inspection in every five units)			09								[manual operation time per unit] $= \frac{18"}{2} = 9"$
			Total									

FIGURE 10.2
Part production capacity sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The *manual operation time* and the *machine automatic processing time* are measured with a stopwatch.

- The manual operation time should not include the walking time at the process.

Order of processes	Description of operations	Machine no.	Basic time						Tool's exchange		Production capacity (960 min)	References manual operation ———— machine processing ···········
			Manual operation time		Machine processing time		Completion time per unit		Exchange unit	Exchange time		
			min.	sec.	min.	sec.	min.	sec.			Units	
1	Center dirll	CD-300		07	1	20	1	27	80	1'00"	655	
2	Chamfer	KA-350		09	1	35	1	44	20	30"	549	
									50	30"		

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The completion time per unit in the basic column is the time required for a single unit to be processed.

Order of processes	Description of operations	Machine no.	Basic time						Tool's exchange		Production capacity (960 min)	References manual operation ——— machine processing ········
			Manual operation time		Machine processing time		Completion time per unit		Exchange unit	Exchange time		
			min.	sec.	min.	sec.	min.	sec.			Units	
1	Center dirll	CD-300		07	1	20	1	27	80	1'00"	655	
2	Chamfer	KA-350		09	1	35	1	44	20	30"	549	
									50	30"		

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

❖ If two units are processed simultaneously, or one unit in every few units is inspected for quality control, the completion time per unit will be written in the reference column.

Order of processes	Description of operations	Machine no.	Basic time: Manual operation time		Machine processing time		Completion time per unit		Tool's exchange: Exchange unit	Exchange time	Production capacity (960 min)	References manual operation —— machine processing ······
1	Center dirll	CD-300	min.	sec. 07	min. 1	sec. 20	min. 1	sec. 27	80	1'00"	Units 655	
2-1	Mill	MS-100		(20)	(2	10)	(2	20)	1,000	7'00"	820	10" 10" 2'10"
2-2	Mill	MS-101		(15)	(2	10)	(2	15)	1,000	7'00"		5" 10" 2'10"
	(two stands of machines)			18								[manual operation time per unit] = $\frac{20" + 15"}{2}$ = 17.5" → 18"
3	Bore	BA-235		(08)		(50)		(58)	500	5'00"	1,947	
	(two units processing at a time)			04				29				[manual operation time per unit] = $\frac{8"}{2}$ = 4"
4	Gauge (1/5)			(18)								
	(one unit inspection in every five units)			09								[manual operation time per unit] = $\frac{18"}{2}$ = 9"

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The *exchange units* specify the number of units to be produced before changing the bite or tool.

- The *exchange time* refers to the setup time.

Order of processes	Description of operations	Machine no.	Basic time						Tool's exchange		Production capacity (960 min)	References manual operation ———— machine processing ············
			Manual operation time		Machine processing time		Completion time per unit		Exchange unit	Exchange time		
			min.	sec.	min.	sec.	min.	sec.			Units	
1	Center dirll	CD-300		07	1	20	1	27	80	1'00"	655	
2	Chamfer	KA-350		09	1	35	1	44	20	30"	549	
									50	30"		

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

❖ The *production capacity* is computed by the following formula.

$$N = \frac{T}{C+m} \quad \text{or} \quad \frac{T-mN}{C}$$

click.

- N = production capacity in terms of units of output
- C = completion time per unit
- m = setup time per unit
- T = total operation time
- mN = summation of total setup time

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- With the cycle time and the manual operation time per unit for each operation, the *standard operations routine* of each worker must be determined.

- The number of different operations that each worker should be assigned must be calculated.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The *standard operations routine* is the order of actions that each worker must perform within a given cycle time.

- With the cycle time and the manual operation time per unit for each operation, the standard operations routine of each worker must be determined.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

❖ The standard operations routine serves two purposes.

- It provides the worker with the order or routine to pick up work, put it on the machine, and detach it after processing.
- It gives the sequence of operations that the multi-functioned worker must perform at various machines within a cycle time.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

❖ 1. The cycle time is drawn with a red line

Item no.	3561–4630	Standard Operations Routine Sheet No. 1	Date	Oct. 15, '81	Necessary quantity per day	240 units	Manual operation ———
Process name	Machining: part 2		Worker's position & name		Cycle time	2 min.	Machine processing - - - - - ; Walking ~~~~

Order of operations	Names of operations	Time: Manual	Time: Machine
1	Pick up the material from the pallet	01"	—
2	CD-300: center drill	07"	1'20"
3	KA-350: chamfer	09"	1'35"
4	KB-400: ream	09"	1'25"
5	KC-450: ream	10"	1'18"
6	NE-200	08"	50"
7	GR-101	05"	—
8	SA-130	07"	1'10"
9	JI-500	10"	1'30"
10	HU-400	12"	55"
11	Wash, attach the nipple, put in the pallet	20"	—

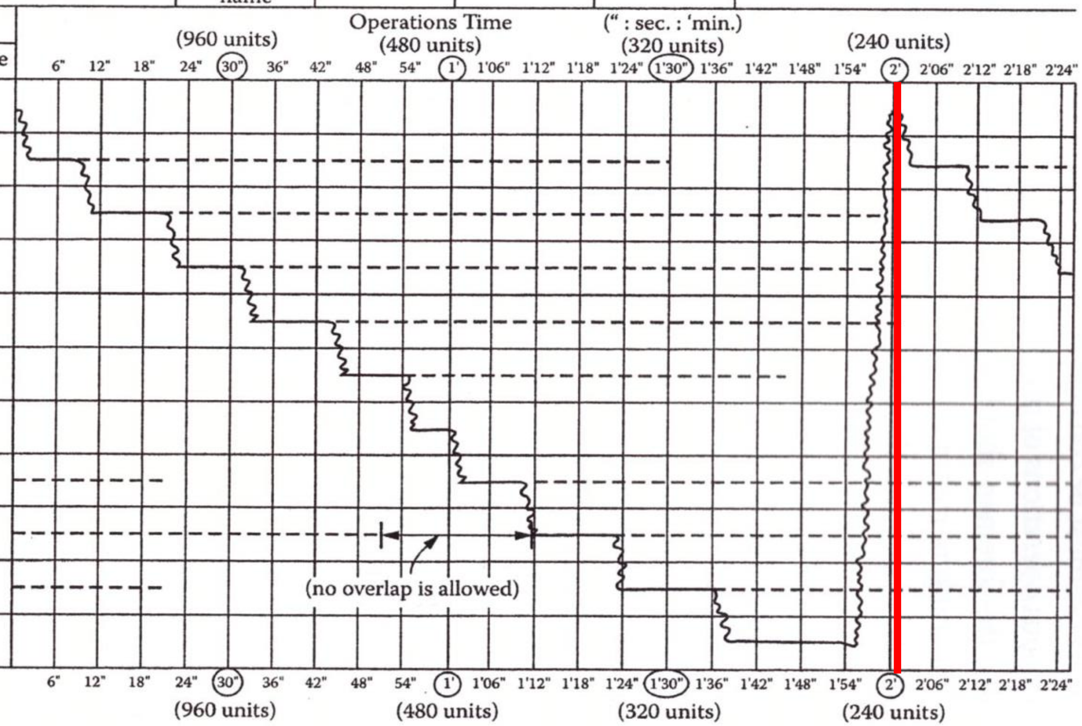


FIGURE 10.3
Standard operations routine sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

2. The approximate range of processes assigned to one worker should be decided.

Item no.	3561–4630	Standard Operations Routine Sheet No. 1	Date	Oct. 15, '81	Necessary quantity per day	240 units
Process name	Machining: part 2		Worker's position & name		Cycle time	2 min.

