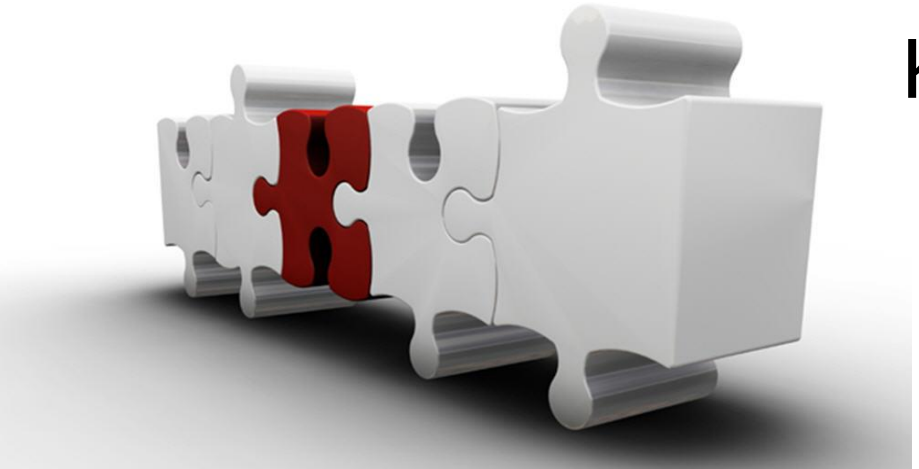
The LeanMan

Lean Principles

Facilitator Guide



Kanban Simulation

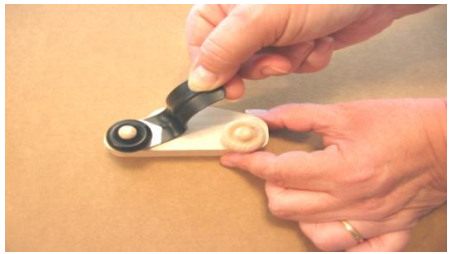
With Heijunka Control

Leveling the waves

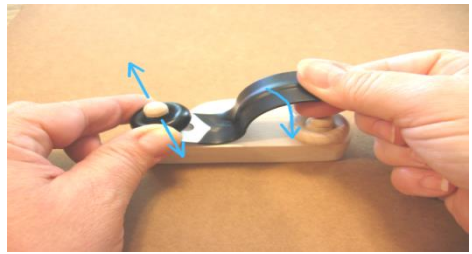
A word about safety and ergonomics:

- The simulation exercises use small components to produce toy cars. They are attractive to small children, therefore use caution when storing the components and keep them away from small children to prevent choking.
- The wooden pegs used to mount the wheels are made of a hard wood and should provide stable use over a long time. However, all wood will absorb moisture in high humidity conditions causing a slight swelling of the fibers and resulting is a tight fit of the wheel assembly. If this happens, the pegs may be reconditioned to remove the excess moisture by following the process **Instructions for microwave drying wooden pegs.doc** provided on the CD.
- If a tight peg / wheel assembly is difficult to remove, use the wheel extraction tool provided. Follow the instructions as shown.

To remove a tight wheel assembly, gently slide the wheel extraction tool under the wheel and around the axle peg.

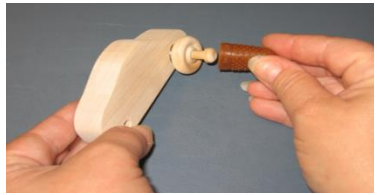


Slowly pry up against the underside of the wheel or disk, with the tip of the tool centered with the peg, to bring the peg straight out of the hole.



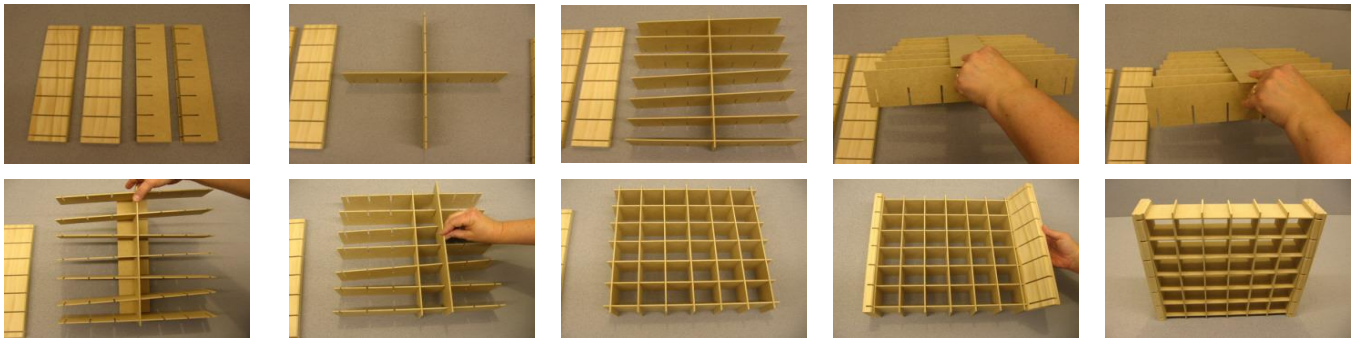
Gently rock the axle back and forth while pressing downward on the extraction tool handle. Use care not to flip the wheel and disk into the air. Do not bend the tool – press slowly and rock the peg loose.

- When inserting the wheel / peg assembly onto the car body, use a slight clockwise twist of the peg to ease insertion. Use the ergonomic tool provided to grip the peg and prevent finger soreness over the duration of the simulation event.



Assemble the Heijunka Box. (Note: Box is part of the Deluxe *Plus* Heijunka or LM Heijunka Upgrade packages – if you do not have a box, use color tape to create squares on a table surface to act as the box)

1. Caution: The hardboard material used is very stiff, and will crack if bending pressure is applied. Use care and go slowly to assure continued long use of the Heijunka Box.
2. Start by assembling the center boards by placing the first board with the open slots up.
3. Insert all cross boards with their slot down.
4. Lay a board across the intersection and slowly lift and rotate the partial box over onto its back
5. Insert the remaining cross boards, carefully juggling each interconnecting board until the slots line up
6. Attach the side brace boards by aligning the slot cuts with the cross board edges. The brace boards are slightly wider than the cross boards, which should align with the bevel cut edge of the brace.
7. Stand the Heijunka Box upright on a level surface.
8. When finished using the box, disassemble the box carefully so the brittle edges do not crack. Store in the protective foam lined kit container.



Simulation Support Items

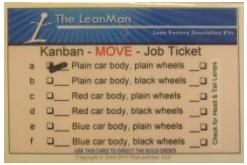
The Kanban Simulation uses several kanban related items during the simulation process. Some are less obvious than others. The facilitator may choose to include any of them, or exclude them, to see the affect on flow at any time during the simulation exercise.

The slotted blocks act as the kanban post. They hold the kanban production and kanban move cards while waiting to be acted upon. Typically in this simulation they are at the warehouse operation, but could also be at the planning dept or at the stockroom.

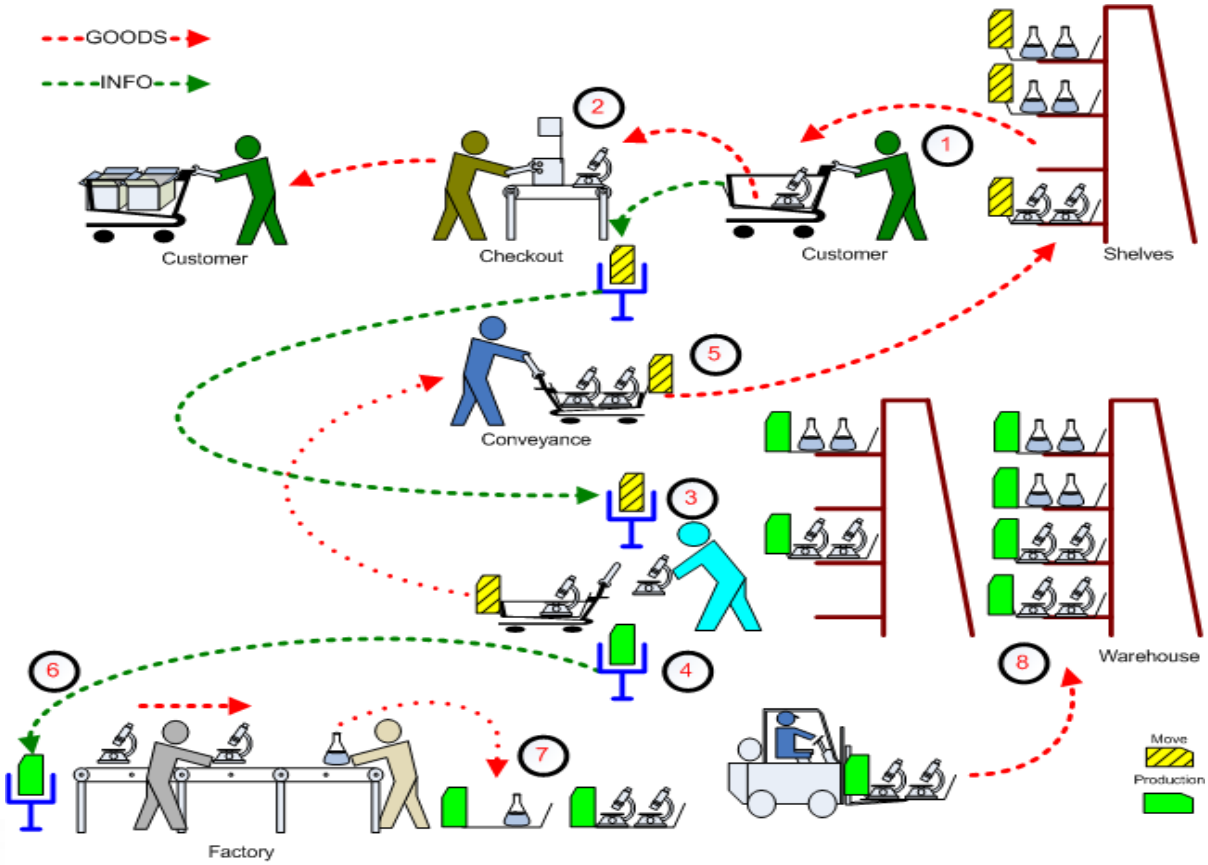
The kanban Move card, also known as the Job Ticket card in the older simulation kits, acts as the single kanban card system's main kanban for conveying specific information such as model type and options. The kanban Production card is used in the dual kanban system, and circulates on the factory side, while the Move card circulates on the delivery side.

Other types of kanban such as the kanban signal flags can also be used to trigger action such as signaling conveyance to pick up and deliver something. The material requisition card can be used to order just the amount of inventory needed to maintain flow and low inventory cost.

Other support items such as the wheel assembly holding fixtures and plastic kit bags are used to develop flow and lean practices.



Supermarket Concept and the use of Kanban Cards



Kanban Simulation with Heijunka

Kanban Cards

Refer to the supermarket concept flow diagram:

1. A customer picks up the goods he wants from the shelf.
2. At the checkout, the move card is collected into a kanban post (a collection box)
3. Move cards are sent to the warehouse. As goods are picked, the move card is exchanged with the production card that was attached to the goods.
4. As the exchange takes place, production cards are collected into another kanban post.
5. The goods are retrieved from the warehouse and delivered to the supermarket shelves with the move cards attached.
6. Production cards are brought back to the factory, where operators will manufacture only the amount indicated by the production cards.
7. When production is completed, production cards are attached to the goods.
8. Goods are then transferred to the warehouse.

End of Cycle.

Excerpt from The New Manufacturing Challenge by Kiyoshi Suzaki 1987

Exercise Scenario: The ZoomZoom Car Company

- The ZoomZoom Car company sales cars from its Showroom, where all six models are typically on display, although one or two may have been delivered and not yet replenished.
- The Customer can choose from any of the car models although not all models may be available on hand for immediate delivery. The customer is limited to placing only one order every two minutes. Cars not yet on-hand may be ordered and the sales admin person records the model and the time the order was placed. Delivery takes place as soon as the replenishment car arrives from the warehouse, and the sales admin records the time. Delivery is usually immediate from the showroom stock, but the company advertises a lead time of no more than two minutes. A car delivered two minutes or longer after the order is placed is considered late.
- The Showroom is replenished from the ZoomZoom Warehouse, where typically all six models are in stock. Replenishment orders are usually satisfied immediately from stock, although the lead time goal from the factory is less than two minutes when waiting for a replenishment order to arrive.
- The Factory consists of a Planning Dept, a Stockroom, and an Assembly Line. Orders sent from the Warehouse are received by planning and issued to the Factory to initiate the replenishment process. Orders are processed in the order received.
- The six car models are: 1) plain car with plain wheels 2) plain car with black wheels 3) red car with plain wheels 4) red car with black wheels 5) blue car with plain wheels and 6) blue car with black wheels.

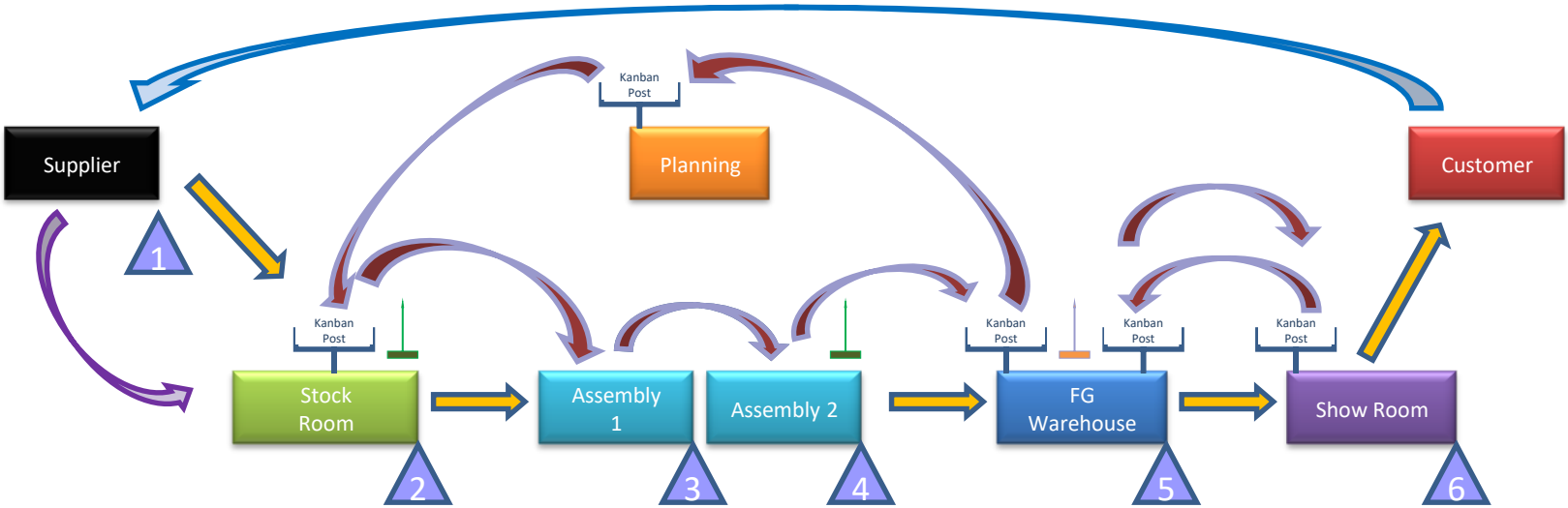
Facilitator note: additional models can be created using Avery ¼” yellow and red sticker dots as head and tail lamps.

Things to do during each exercise:

- Each exercise requires 8 to 10 participants to run the simulation and any number of participants in the observation team.
- Place the participant placemats and kit materials around the tables as shown in the suggested room set up. Note: a good distance between the showroom and warehouse is recommended. Place the Customer List at the customer station. If used, assemble the Heijunka Box following the pictorials.
- Have the participants sit and read the process on their placemat, and if extra participants are available as observers, tell them to stand behind the hands-on participants and watch the action.
- Conveyance people move materials and kanban cards as needed. If a department calls out “Conveyance” respond to that call and ask what is to be moved if not obvious. Note: room arrangements may require more than one conveyance person.
- Observers perform the 10-Second Test to look for NVA opportunities and graph the results. Use the observations for discussion after the event. Stop the simulation (freeze action) and observe the position of kits, materials, work in progress, stock levels etc. Discuss ways to improve. Start back up and run until concepts are understood.
- For exercise 3 and 4, have the timekeeper call start when ready and start the timer. Tell everyone to follow their process. Timing is very important, so it will naturally require a bit of time to get everyone accustomed to their role and the expectations placed upon them. Option: do not use a time keeper and just flow at the rate the operators are able to process orders. You may find decreasing the order frequency from two minutes to one minute a bit of fun, and should actually work for exercise #4.

Exercise #1

Kanban Single Card Customer-Pull Method



Baseline configuration.

Customer demand-pull initiates replenishment using a single move kanban card (job order card) request from showroom to finished goods, and from finished goods to the Planner.

Planner pushes stockroom to push product to finished goods. Raw materials are delivered from the supplier as they become available.

Kanban Single Card Customer-Pull Method

The Supplier takes in completed cars and disassembles them into piles of components which are delivered to the stockroom as they become available. A kanban signal flag may be used to alert Conveyance to deliver the materials to the Stock Room.

The Stock Room receives inventory from the supplier as it is available (MRP Push). Conveyance will see the raised flag at the supplier and deliver the materials to the stockroom, and return any empty totes from the stockroom back to the supplier. The Stock Room receives Job Kanban Cards with car models checked from the Planner. Upon receiving a card, picks the necessary component materials and places them into a kit bag along with the Job Kanban Card, and places the bag at the output area and raises the Kanban Signal Flag for the Conveyance person to pick up the kit bag and deliver it to the Assembly 1 input, and returns any empty kit bags to the Stock Room.

The Assembly 1 and Assembly 2 operators build the subassemblies and complete the car, placing it at the output along with the Job Kanban Card, and raises the Kanban Signal Flag for Conveyance to deliver the product to the Finished Goods Warehouse. To simulate labor variation, plain models with black wheels require a 5 second delay at assembly 2, Red models with black wheels delay 10 seconds, and Blue models with black wheels delay 15 seconds before passing to finished goods. No other work can be performed while waiting out the delay.

Facilitator Option: A Detail operator placed between assy 1 and assy 2 operators applies the Head and Tail lamps to the car body as specified on the Job Order card. This option provides some flexibility in adding a participant to the simulation event.

Kanban Single Card Customer-Pull Method

The Warehouse receives replenishment orders from the Show Room as a Job Kanban Card. If a matching car is in stock, the FG Administrator sends the car from stock and its Job Kanban Card to the Showroom, and returns the Show Room Job Kanban Card to the Planner for replenishment of the warehouse stock. If no match yet exists, the FG Admin holds the Show Room card until a matching car arrives. A kanban signal flag may be used to initiate a Conveyance move.