Legend: Manual operation ——— ; Machine processing - - - - - ; Walking ∿∿∿∿

Order of operations	Names of operations	Time: Manual	Time: Machine
1	Pick up the material from the pallet	01"	—
2	CD-300: center drill	07"	1'20"
3	KA-350: chamfer	09"	1'35"
4	KB-400: ream	09"	1'25"
5	KC-450: ream	10"	1'18"
6	NE-200	08"	50"
7	GR-101	05"	—
8	SA-130	07"	1'10"
9	JI-500	10"	1'30"
10	HU-400	12"	55"
11	Wash, attach the nipple, put in the pallet	20"	—

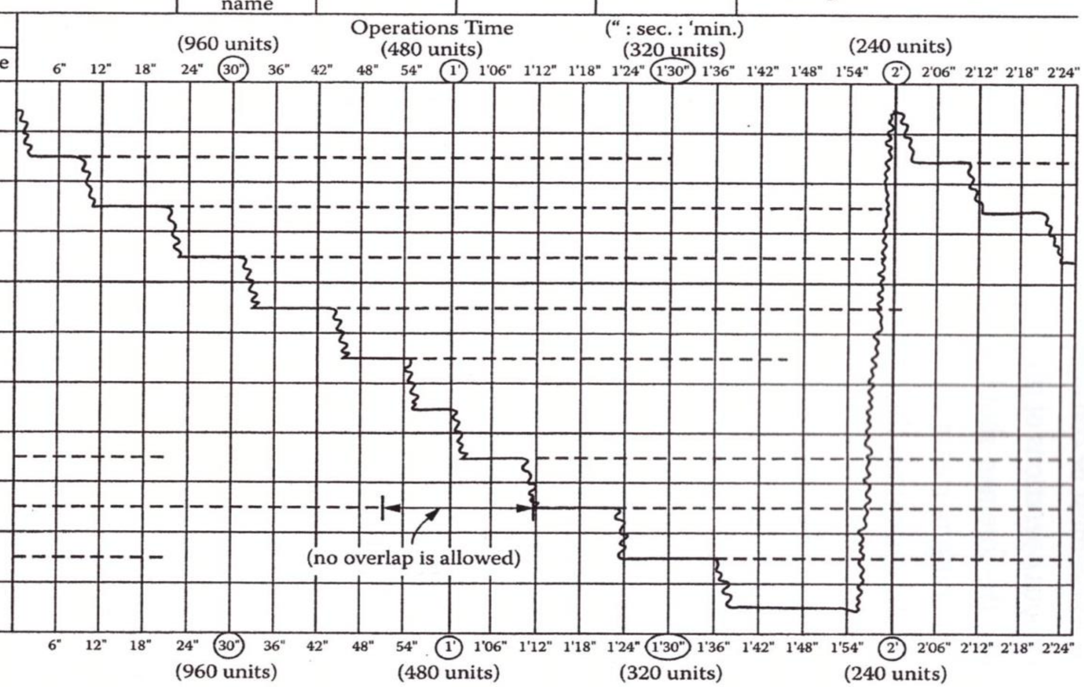
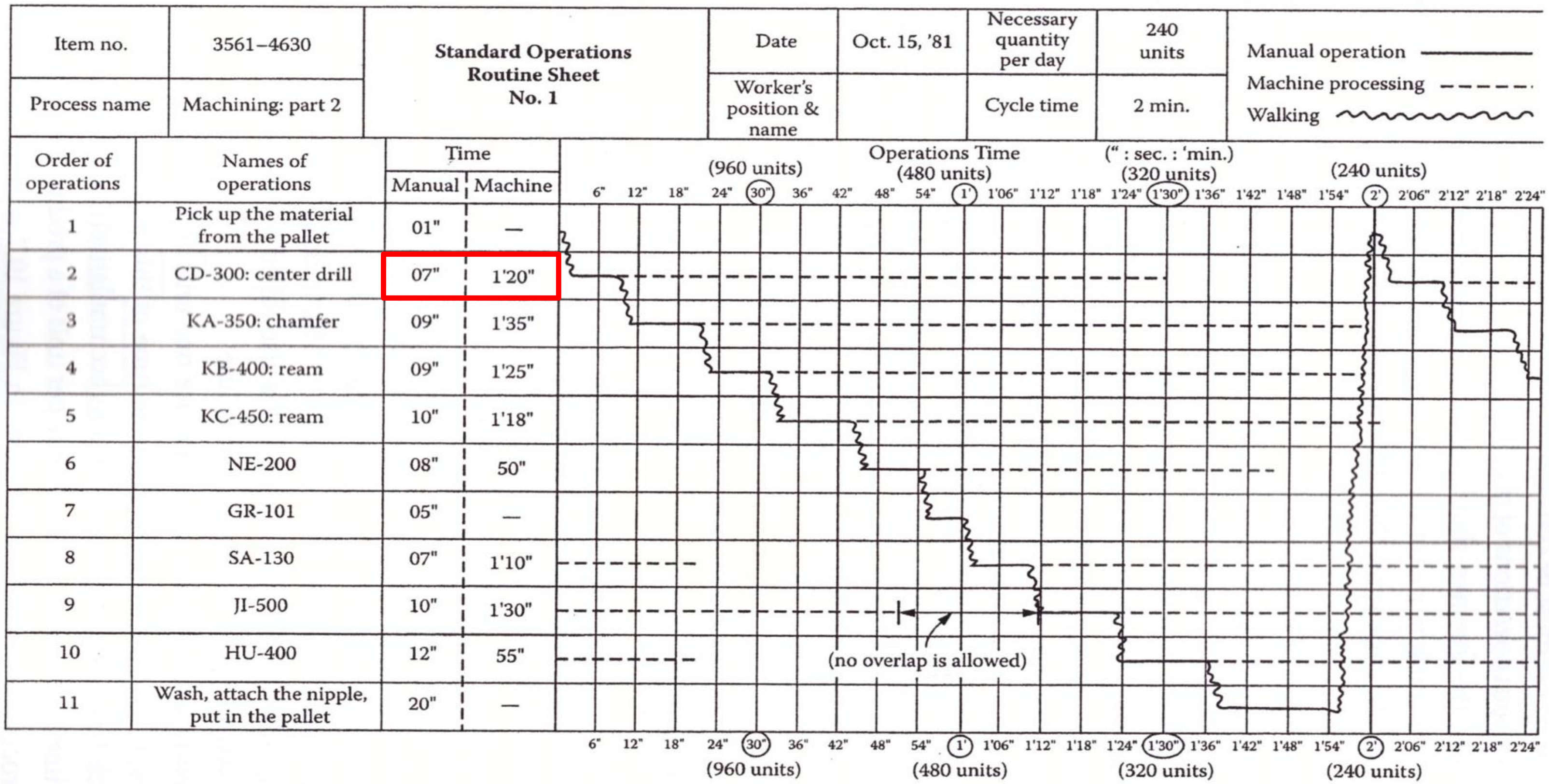


FIGURE 10.3
Standard operations routine sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

3. The manual operation and machine processing times for the first machine are first drawn.



Item no.	3561–4630	Standard Operations Routine Sheet No. 1	Date	Oct. 15, '81	Necessary quantity per day	240 units
Process name	Machining: part 2		Worker's position & name		Cycle time	2 min.