The Show Room sells cars either from on-hand stock or takes an order by photo. As a car is delivered to the Show Room, the Show Room admin person removes the Job Kanban Card and sends it to the FG Warehouse for replenishment as the car is delivered to the customer, or if replacing Show Room stock, leaves the card with the car and moves both to stock. Delivery to the customer for all cars is on-time if done in under two minutes, regardless if taken from stock or ordered from the factory. Note: use a 1 to 6 numbered die to select a car.

The Customer orders one car every two minutes at random. Upon delivery sends the Car to the Supplier for disassembly back into components. On-time delivery metrics are maintained by the customer.

The Conveyance person(s) moves material as requested, either by hearing “conveyance” being called out by an operator or by observing the presence of a raised kanban flag. Priority attention is discussed and assigned by the team as part of the kaizen discussions.

The Planner receives order kanbans from the warehouse and initiated replenishment by sending the order to the stockroom.

Tools and Support Items, and opportunities for observers to take notes:

The Stock Room requires raw components, kit bags and Kanban Cards to perform its function. The raw components are supplied as part of the material loop used to sustain the simulation event without regard to the finite number of items in the Car Factory Kit. The kit bags are intentionally limited to 5 bags. The backward flow of empty bags are necessary for the Stock Room to function, and is dependant upon a downstream process to "remember" to perform this side task.

The Assembly 1 person loads subassembly fixtures with the 4 subassemblies necessary to complete the car by the Assembly 2 person. The number of fixtures is 5 and therefore must be returned backward upstream in order for the Assembly 1 person to continue. Both build the car according to the Job Card.

The Warehouse person maintains a stock of completed cars which is used to replenish the Show Room stock upon demand. This person acts as the gate keeper flowing cars in one direction and replenishment Kanban Cards in the other. The single Kanban Card can be a bit confusing so the Warehouse Admin person must take extra steps to keep track of requests where on-hand inventory does not have the needed model.

The Show Room person sells cars for on-hand stock, or takes an order for the model that is missing. Since it's already on the replenishment loop, the sales person must take extra steps to record the model and time ordered, and track on-time delivery performance. On-Time is <= two minutes.

Use of multiple types of kanbans:

The use of kanban types is in part dependent upon the room setup and distance between operators in the process flow. The greater the distance for this first simulation event provides opportunities to fully explore the various methods.

The Stock Room uses a kanban signal flag, monitored by Conveyance, to move materials out of its area. It also flows the Kanban Job Card from planning through to assembly, using it to also control what kit materials are needed.

The Assembly 1 and assembly 2 operators build the car according to the Job Order kanban card. Assembly 2 may also use a kanban signal flag for Conveyance to move materials if the distance to the Warehouse is great.

The Warehouse person uses a kanban post to receive replenishment kanban cards from the Show Room, and may use one to deliver replenishment kanban cards to Planning. The Warehouse may also use a kanban signal flag to Conveyance to move materials or cards.

Kanban types may be visual such as flags or Andon lights; aural devices such as verbal calls or buzzers; or physical devices such as kanban cards and kanban squares.

Use of inventory buffers and Earned Value metrics:

EV = Sales – COGS – Capital; capital is the number of tables, chairs, fixtures, bags, totes, etc. used.

The Supplier inventory (1) is not part of the “company” inventory until transacted to Stock. Do not count it as part of EV unless it has been delivered to the stockroom.

The Stock Room inventory buffer (2) is the sum of the components on hand. For EV calculations, consider picked kits as raw inventory.

The Assembly 1 (3) and Assembly 2 (4) inventory is the sum of the WIP kits at each station.

The Warehouse inventory (5) is the sum of the completed cars on hand in stock, and any undelivered cars waiting for Conveyance.

The Show Room inventory (6) is the sum of the completed cars on hand in stock. Any undelivered cars waiting for Customer pickup are assumed delivered.

Note: watch for piles of inventory between operation stages caused by the PUSH system and individual stage cycle time imbalance. Stop the simulation (freeze action) and have the participants count the inventory items at each station and enter the numbers on the excel metrics chart. Compare the results as you make improvements to flow.

Kanban Single Card Customer-Pull Method

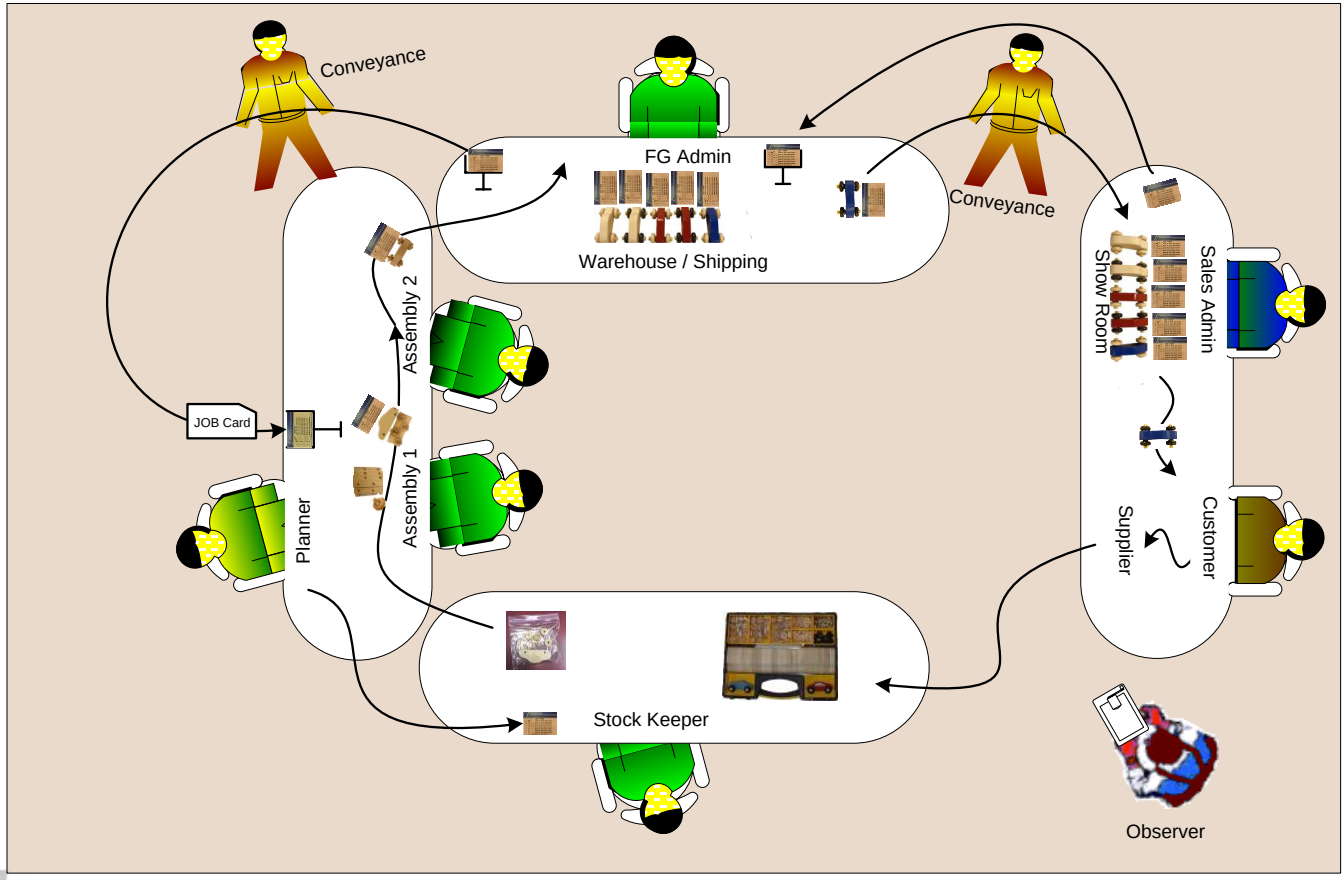
	A	B	C
1	Financial Chart		Single Kanban System
2		#	$
3	Sales		
4	# Delivered x $500 ea	20	$ 10,000.00
5	**Total SALES =**		**$ 10,000.00**
6			
7	COGS: Cost of goods sold		
8	Sales Raw Mtl = # sold x $100 ea	20	$ 2,000.00
9	Labor = # workers x $165 ea	8	$ 1,320.00
10	Labor OT = total # minutes OT x $40 ea	0	$ -
11	Overhead = # tables used x $10 ea	4	$ 40.00
12	Scrap = # rejects x $100 ea	0	$ -
13	**Total of COGS =**		**$ 3,360.00**
14			
15	Capital Charges		
16	Work in Progress: WIP		
17	Stockroom = #kits in bags x $100 ea	3	$ 300.00
18	Assembly 1 = # assembled subs x $10 ea	8	$ 80.00
19	Assembly 2 = # of partial cars x $60 ea	2	$ 120.00
20	Warehouse = # cars in stock x $100 ea	5	$ 500.00
21	Show Room = # cars in stock x $100 ea	5	$ 500.00
22	Facilities		
23	# tables used x $15 ea	4	$ 60.00
24	# Tool Fixtures used x $10 ea	5	$ 50.00
25	# Tool material totes used x $5 ea	5	$ 25.00
26	**Total of CAPITAL CHARGES =**		**$ 1,635.00**
27			
28	EVA = Sales - COGS - Capital Charges		
29	**Earned Value =**		**$ 5,005.00**
30	**Gross Margin =**		**50.1%**

Facilitator: Stop the 1st event and have the operators freeze movement.

Go around to each operator and count the work-in-progress inventory, capital equipment, and resources at each process location and fill in the Financial Chart and the Inventory Chart. Both are Excel worksheets that calculate the results. Feel free to add items to the chart for working capital and facilities if they are important to your participants.

During the simulation, the observers performed the 10-Second Test to locate waste and improvement opportunities. Discuss these observations with the team and how they might affect the bottom line EV and Margin.

Suggested room set up – 1st exercise



Exercise Number 1 – Single Kanban Card pull system.

- The purpose of this first round of simulation is to provide an opportunity for each participant to become accustomed to their role and the flow of product when using a kanban card system. We will use the LeanMan Job Ticket Card as the kanban. The customer role is to demand cars at random from the Showroom, which initiates the kanban pull of a replacement car through the manufacturing process and back into the Showroom.

- In this first exercise, the kanban card is removed from the car at the time of delivery and sent to the warehouse where the replenishment order is satisfied from warehouse finished goods stock if available, or as soon as the replenishment car is received from the factory. Either way a replenishment car for finished goods is needed, so the Warehouse sends the kanban to the planner who in turn sends the order to the stock room for the stock keeper to initiate build of the replenishment item by picking the job kit and delivering it to the assembly line.

- To simulate labor variation, each model with black wheels requires a delay at final assembly.

- Run the simulation for several minutes to establish a flow. The team should then stop a few times to discusses the pros and cons of this system, such as erratic flow, lack of a prioritizing system, and product cycle time variation. The discussion is augmented by team observers performing the 10 Second Test to discover waste opportunities. When this process is understood, proceed to Exercise #2

Customer: Exercise #1

Initial Conditions

- Hold the 1st order until at least 3 cars have been delivered to the showroom

a b c d e f

Tasks

- Task1: order 1 car every two minutes by picking randomly from the showroom inventory, or sales photo. Try to keep the selection mixed, i.e. there are only a few of the color car bodies so order them infrequently.
- OPTIONAL Task 2: The simulation may be run in loop mode to provide sufficient materials to support an extended simulation period. If true, then as each car is delivered disassemble it into its component parts. Use the ergonomic wheel extractor tool and peg finger guard as needed.
- Send the components to the Stockroom. Note that it is particularly important the color car body parts are returned immediately due to the few number of them available.

  (if distance is involved, call Conveyance transport the materials.)

Constraints

- Only one Car order can be placed every two minutes.
- On-Time delivery as advertised is under two minutes.

Ergonomic Assembly Tool

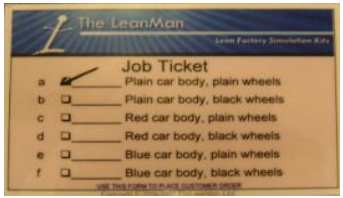
To remove a tight wheel assembly, gently slide the wheel extraction tool under the wheel and around the axle peg.

Slowly pry up against the underside of the wheel or disk, with the tip of the tool centered with the peg, to bring the peg straight out of the hole.

Gently rock the axle back and forth while pressing downward on the extraction tool handle. Use care not to flip the wheel and disk into the air. Do not bend the tool – press slowly and rock the peg loose.

Showroom: Exercise #1

Initial Conditions



- The showroom holds 1 each of the 6 models, with a **Kanban Card** attached to each (use Job Ticket Card).

Tasks

- Task 1: As the Customer demands a car model, remove its **Kanban Card** and deliver the car from inventory to the customer. The customer may order only 1 car every two minutes by picking randomly from the available showroom inventory, or by sales photo (a thru f). If the car is not yet available, record the time the order is placed and the time the car is delivered.
- Task 2: accept completed cars from the warehouse along with its **Kanban Card**.
- Send the **Kanban Card** removed from the delivered car to the Warehouse for replenishment. (if distance is involved, call Conveyance to transport the card.)

Constraints

- Only one Customer order can be placed every two minutes.
- Customer can only choose from available showroom stock.

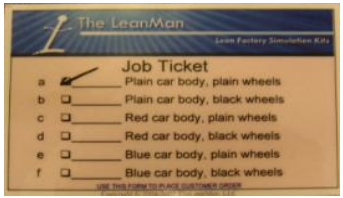
Metrics Option

- The back of the Job Ticket Card can be used to record factory cycle time by recording the time the order is placed to the Warehouse and then again as the car is delivered to the Showroom. Goal is less than two minutes.
- Record the exercise time in minutes, the total number of cars delivered and the cycle time for each. Use Little's Law to calculate average WIP.

TH (avg) = WIP (avg) x Cycle Time (avg)

Finished Goods Warehouse: Exercise #1

Initial Conditions



- Initial start up conditions: finished goods inventory holds 1 each of the 6 models, with a **Kanban Card** attached to each (use Job Ticket Card).
- Maintain an open order metric sheet, and record open orders as detailed in the steps below.

Tasks

- Task 1: Accept order requests from the Showroom. This will be via a **Kanban Card** with the specific car body, color and wheel choice marked. If a match exists in the warehouse Inventory, send the car and **Kanban Card** from inventory to the Showroom. (if distance is involved, call Conveyance to transport the material.) If no on-hand inventory match exists, record the open order car type and color choice on the open order metric sheet.
- Task 2: Accept the completed car and **Kanban Card** from Assembly 2. Use the open order metric sheet to determine if an open order request from the Show Room is active for this specific car type, and if true send the car and **Kanban Card** to the Showroom. Send the **Kanban Card** received from the Showroom to the Planning Department for replenishment.

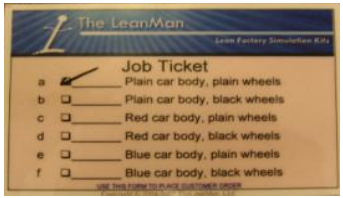
  (if distance is involved, call Conveyance to transport the card or car as appropriate.)
- If no open order exists, send the car and **Kanban Card** to the warehouse FG inventory.

Constraints

- Only one Showroom order can be placed every two minutes.
- Factory lead time goal is under two minutes.

Planning Dept: Exercise #1

Initial Conditions



- Initial start up conditions: the Showroom and Finished Goods each holds 1 each of the 6 models, so to start create 12 kanbans, two of each car type. The completed cars will have a **Kanban Card** attached to each (use Job Ticket Card).
- Issue each of the 12 kanbans to the stockroom to begin the simulation.

Tasks

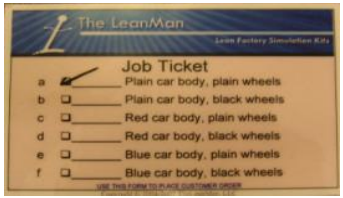
- Task 1: Accept **Kanban Card** from the warehouse and verify the card is clearly marked with a car body and wheel color selection. (if the wet erase marker has smudged, make it readable)
- Send the **Kanban Card** to the Stockroom to initiate the manufacturing cycle.
  (if distance is involved, call Conveyance to transport the card.)

Constraints

- The factory lead time goal is less than two minutes.

Stockroom: Exercise #1

Initial Conditions



- Stock tray with wheels, pegs, disks and bodies available, and five Zip bags used to hold picked kits.
- Locate the ergonomic wheel extraction tool at the station.

Tasks

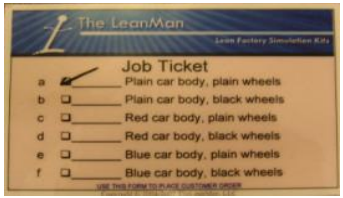
- TASK 1: receive a **Kanban Card** with car type checked off. Pick the parts and color items as appropriate, place all components into kit bag along with the **Kanban Card**.
- Send the kit bag to the Assembly 1 input.
  (if distance is involved, call Conveyance to transport the bag.)
- OPTIONAL: if simulation is run as a loop, receives component materials from the Supplier and replenishes the stock tray.

Constraints

- The factory lead time goal is less than two minutes.

Assembly 1: Exercise #1

Initial Conditions



- Locate the five subassembly fixture blocks at the station.

Tasks

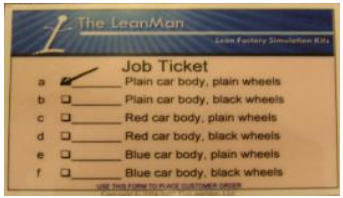
- TASK 1: Accept Zip bag with picked kit from the Stockroom and empty the bag. Verify the material matches the requirements for the model selected on the **Kanban Card** . If not, return the kit to the Stockroom. If correct, return the empty bag to the Stockroom. (if distance is involved, call Conveyance to transport the bag.)
- TASK 2: Assemble the Axle, Wheel and Disk subassembly and mount onto the holding fixture. Do this for each of the four subassemblies.
- Send the holding fixture, car body and **Kanban Card** to the Assembly 2 input. (if distance is involved, call Conveyance to transport the material.)

Constraints

- The total factory lead time goal is less than two minutes.

Assembly 2: Exercise #1

Initial Conditions



- Locate ergonomic peg insertion tool at station. Insert pegs with a slight twist as you push the peg into the hole. Remove with a slight twist as you pull the peg from the hole.

Tasks

- TASK 1: Accept the car body, the subassembly holding fixture and the **Kanban Card** from Assembly 1.
- TASK 2: Assemble the Axle/Wheel/Brake subassemblies (4) onto the car body. Return the empty holding to Assembly 1.
  (if distance is involved, call Conveyance to transport the fixture.)
- TASK 3: Perform inspection and rework as necessary. Wheels should rotate freely, adjust as needed. Wheels and car body should be the correct color per the **Kanban Card**.
- If the car has black wheels, delay the car for 5 seconds, if Red with black wheels, delay 10 seconds, and if Blue with black wheels delay 15 seconds. (this simulates a labor variation in the models)
  During this waiting time you are not to perform any other task.
- Send the completed car and **Kanban Card** to the Finished Goods Warehouse input.
  (if distance is involved, call Conveyance to transport the material.)

Ergonomic tool in use

Constraints

- The total factory lead time goal is less than two minutes, all models.