Manual operation ——— Machine processing - - - - - Walking ∿∿∿∿

Order of operations	Names of operations	Time: Manual	Time: Machine
1	Pick up the material from the pallet	01"	—
2	CD-300: center drill	07"	1'20"
3	KA-350: chamfer	09"	1'35"
4	KB-400: ream	09"	1'25"
5	KC-450: ream	10"	1'18"
6	NE-200	08"	50"
7	GR-101	05"	—
8	SA-130	07"	1'10"
9	JI-500	10"	1'30"
10	HU-400	12"	55"
11	Wash, attach the nipple, put in the pallet	20"	—

FIGURE 10.3
Standard operations routine sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

4. Decide the next operation of this worker.

Item no.	3561–4630	Standard Operations Routine Sheet No. 1	Date	Oct. 15, '81	Necessary quantity per day	240 units	Manual operation ————
Process name	Machining: part 2		Worker's position & name		Cycle time	2 min.	Machine processing - - - - - ; Walking ∿∿∿∿

Order of operations	Names of operations	Time: Manual	Time: Machine
1	Pick up the material from the pallet	01"	—
2	CD-300: center drill	07"	1'20"
3	KA-350: chamfer	09"	1'35"
4	KB-400: ream	09"	1'25"
5	KC-450: ream	10"	1'18"
6	NE-200	08"	50"
7	GR-101	05"	—
8	SA-130	07"	1'10"
9	JI-500	10"	1'30"
10	HU-400	12"	55"
11	Wash, attach the nipple, put in the pallet	20"	—

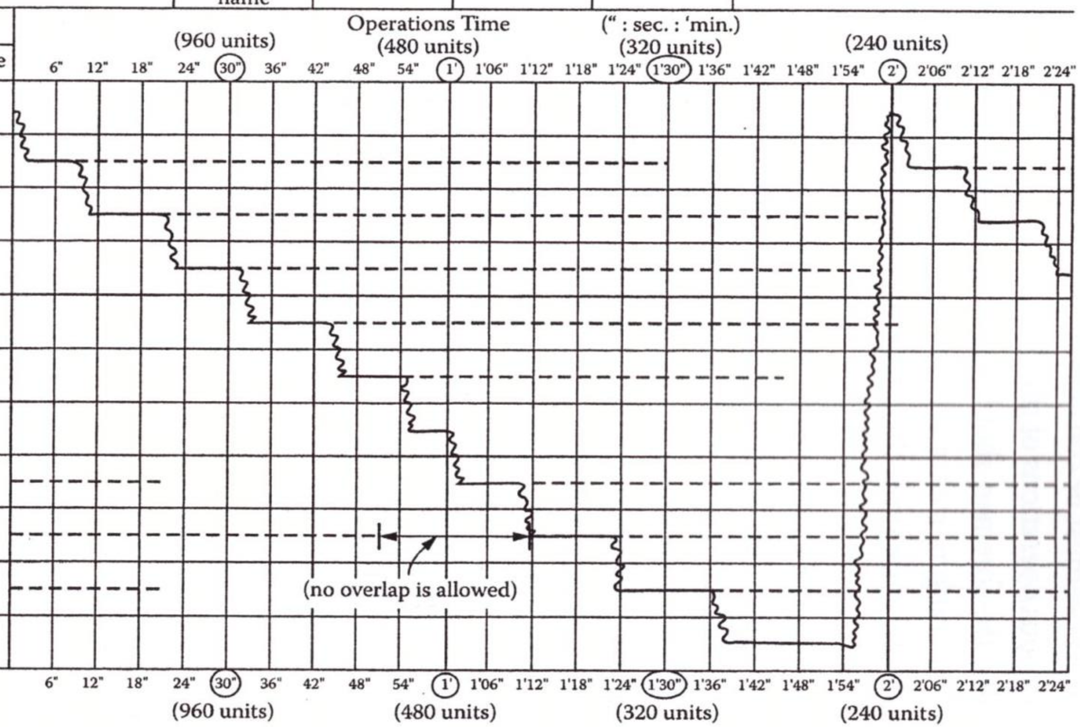


FIGURE 10.3
Standard operations routine sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

5. Repeat Steps 3 and 4 until the whole operations routine can be determined.

Item no.	3561–4630	Standard Operations Routine Sheet No. 1	Date	Oct. 15, '81	Necessary quantity per day	240 units	Manual operation ————
Process name	Machining: part 2		Worker's position & name		Cycle time	2 min.	Machine processing – – – – – Walking ∿∿∿∿∿

Order of operations	Names of operations	Time: Manual	Time: Machine
1	Pick up the material from the pallet	01"	—
2	CD-300: center drill	07"	1'20"
3	KA-350: chamfer	09"	1'35"
4	KB-400: ream	09"	1'25"
5	KC-450: ream	10"	1'18"
6	NE-200	08"	50"
7	GR-101	05"	—
8	SA-130	07"	1'10"
9	JI-500	10"	1'30"
10	HU-400	12"	55"
11	Wash, attach the nipple, put in the pallet	20"	—

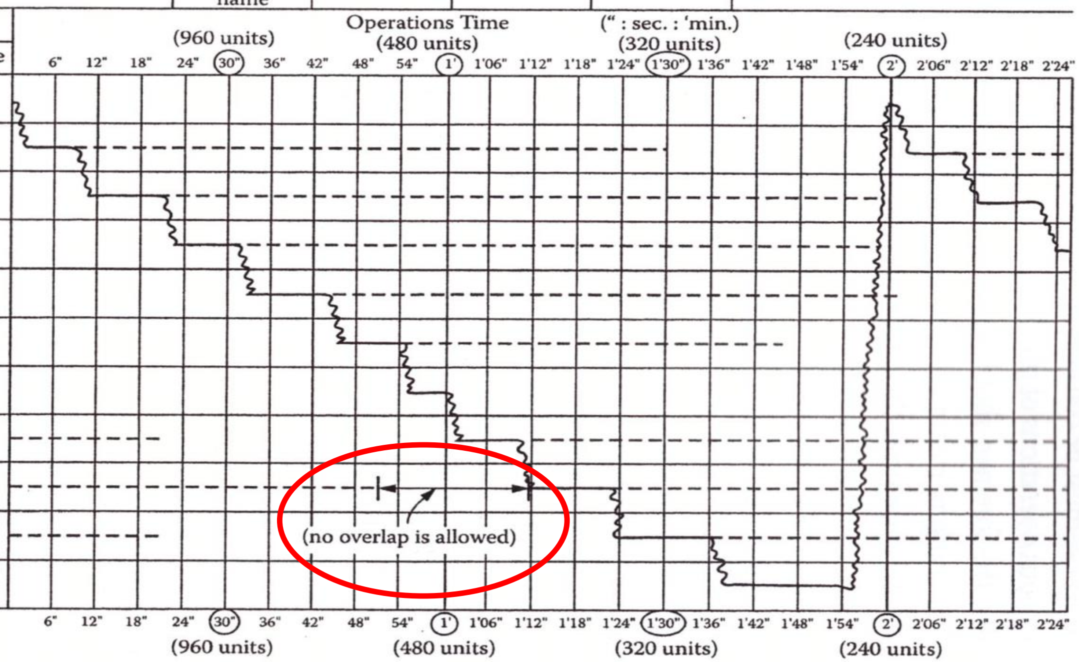


FIGURE 10.3
Standard operations routine sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

6. The route must be completed at the initial operation of the next cycle.

Item no.	3561–4630	Standard Operations Routine Sheet No. 1	Date	Oct. 15, '81	Necessary quantity per day	240 units	Manual operation ———
Process name	Machining: part 2		Worker's position & name		Cycle time	2 min.	Machine processing - - - - - Walking ∿∿∿

Order of operations	Names of operations	Time: Manual	Time: Machine
1	Pick up the material from the pallet	01"	—
2	CD-300: center drill	07"	1'20"
3	KA-350: chamfer	09"	1'35"
4	KB-400: ream	09"	1'25"
5	KC-450: ream	10"	1'18"
6	NE-200	08"	50"
7	GR-101	05"	—
8	SA-130	07"	1'10"
9	JI-500	10"	1'30"
10	HU-400	12"	55"
11	Wash, attach the nipple, put in the pallet	20"	—

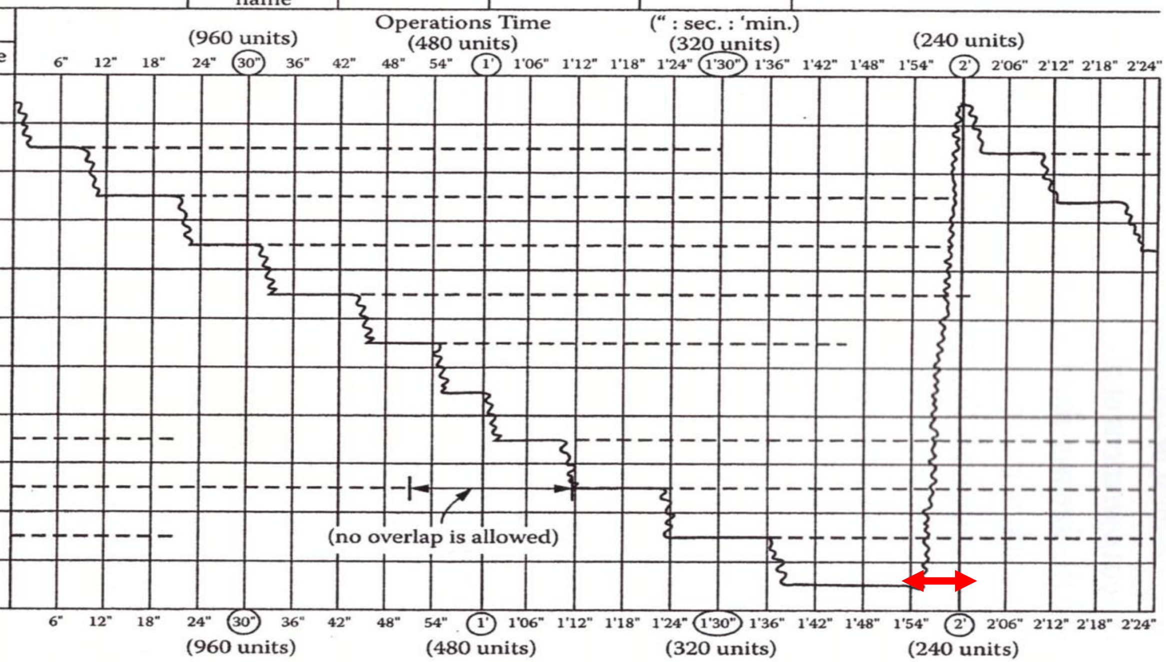


FIGURE 10.3
Standard operations routine sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

7. If the final wind-up point meets the red line of cycle time, the routine as an appropriate mix.

   If the final operation ends before the line, try to add some more operations.

8. The foreman should actually try to perform this operations routine.

❖ The layout of processes must be such that each worker has the same cycle time for production line balancing.

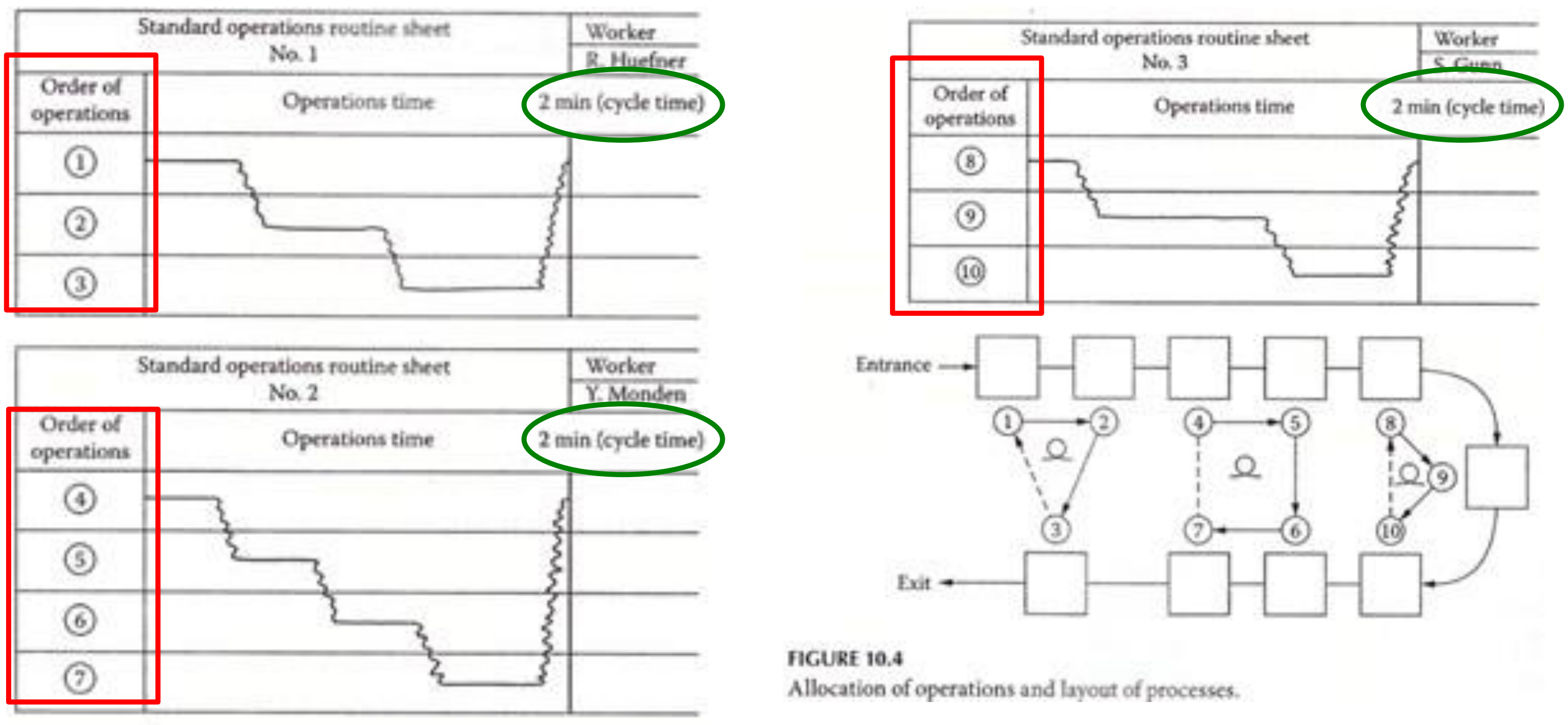


FIGURE 10.4
Allocation of operations and layout of processes.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- If the waiting time is too long, a double cycle time can be set to have simultaneous operations by two or three workers subject to the same operations routine.