Timekeeper: Exercise #1

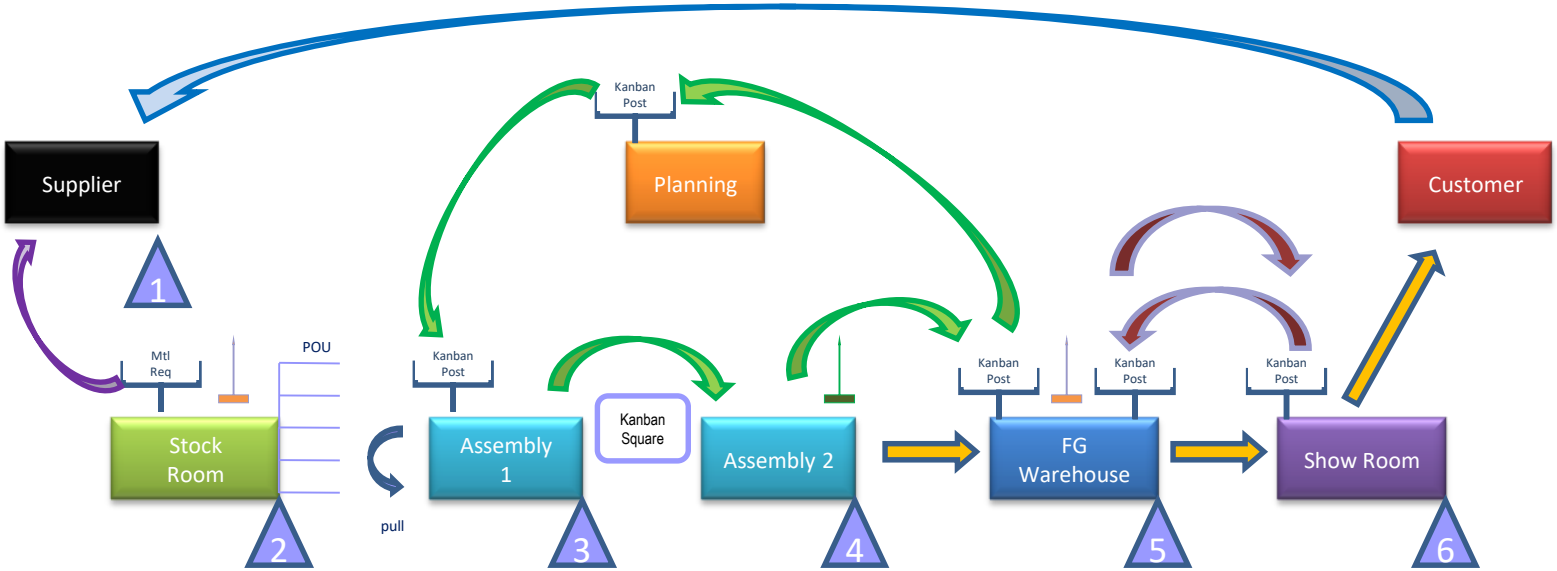
Keep time for the simulation event, provide the time stamps used for metrics.

Timekeeping

- Start the simulation event and the stopwatch. Time the overall event and run for at least 20 total minutes (40 if event time permits), then call stop.
- At time zero, call start.
- The simulation operation will run for a total of 20 minutes (or 40) on the stopwatch.
  Call “all stop” to end the simulation. You may allow conveyance to continue
  for another minute until all cars in process are delivered and metrics are complete.

Exercise #2

Kanban Dual Card Customer-Pull Method



Dual Kanban configuration.

Customer demand-pull initiates replenishment using a move kanban card (job order card) request from showroom to the finished goods warehouse, and the warehouse uses a production kanban sent to the Planner for replenishment.

Additional lean improvements such as local point of use inventory and supplier kanban release are implemented.

Kanban Dual Card Customer-Pull Method

The Supplier takes in completed cars and disassembles them into piles of components. Upon receiving a Material Requisition Card from the Stock Room gathers the requested components into a tote bin and calls Conveyance to deliver the item to the Stock Room.

The Stock Room manages inventory, and when a component level is low, raises the kanban Signal Flag and places a Material Requisition Card with the needed items checked into the output area by the flag. The Stock Keeper monitors the Assembly 1 area POU levels and refills as appropriate.

The Assembly 1 operator receives Production Kanban Card with a car model checked from the Planner. Upon receiving a card, picks the necessary component materials from the POU inventory and assembles the 4 subassembly items, placing each into KanBan Square located between Assembly 1 and Assembly 2 positions along with the car body and Production Kanban Card. Note: The Assembly 1 operator may only move materials into the kanban square when it is empty. If the Assembly 2 person has not yet cleared the square, then wait.

The Assembly 2 operator pulls the material from the square and completes the car, waits any required time delay (if black wheels) and then placing the car at the output along with the Production Kanban Card, and raises the Kanban Signal Flag for Conveyance to deliver the product to the Finished Goods Warehouse. The Assembly 2 operator may only retrieve material from the kanban square after delivering any current car in process. To simulate labor variation, plain models with black wheels require a 5 second delay at assembly 2, Red models with black wheels delay 10 seconds, and Blue models with black wheels delay 15 seconds before passing to finished goods. No other work can be performed while waiting out the delay.

Kanban Dual Card Customer-Pull Method

Facilitator Option: The Detail person, if used, can be added in after Assembly 2. In this case, the detail person delivers the car to the warehouse via conveyance.

The Warehouse receives replenishment orders from the Show Room as a Move Kanban Card. If a matching car is in stock, the Warehouse Administrator sends the car and the Move Kanban Card to the Showroom, and returns the Production Kanban Card to the Planner for replenishment. If no match yet exists, the Admin holds the Move card until a matching car arrives. A kanban signal flag may be used to initiate a Conveyance move.

The Show Room sells cars either from on-hand stock or by photo. As a car is delivered, the Show Room removes the Move Kanban Card and sends it to the FG Warehouse for replenishment. Delivery for all cars is on-time if done in under two minutes.

The Customer orders one car every two minutes at random. Upon delivery sends the Car to the Supplier for disassembly back into components.

The Conveyance person(s) moves material as requested, either by hearing “conveyance” being called out by an operator or by observing the presence of a raised kanban flag.

The Planner receives Production kanbans from the warehouse and initiates replenishment by sending the order to the Assembly 1 operator.

Kanban Dual Card Customer-Pull Method

	A	B	C	D	E
1	Financial Chart		Single Kanban System		Dual Kanban System
2		#	$	#	$
3	Sales				
4	# Delivered x $500 ea	20	$ 10,000.00	20	$ 10,000.00
5	**Total SALES =**		**$ 10,000.00**		**$ 10,000.00**
7	COGS: Cost of goods sold				
8	Sales Raw Mtl = # sold x $100 ea	20	$ 2,000.00	20	$ 2,000.00
9	Labor = # workers x $165 ea	8	$ 1,320.00	8	$ 1,320.00
10	Labor OT = total # minutes OT x $40 ea	0	$ -	0	$ -
11	Overhead = # tables used x $10 ea	4	$ 40.00	4	$ 40.00
12	Scrap = # rejects x $100 ea	0	$ -	0	$ -
13	**Total of COGS =**		**$ 3,360.00**		**$ 3,360.00**
15	Capital Charges				
16	Work in Progress: WIP				
17	Stockroom = #kits in bags x $100 ea	3	$ 300.00	0	$ -
18	Assembly 1 = # assembled subs x $10 ea	8	$ 80.00	4	$ 40.00
19	Assembly 2 = # of partial cars x $60 ea	2	$ 120.00	1	$ 60.00
20	Warehouse = # cars in stock x $100 ea	5	$ 500.00	5	$ 500.00
21	Show Room = # cars in stock x $100 ea	5	$ 500.00	6	$ 600.00
22	Facilities				
23	# tables used x $15 ea	4	$ 60.00	4	$ 60.00
24	# Tool Fixtures used x $10 ea	5	$ 50.00	0	$ -
25	# Tool material totes used x $5 ea	5	$ 25.00	0	$ -
26	**Total of CAPITAL CHARGES =**		**$ 1,635.00**		**$ 1,260.00**
28	EVA = Sales - COGS - Capital Charges				
29	**Earned Value =**		**$ 5,005.00**		**$ 5,380.00**
30	**Gross Margin =**		50.1%		53.8%