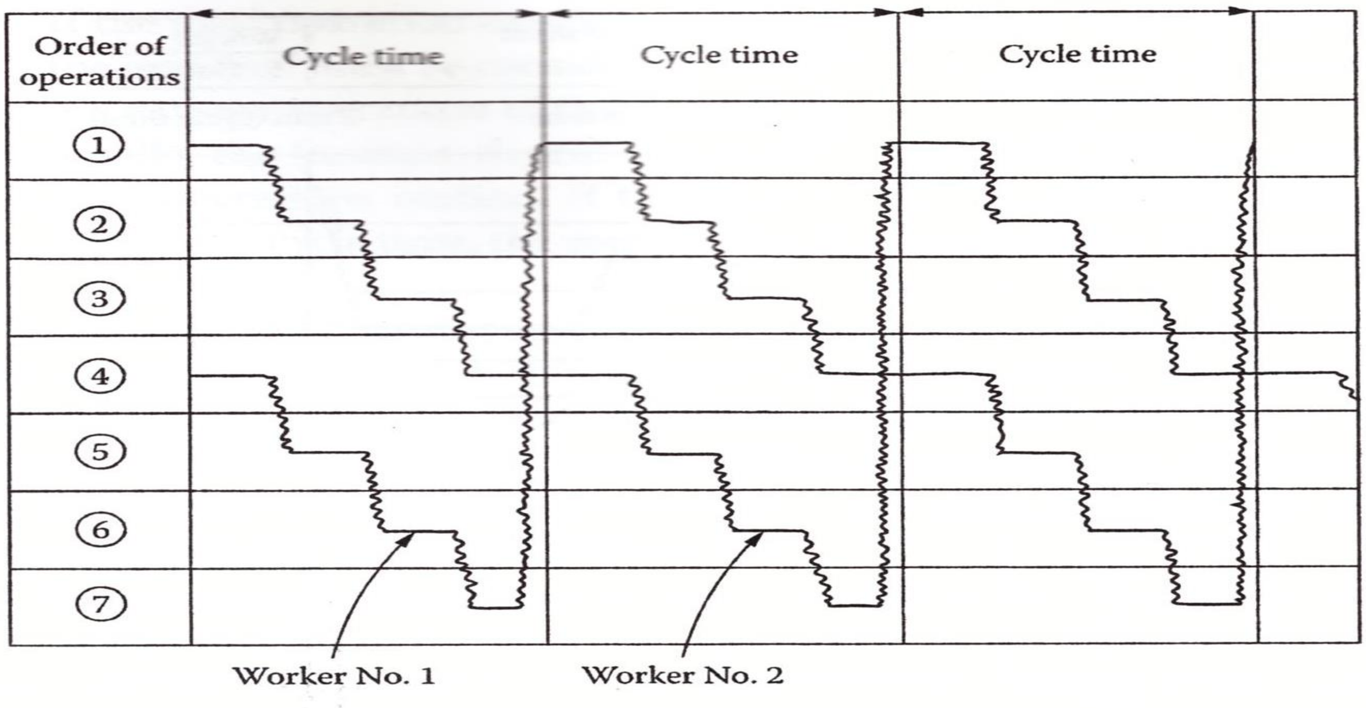


FIGURE 10.5
Double cycle time for use by two workers.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- In the "Yo-i-don" system, Yo-i-don means *ready*, *set*, *go*.

- It is a method for balancing the production timing (synchronization) among various processes where there is no conveyor belt.

- It can also be used to measure the production capacity of each process.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- Consider an example in a body welding plant.
  - 6 underbody processes
  - 6 side-body processes
  - 4 main-body processes

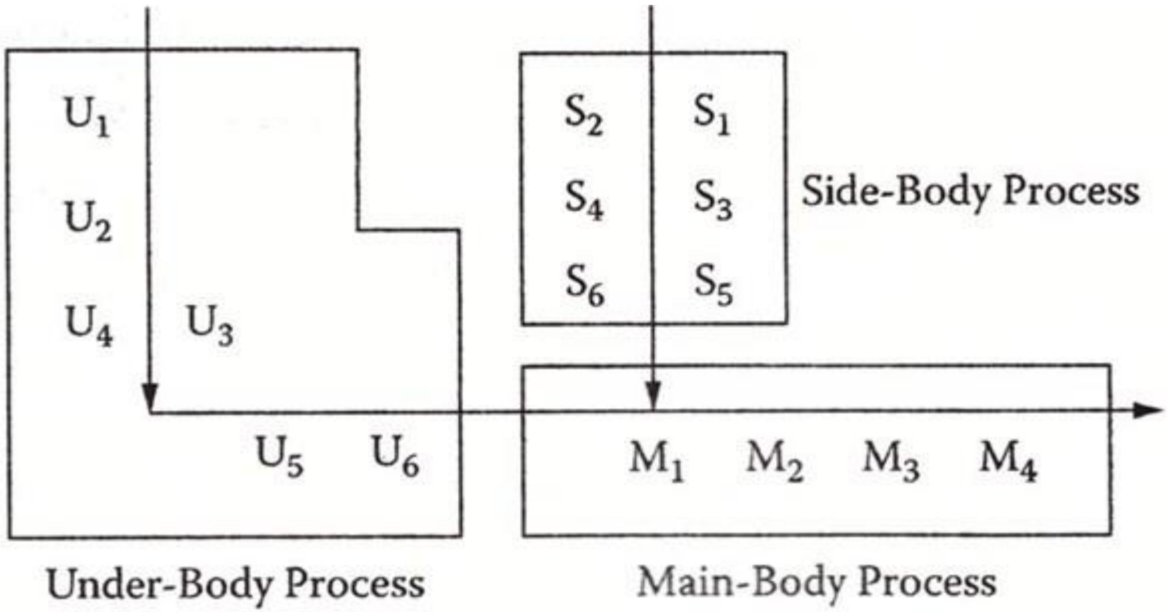


FIGURE 10.6
Process in a body welding plant.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The cycle time for one product is 3 minutes 35 seconds.
- Divide the cycle time into 3 equal portions accumulatively as 1/3, 2/3, and 3/3.

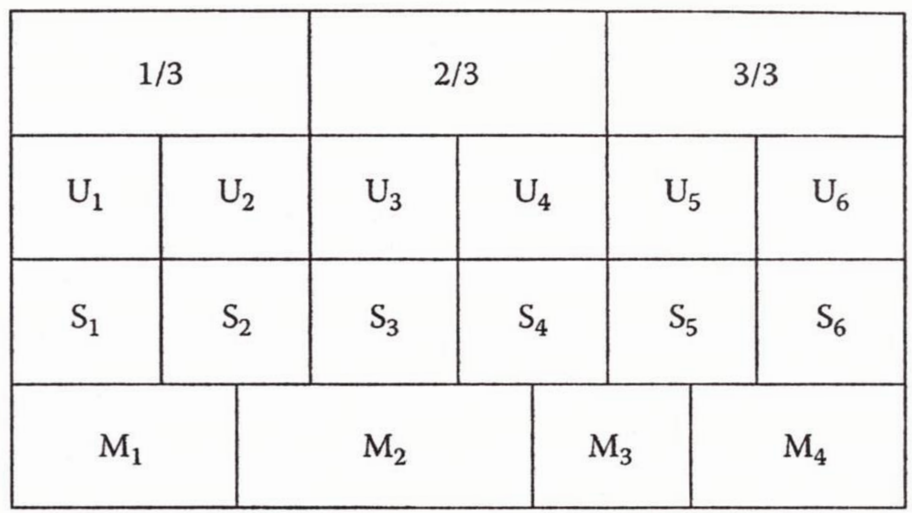


FIGURE 10.7
Andon of the body plant.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The worker in each process pushes his button when his job is finished.

- After 3 minutes 35 seconds, the red lamp on andon only go on automatically at the processes where the job is not completed.

- The whole line stops operation while a red lamp is on until the delayed processes are finished.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- Machine sequencing is important in complex operation routines.

- The setup problem should be taken into consideration when different machines are laid out in succession.

- Toyota uses a setup approach called *one-shot setup*.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- Suppose there are 4 kinds of machines in succession such as a bending machine (*W*), a punch press (*X*), a welding machine (*Y*), and a boring machine (*Z*).
- One multi-functioned worker handles these machines.
- He is now processing part A and he must next process part B in these machines.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- When switching from producing A to producing B, the machines should be set up.

- If the worker set up the four machines after processing all of part A at these machines, the lead time is quite long.

- Under the *one-shot setup*, he begins the setup for part B while part A is still in process.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

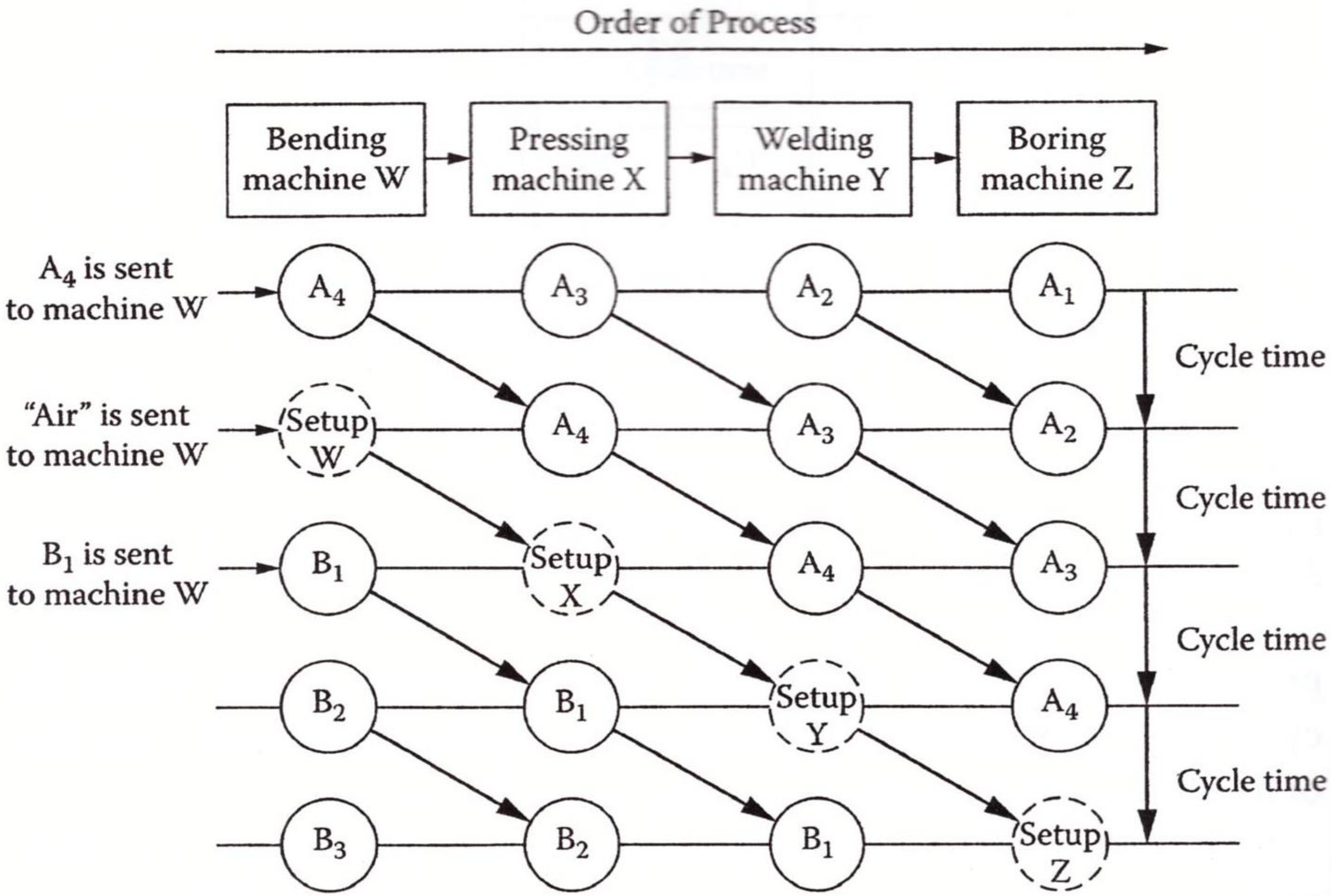


FIGURE 10.8
One-shot setup.

SCM Lab.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

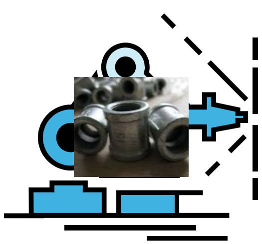
- The *standard quantity of work-in-process* is the minimum necessary quantity of work-in-process within the production line.

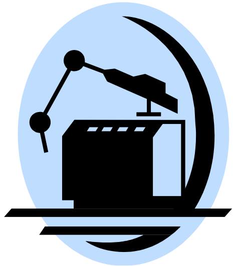
  - the work laid out and held between machines
  - the work attached to each machine

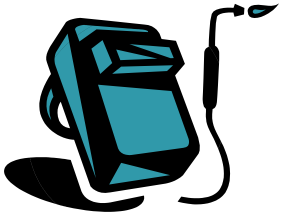
- It does not include the inventory of completed products.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The standard quantity varies according to the following different operations routines.
- If the operations routine is in accordance with the order of process flow, there will be no work held between machines.

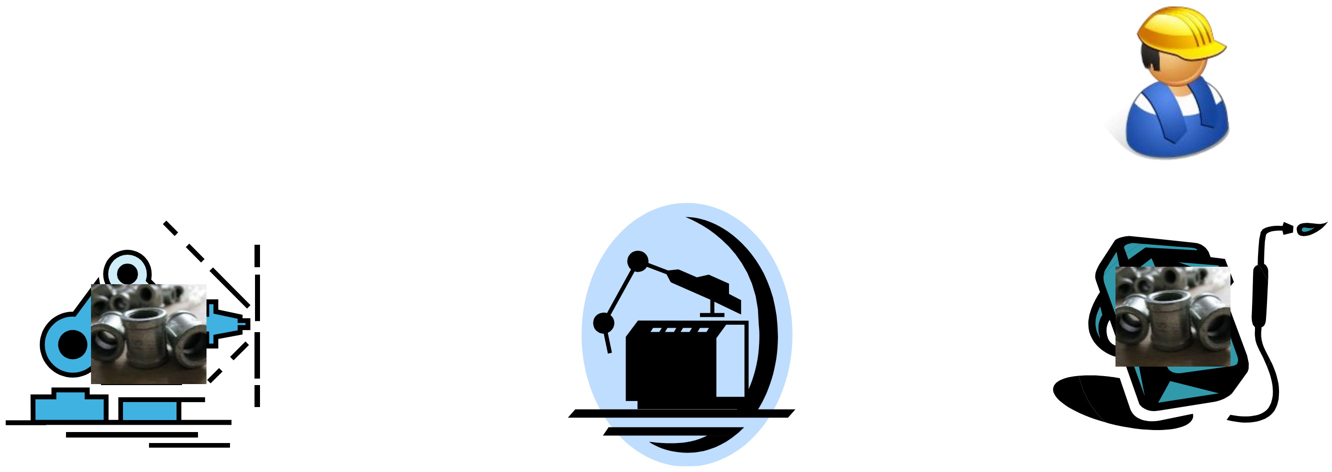






10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- If the operations routine is in an opposite direction to the order of process flow, there will be at least one piece of work held between machines.