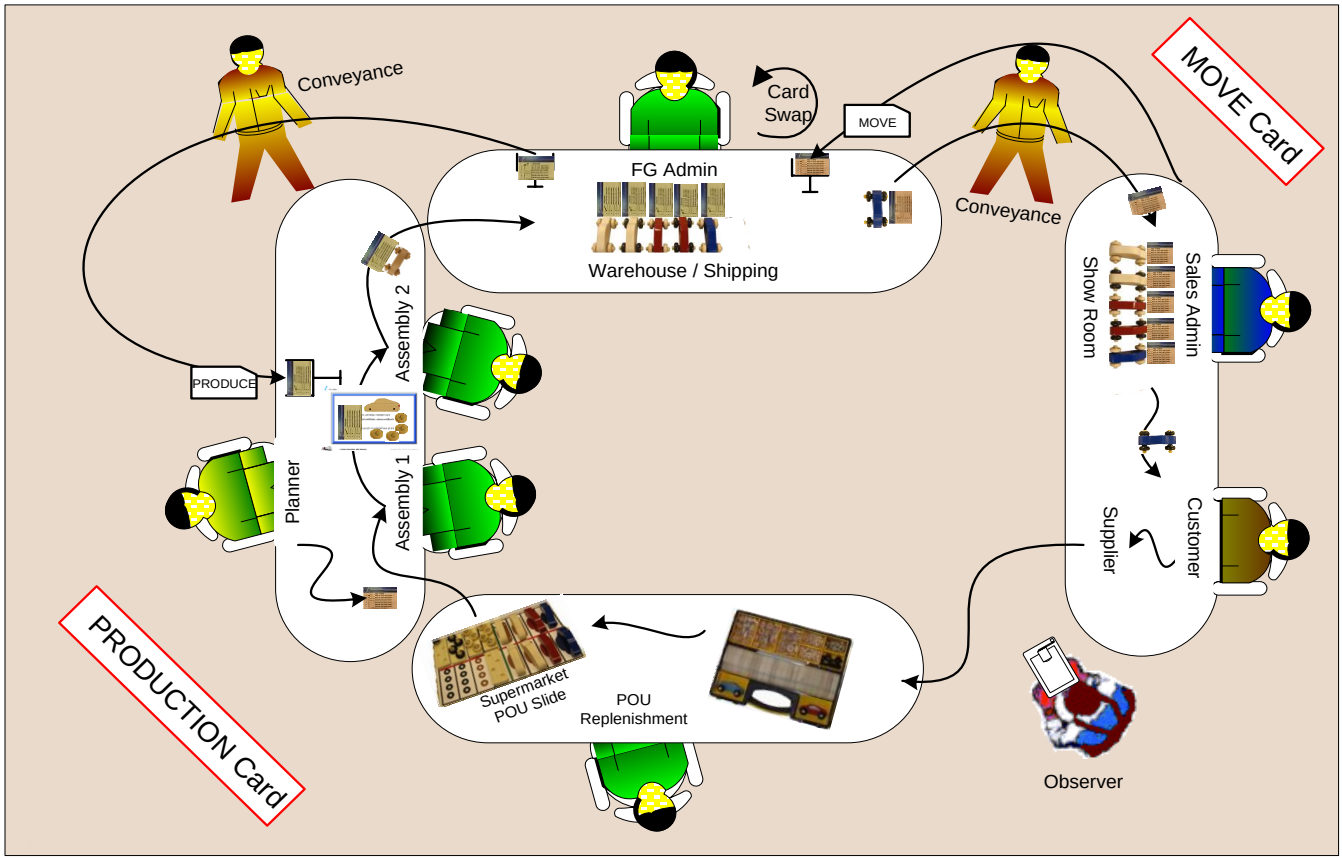
Facilitator: Stop the 2nd event and have the operators freeze movement.

Go around to each operator and count the work-in-progress inventory, capital equipment, and resources at each process location and fill in the Financial Chart and the Inventory Chart Excel worksheets.

Discuss the observation notes taken during the event with the team and how the use of a dual-card system, POU inventory, and kanban release of raw stock from the supplier have affected the bottom line EV and Margin.

Suggested room set up – 2nd exercise

2



Exercise Number 2 – Two Kanban Card pull system

- The purpose of this second round of simulation is to introduce the more classical two-kanban system, using a MOVE Card to manage completed product and a PRODUCTION Card to manage the factory. We will use the LeanMan Job Card (MOVE) and the Heijunka Card (PRODUCTION) respectively.

- This system provides a bit more control for situations where the delivery point is separated at a distance from the manufacturing operation. The operational difference between exercise #1 and #2 concerning the benefit of two cards will be visually obvious as the simulation proceeds.

- We will also implement a point of use inventory supermarket slide board. This lean tool will provide the team with better control of their process cycle time and execution to plan, and eliminate the waste of moving kit bags back upstream.

- We will implement a kanban square material regulator between Assembly 1 and assembly 2 positions, locate each within arms reach of the square, and eliminate the waste of moving the subassembly holding fixtures back upstream.

- Participants are invited to stop the simulation at any time to discuss observed pros and cons of this dual card system, and to gather data for metric calculations.

Customer: Exercise #2 [same as #1]

Initial Conditions

- Hold the 1st order until at least 3 cars have been delivered to the showroom

a b c d e f

Tasks

- Task1: order 1 car every two minutes by picking randomly from the showroom inventory, or sales photo. Try to keep the selection mixed, i.e. there are only a few of the color car bodies so order them infrequently.
- OPTIONAL Task 2: The simulation may be run in loop mode to provide sufficient materials to support an extended simulation period. If true, then as each car is delivered disassemble it into its component parts. Use the ergonomic wheel extractor tool and peg finger guard as needed.
- Send the components to the Stockroom. Note that it is particularly important the color car body parts are returned immediately due to the few number of them available.

  (if distance is involved, call Conveyance transport the materials.)

Constraints

- Only one Car order can be placed every two minutes.
- On-Time delivery as advertised is under two minutes.

Ergonomic Assembly Tool

To remove a tight wheel assembly, gently slide the wheel extraction tool under the wheel and around the axle peg.

Slowly pry up against the underside of the wheel or disk, with the tip of the tool centered with the peg, to bring the peg straight out of the hole.

Gently rock the axle back and forth while pressing downward on the extraction tool handle. Use care not to flip the wheel and disk into the air. Do not bend the tool – press slowly and rock the peg loose.

Exercise #2
Customer Order Sequence

Random Demand

Use a wet-erase marker to check off the orders as they are placed, and again as they are delivered.

This is **a suggested sequence** if the simulation is to be run in competing teams so metrics are to some extent comparable.

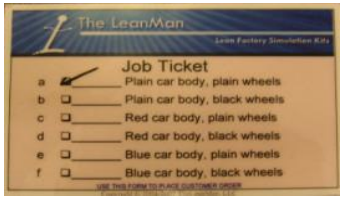
It also allows some comparisons between exercise 1 thru 4

Customer List - random sequence					
Seq			**Car**	**Wheels**	**Details**
Pitch 1		2 minutes			
1	a	☐ ☐	Plain	Plain	Yes
2	a	☐ ☐	Plain	Plain	Yes
3	b	☐ ☐	Plain	Black	Yes
4	a	☐ ☐	Plain	Plain	Yes
5	b	☐ ☐	Plain	Black	Yes
Pitch 2		2 minutes			
6	d	☐ ☐	Red	Black	No
7	e	☐ ☐	Blue	Plain	No
8	a	☐ ☐	Plain	Plain	Yes
9	c	☐ ☐	Red	Plain	No
10	f	☐ ☐	Blue	Black	No
Pitch 3		2 minutes			
11	a	☐ ☐	Plain	Plain	Yes
12	a	☐ ☐	Plain	Plain	Yes
13	a	☐ ☐	Plain	Plain	Yes
14	a	☐ ☐	Plain	Plain	Yes
15	b	☐ ☐	Plain	Black	Yes
Pitch 4		2 minutes			
16	a	☐ ☐	Plain	Plain	Yes
17	d	☐ ☐	Red	Black	No
18	e	☐ ☐	Blue	Plain	No
19	b	☐ ☐	Plain	Black	Yes
20	b	☐ ☐	Plain	Black	Yes

Customer List - random sequence					
Seq			**Car**	**Wheels**	**Details**
Pitch 5		2 minutes			
21	c	☐ ☐	Red	Plain	No
22	f	☐ ☐	Blue	Black	No
23	a	☐ ☐	Plain	Plain	Yes
24	d	☐ ☐	Red	Black	No
25	e	☐ ☐	Blue	Plain	No
Pitch 6		2 minutes			
26	a	☐ ☐	Plain	Plain	Yes
27	a	☐ ☐	Plain	Plain	Yes
28	a	☐ ☐	Plain	Plain	Yes
29	b	☐ ☐	Plain	Black	Yes
30	c	☐ ☐	Red	Plain	No
Pitch 7		2 minutes			
31	f	☐ ☐	Blue	Black	No
32	a	☐ ☐	Plain	Plain	Yes
33	b	☐ ☐	Plain	Black	Yes
34	d	☐ ☐	Red	Black	No
35	e	☐ ☐	Blue	Plain	No
Pitch 8		2 minutes			
36	a	☐ ☐	Plain	Plain	Yes
37	a	☐ ☐	Plain	Plain	Yes
38	b	☐ ☐	Plain	Black	Yes
39	c	☐ ☐	Red	Plain	No
40	f	☐ ☐	Blue	Black	No

Showroom: Exercise #2 [same as #1]

Initial Conditions



- The showroom receives 1 each of the 6 models, with a **Move Card** attached to each (use Job Ticket Card as the Move Kanban).

Tasks

- Task 1: As the Customer demands a car model, remove its **Move Card** and deliver the car from inventory to the customer. The customer may order only 1 car every two minutes by picking randomly from the available showroom inventory, or by sales photo (a thru f). If the car is not yet available, record the time the order is placed and the time the car is delivered.
- Task 2: accept completed cars from the warehouse along with its **Move Card**.
- Send the **Move Card** removed from the delivered car to the Warehouse for replenishment. (if distance is involved, call Conveyance to transport the card.)

Constraints

- Only one Customer order can be placed every two minutes.
- Customer can only choose from available showroom stock.

Metrics Option

- The back of the Job Ticket Card can be used to record factory cycle time by recording the time the order is placed to the Warehouse and then again as the car is delivered to the Showroom. Goal is less than two minutes.
- Record the exercise time in minutes, the total number of cars delivered and the cycle time for each. Use Little's Law to calculate average WIP.

TH (avg) = WIP (avg) x Cycle Time (avg)

Exercise #2
Order Delivery Metrics

Random Demand

Use a wet-erase marker to check off the orders as they are placed, and again as they are delivered.

Any order delivered two minutes or more after the customer places the order is considered late.