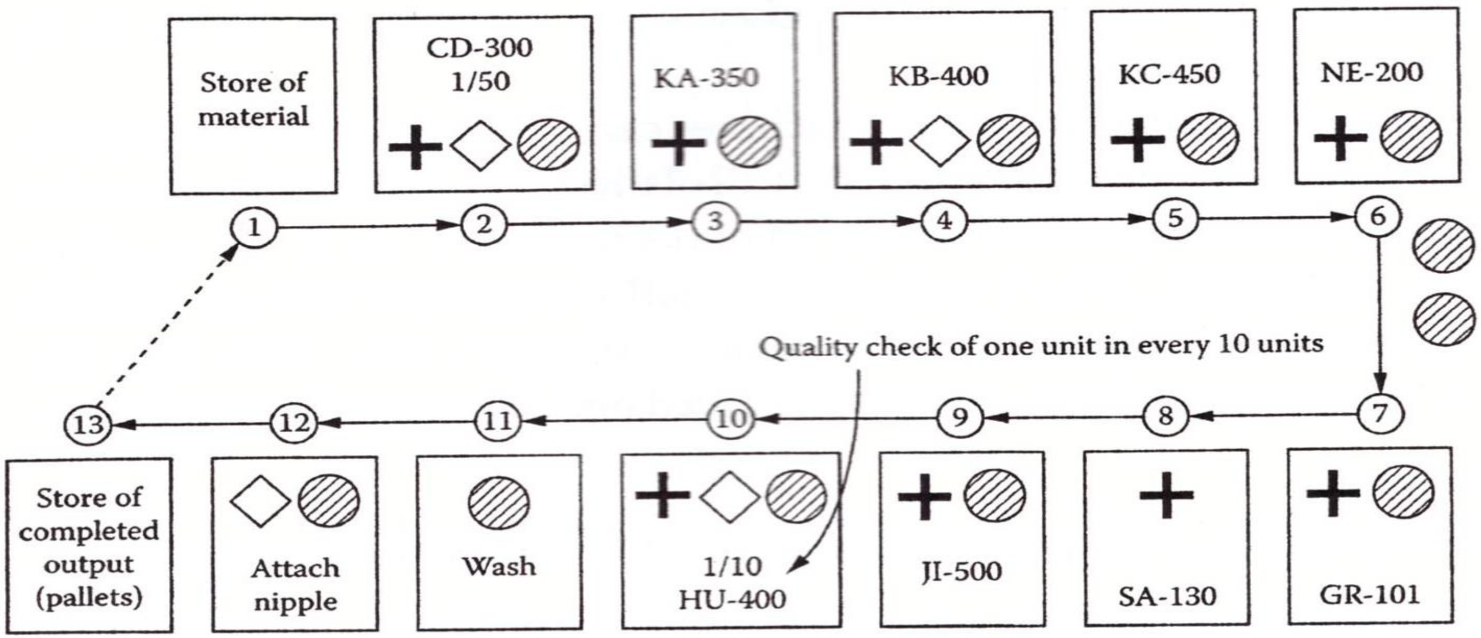
10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

❖ The following points should be considered when determining the standard quantity.

- the quantity necessary for checking the product quality at necessary positions of the process

- the quantity necessary to be held until the temperature of a unit from the preceding machine goes down to a certain level

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS



Cycle time	Net operating time	Standard quantity of work-in-process	Quality check	Attention to safety	Worker's no. / Total workers of the process
2 min	2 min	◍	◇	+	2/3

FIGURE 10.9
Standard operations sheet.

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The *standard operations sheet* is the final item needed for standardizing the operations at Toyota.

- cycle time
- operations routine
- standard quantity of work-in-process
- net operating time
- positions to check product quality
- positions to pay attention to worker safety

10.2 DETERMINING THE COMPONENTS OF STANDARD OPERATIONS

- The *standard operations sheet* is displayed so that each worker of the process can see it.

  - It is a guideline for each worker to keep the standardized operations routines.

  - It helps the foreman check to be sure that each worker is following standard operations.

10.3 PROPER TRAINING AND FOLLOW-UP: THE KEY TO IMPLEMENTING A SUCCESSFUL SYSTEM

- The foreman must be able to perform the standard operations perfectly and then instruct his workers to do so.

- The supervisor (foreman) should explain the reasons why the standards must be kept.

10.3 PROPER TRAINING AND FOLLOW-UP: THE KEY TO IMPLEMENTING A SUCCESSFUL SYSTEM

- Two sheets help workers thoroughly understand the standards.

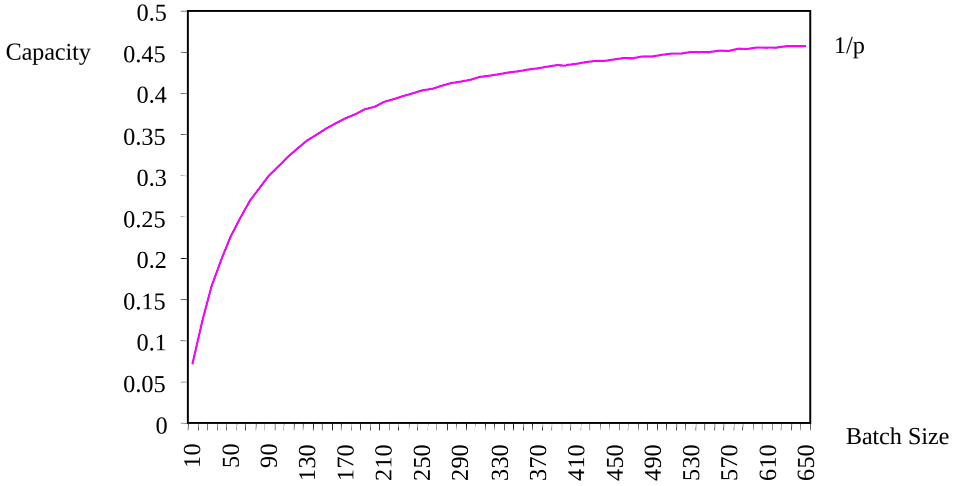
  - *Operations key points note* describes the important points of each operation.

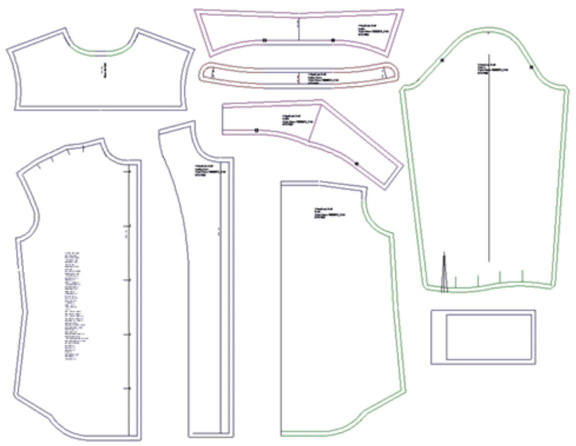
  - *Operations guidance note* explain the details of each operation and methods for checking product quality.

PROCESS ANALYSIS WITH BATCHING

- Capacity calculation for the resource with set-up changes:
- $$\text{Capacity given Batch Size} = \frac{\text{Batch Size}}{\text{Set-up time} + \text{Batch-size} * \text{Time per unit}}$$

- Capacity increases with batch size:



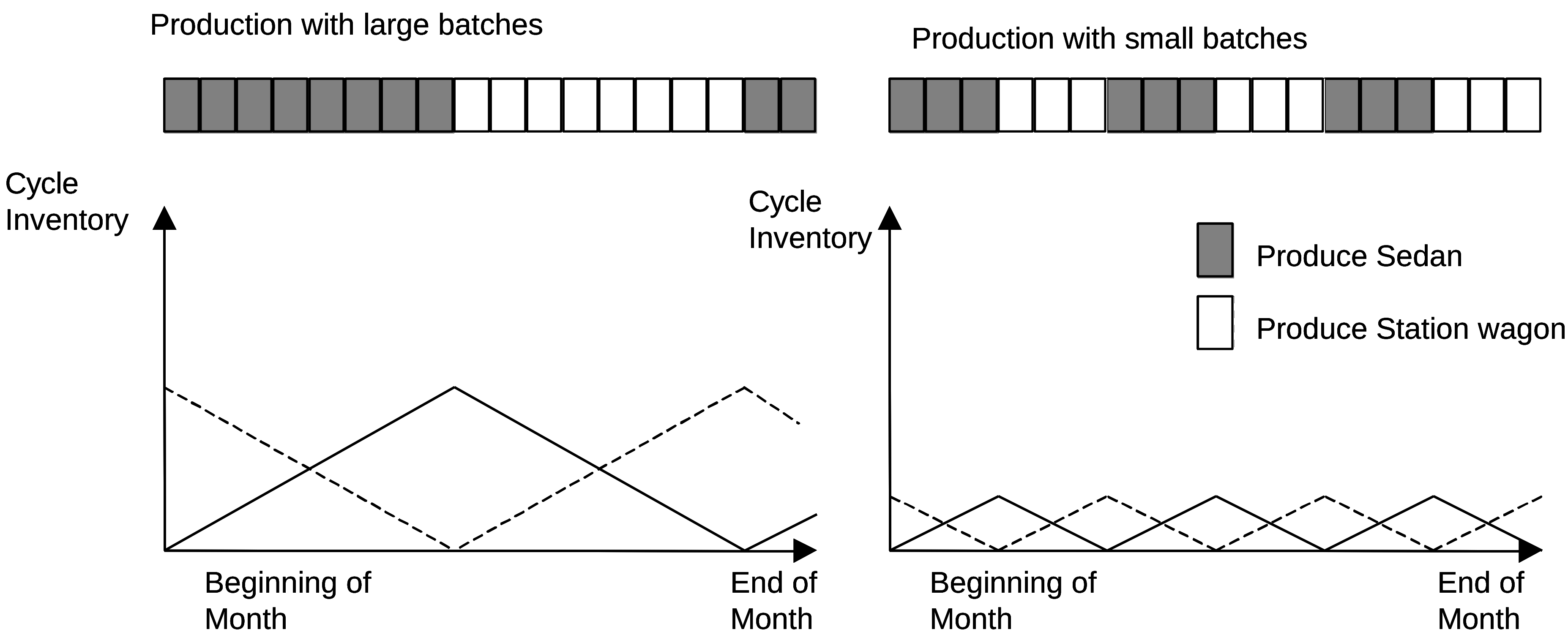


Example: Cutting Machine for shirts

20 minute cutting time (irrespective of the number of shirts)

4 minute/unit preparation time

PROCESS ANALYSIS WITH BATCHING

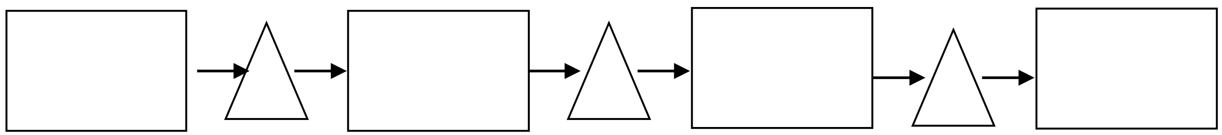


- Large batch sizes lead to more inventory in the process
- This needs to be balanced with the need for capacity
- Implication: look at where in the process the set-up occurs

  If set-up occurs at non-bottleneck => decrease the batch size

  If set-up occurs at the bottleneck => increase the batch size

PROCESS ANALYSIS WITH BATCHING



	Cutting	Section 1	Section 2	Finishing
Set-up time:	20 minutes	-	-	-
Activity time:	4 min/unit	40 min/unit	30 min/unit	3 min/unit
Resources:	1 Cutting machine	8 workers	5 workers	1 worker

What is the capacity of the cutting machine with a batch size of 15? ? unit/min

What is the capacity of the overall process?

How would you set the batch size?

PROCESS ANALYSIS WITH BATCHING

- Equate the capacity of the step with setup with the capacity of the step from the remaining process that has the smallest capacity!

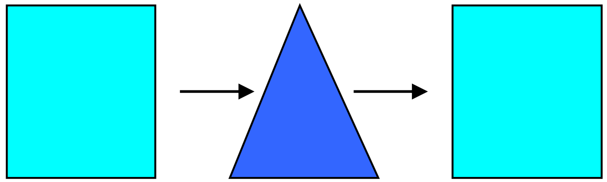
$$\text{Capacity given Batch Size (C)} = \frac{\text{Batch Size (B)}}{\text{Set-up time (S)} + \text{Batch-size (B)} * \text{Time per unit (p)}}$$

Flow Rate (F)

F= B/(S+Bp) => B=FS/(1-Fp)

$$\text{Recommended Batch Size (B)} = \frac{\text{Flow Rate (F)} * \text{Setup Time (S)}}{1- \text{Flow Rate (F)} * \text{Time per unit (p)}}$$

PROCESS ANALYSIS WITH BATCHING



Milling Machine **Assembly process**

	Setup time	Activity time
Milling	120	2
Assembly	0	3

Capacity (B=12) Milling: 0.0833unit/min (bottleneck)
Assembly: 0.33unit/min

Capacity (B=300) Milling: 0.4166unit/min
Assembly: 0.33unit/min (bottleneck)

Recommended Batch Size?
(0.333*120)/(1-0.333*2)=120units!

PROCESS ANALYSIS WITH BATCHING

- Batching is common in low volume / high variety operations
- Capacity calculation changes:

$$\text{Capacity given Batch Size} = \frac{\textit{Batch Size}}{\textit{Set-up time + Batch-size*Time per unit}}$$

- This reflects economies of scale (similar to fixed cost and variable cost)
- You improve the process by:

<u>Setting the batch size:</u>
(a) If set-up occurs at the bottleneck => Increase the batch size
(b) If set-up occurs at a non-bottleneck => Reduce the batch size
(c) Find the right batch size by solving equation

<u>Reducing set-up times:</u>
(a) SMED method separates between internal and external set-ups
(b) Do external set-ups off-line, i.e., while the process is still running
=> enables mixed model production (Heijunka:平準化)

Set-up time reduction is also powerful in other settings, such as OR’s or airplanes