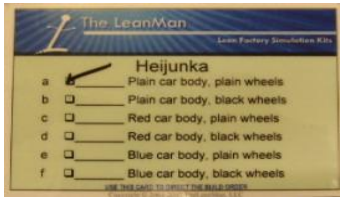
Customer List - random sequence					
Seq			Car	Wheels	Details
Pitch 1		2 minutes			
1	a	☐ ☐	Plain	Plain	Yes
2	a	☐ ☐	Plain	Plain	Yes
3	b	☐ ☐	Plain	Black	Yes
4	a	☐ ☐	Plain	Plain	Yes
5	b	☐ ☐	Plain	Black	Yes
Pitch 2		2 minutes			
6	d	☐ ☐	Red	Black	No
7	e	☐ ☐	Blue	Plain	No
8	a	☐ ☐	Plain	Plain	Yes
9	c	☐ ☐	Red	Plain	No
10	f	☐ ☐	Blue	Black	No
Pitch 3		2 minutes			
11	a	☐ ☐	Plain	Plain	Yes
12	a	☐ ☐	Plain	Plain	Yes
13	a	☐ ☐	Plain	Plain	Yes
14	a	☐ ☐	Plain	Plain	Yes
15	b	☐ ☐	Plain	Black	Yes
Pitch 4		2 minutes			
16	a	☐ ☐	Plain	Plain	Yes
17	d	☐ ☐	Red	Black	No
18	e	☐ ☐	Blue	Plain	No
19	b	☐ ☐	Plain	Black	Yes
20	b	☐ ☐	Plain	Black	Yes

Customer List - random sequence					
Seq			Car	Wheels	Details
Pitch 5		2 minutes			
21	c	☐ ☐	Red	Plain	No
22	f	☐ ☐	Blue	Black	No
23	a	☐ ☐	Plain	Plain	Yes
24	d	☐ ☐	Red	Black	No
25	e	☐ ☐	Blue	Plain	No
Pitch 6		2 minutes			
26	a	☐ ☐	Plain	Plain	Yes
27	a	☐ ☐	Plain	Plain	Yes
28	a	☐ ☐	Plain	Plain	Yes
29	b	☐ ☐	Plain	Black	Yes
30	c	☐ ☐	Red	Plain	No
Pitch 7		2 minutes			
31	f	☐ ☐	Blue	Black	No
32	a	☐ ☐	Plain	Plain	Yes
33	b	☐ ☐	Plain	Black	Yes
34	d	☐ ☐	Red	Black	No
35	e	☐ ☐	Blue	Plain	No
Pitch 8		2 minutes			
36	a	☐ ☐	Plain	Plain	Yes
37	a	☐ ☐	Plain	Plain	Yes
38	b	☐ ☐	Plain	Black	Yes
39	c	☐ ☐	Red	Plain	No
40	f	☐ ☐	Blue	Black	No

Finished Goods Warehouse: Exercise #2

Initial Conditions

- Initial start up conditions: finished goods inventory holds 1 each of the 6 models, with a **Production Card** attached to each (use Heijunka Card).
- At start up, the planner will issue six Move Cards to the warehouse to act as orders from the Showroom. Fill the orders as cars are available.



Production Card

Tasks

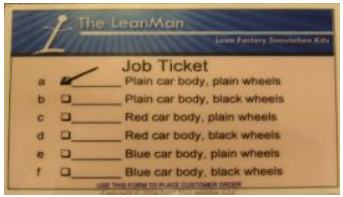
- Task 1: Accept order requests from the Showroom. This will be via a **Move Card** with the specific car body, color and wheel choice marked.

  If a match exists in the warehouse Inventory, swap the **Production Card** from the car with the **Move Card**, and send the car with **Move Card** to the Showroom. (if distance is involved, call Conveyance to transport the material.) If no match exists, set the **Move Card** aside until manufacturing delivers a car to match.
- Task 2: Accept the completed car and **Production Card** from Assembly 2. Check to see if a **Move Card** is waiting for a match request from the Show Room, and if true swap the **Production Card** and **Move Card** and send the car and **Move Card** to the Showroom.

  (if distance is involved, call Conveyance to transport the card or car as appropriate.)
- If no open order exists, send the car and **Production Card** to the warehouse FG inventory.

Constraints

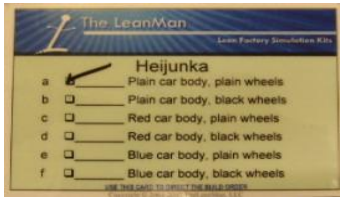
- Only one Showroom order can be placed every two minutes.
- Factory lead time goal is under two minutes.

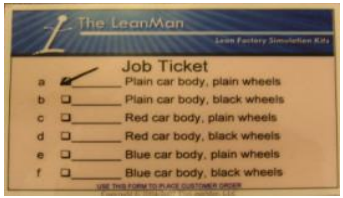


Move Card

Planning Dept: Exercise #2

Initial Conditions





- If not already set in place from exercise #1, the Showroom and Finished Goods each holds 1 each of the 6 models, so to start create 6 Production kanbans, one of each car type. The completed cars will have a **Production Card** attached to each (use Heijunka Card).
- Create 6 Move Cards, 1 for each of the 6 models, and call conveyance to deliver them to the Finished Goods Warehouse.
- Issue each of the kanbans to the stockroom to begin the simulation.

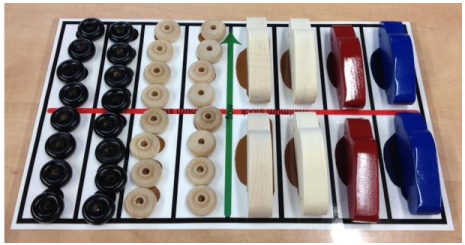
Tasks

- Task 1: Accept **Production Card** from the warehouse and verify the card is clearly marked with a car body and wheel color selection. (if the wet erase marker has smudged, make it readable)
- Send the **Production Card** to the Assembly 1 department to initiate the manufacturing cycle. (if distance is involved, call Conveyance to transport the card.)

Constraints

- The factory lead time goal is less than two minutes.

Stockroom: Exercise #2



Initial Conditions

- Stock tray with wheels, pegs, disks and bodies available, Supermarket Slide point of use (POU) inventory located within reach of the assembly 1 person, and the slide is loaded with components.

Tasks

- TASK 1: maintain the POU inventory levels on the slide as materials are withdrawn by the Assembly 1 person. Retrieve materials out of the stock tray as needed.

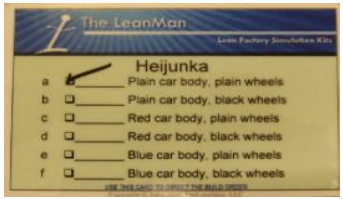
  OPTIONAL: if simulation is run as a loop, receives component materials from the Supplier and replenishes the stock tray.

Constraints

- The color car bodies are few in number and should take precedence to replenish as soon as they become available.

Assembly 1: Exercise #2

Initial Conditions



- Locate the kanban square between Assembly 1 and Assembly 2, and both stations should be located within arms reach of the kanban square for easy hand-off of materials.

Tasks

- TASK 1: Accept **Production Card** from the planner. Withdraw the necessary materials as specified on the **Production Card** from the POU slide. Note color choice for car body and wheels.
- Task 2: Place the car body and **Production Card** on the Kanban Square. Assemble each Axle, Wheel and Brake subassembly and place onto the kanban square as each is completed.
- Repeat step 1 and 2 for the next **Production Card** in the sequence received from the planner.

  Note: do not place any material onto the kanban square until the previous job has been completely removed by Assembly 2.

Constraints

- The total factory lead time goal is less than two minutes.

Kanban Square

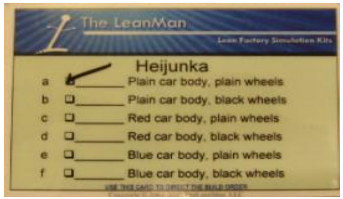
Place Car Body, Kanban Card

and 4 Wheel/Axle/Brake subassemblies here.

Place only one job of material here at a time

Assembly 2: Exercise #2

Initial Conditions



- Locate ergonomic peg insertion tool at station. Insert pegs with a slight twist as you push the peg into the hole. Remove with a slight twist as you pull the peg from the hole.

Tasks

- TASK 1: Remove the car body and the **Production Card** from the Kanban Square, and assemble each Axle/Wheel/Brake subassembly (4) onto the car body as they are placed into the square.
- TASK 2: Perform inspection and rework as necessary. Wheels should rotate freely, adjust as needed. Wheels and car body should be the correct color per the **Production Card**.
- If the car has black wheels, delay the car for 5 seconds, if Red with black wheels, delay 10 seconds, and if Blue with black wheels delay 15 seconds. (this simulates a labor variation in the models)

  During this waiting time you are not to perform any other task.
- Send the completed car and **Production Card** to the Finished Goods Warehouse input.

  (if distance is involved, call Conveyance to transport the material.)

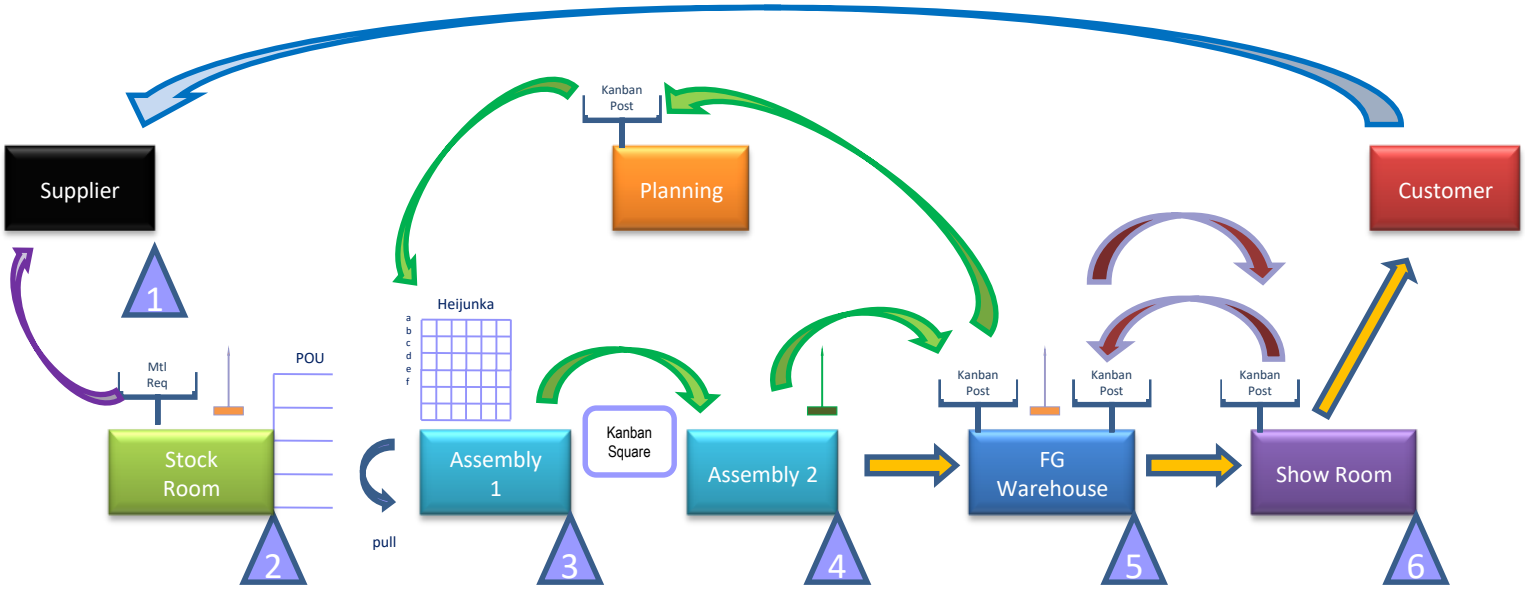
Constraints

- The total factory lead time goal is less than two minutes, all models.

Ergonomic tool in use

Exercise #3

Kanban Dual Card Method w/Heijunka



Dual Kanban configuration.

Lean improvement using a heijunka box sequencing method is implemented to level flow. Finished Goods is Held as low as possible but may be utilized by planning to hold additional completed cars to act as a buffer to maintain customer delivery on time. Extra cars are fit into available slots in the Heijunka Box as time permits.

Kanban Dual Card Method w/Heijunka

The Supplier takes in completed cars and disassembles them into piles of components. Upon receiving a Material Requisition Card from the Stock Room gathers the requested components into a tote bin and calls Conveyance to deliver the item to the Stock Room.

The Stock Room manages inventory, and when a component level is low, raises the kanban Signal Flag and places a Material Requisition Card with the needed items checked into the output area by the flag. The Stock Keeper monitors the Assy1 area POU levels and fills as appropriate.

The Assembly 1 person Pulls the Production Kanban Cards from the heijunka box in sequence, left column first going top to bottom, picks the necessary component materials from the POU inventory and assembles the 4 subassembly items, placing each into Kanban Square located between Assembly 1 and Assembly 2 positions along with the car body and Production Kanban Card. Note: The Assembly 1 operator may only move materials into the kanban square when it is empty. If the Assembly 2 person has not yet cleared the square, then wait.

The Assembly 2 operator pulls the material from the square and completes the car, waits any required time delay (if black wheels) and then placing the car at the output along with the Production Kanban Card, and raises the Kanban Signal Flag for Conveyance to deliver the product to the Finished Goods Warehouse. The Assembly 2 operator may only retrieve material from the kanban square after delivering any current car in process. To simulate labor variation, plain models with black wheels require a 5 second delay at assembly 2, Red models with black wheels delay 10 seconds, and Blue models with black wheels delay 15 seconds before passing to finished goods. No other work can be performed while waiting out the delay.

Facilitator Option: The Detail person, if used, can be added in after Assembly 2. In this case, the detail person delivers the car to the warehouse via conveyance.

The Warehouse receives replenishment orders from the Show Room as a Move Kanban Card. If a matching car is in stock, the Warehouse Administrator sends the car and the Move Kanban Card to the Showroom, and returns the Production Kanban Card taken from the car to the Planner for replenishment. If no match yet exists, the Admin holds the Move card until a matching car arrives. A kanban signal flag may be used to initiate a Conveyance move. The warehouse may also be used to hold extra inventory of completed cars as determined by planning

The Show Room sells cars either from on-hand stock or by photo. As a car is delivered, the Show Room removes the Move Kanban Card and sends it to the FG Warehouse for replenishment. Delivery for all cars is on-time if done in under two minutes.

The Customer orders one car every two minutes at random. Upon delivery sends the Car to the Supplier for disassembly back into components.

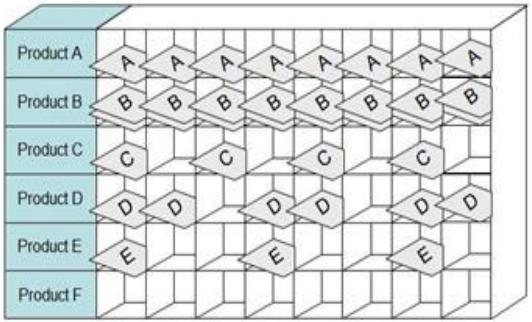
The Conveyance person(s) moves material as requested, either by hearing “conveyance” being called out by an operator or by observing the presence of a raised kanban flag.

Kanban Dual Card Method w/Heijunka

The Planner receives Production kanbans from the warehouse and initiates replenishment by loading the cards into the heijunka box according to level loading calculations. See adjacent chart. Each model type requires a fixed number of seconds as detailed in the chart. Each heijunka column is 300 seconds in duration, and the planner's task is to receive Production kanban cards, match each to it's allotted time in seconds, and calculate the next available position in the heijunka box which both produces the car as soon as practical and also in keeping with the total number of seconds to total as close as possible but not to exceed 300. The task of the planner is to stay ahead of the factory by at least one pitch interval, but preferably two.

The Timekeeper is a method of keeping the system schedule on time. The Timekeeper person places the time keeper device at the top T1 column of the box. At the stroke of 5 minutes, move the time keeper to the T2 column. Do this at each 5 minute mark. This provides a visual representation of schedule to the team so they can judge if they are on time, early or late. Their task is to regulate their touch time to complete all Production kanbans within the active column before time is up, but also not to start the next time period until appropriate. This regulates the over / under production waste.

In this illustration, each time period builds an A and two Bs along with a mix of Cs, Ds and Es. What is clear from the box, from the simple repeating patterns of kanbans in each row, is that the production is smooth of each of these products. This ensures that production capacity is kept under a constant pressure thereby eliminating many issues.



Exercise #3 Heijunka Plan Chart Example

Car	T1	T2	T3	T4	T5	T6
a = 60	/	/		/	/	
b = 65	/	/		/	/	
c = 60	/		/	/		/
d = 70	/		/	/		/
e = 60		/	/		/	/
f = 75		/	/		/	/
Total ≤300 max	255	260	265	255	260	265

- Insert one kanban for each car to be built into the appropriate slot in the sequence they are to be built, starting with T1 top and proceeding down the column. Each card has the value shown for the model. Multiple cards can be in the same box, but the total column value cannot exceed 300 before moving to the next column. Attempt to get as close to 300 for each column for best utilization of labor.
- Each column, or Pitch, is 300 seconds long (5 minutes). The assembly line works its way down each column, starting work at the beginning of the 5 minute period. If work is completed before the start of the next period, they wait. If work is not complete, they must adjust to work more quickly to catch up to the timekeeper.
- Actual mix will depend upon the random selection of cars by the customer. Note, if the customer routinely picks cars with black wheels, the number of cars produced per pitch will be reduced by the labor delay.

Kanban Dual Card Method w/Heijunka

3

	A	B	C	D	E	F	G
1	Financial Chart		Single Kanban System		Dual Kanban System		Dual Kanban System Heijunka
2		#	$	#	$	#	$
3	Sales						
4	# Delivered x $500 ea	20	$ 10,000.00	20	$ 10,000.00	20	$ 10,000.00
5	**Total SALES =**		**$ 10,000.00**		**$ 10,000.00**		**$10,000.00**
6							
7	COGS: Cost of goods sold						
8	Sales Raw Mtl = # sold x $100 ea	20	$ 2,000.00	20	$ 2,000.00	20	$ 2,000.00
9	Labor = # workers x $165 ea	8	$ 1,320.00	8	$ 1,320.00	8	$ 1,320.00
10	Labor OT = total # minutes OT x $40 ea	0	$ -	0	$ -	0	$ -
11	Overhead = # tables used x $10 ea	4	$ 40.00	4	$ 40.00	5	$ 50.00
12	Scrap = # rejects x $100 ea	0	$ -	0	$ -	0	$ -
13	**Total of COGS =**		**$ 3,360.00**		**$ 3,360.00**		**$ 3,370.00**
14							
15	Capital Charges						
16	Work in Progress: WIP						
17	Stockroom = #kits in bags x $100 ea	3	$ 300.00	0	$ -	0	$ -
18	Assembly 1 = # assembled subs x $10 ea	8	$ 80.00	4	$ 40.00	4	$ 40.00
19	Assembly 2 = # of partial cars x $60 ea	2	$ 120.00	1	$ 60.00	1	$ 60.00
20	Warehouse = # cars in stock x $100 ea	5	$ 500.00	5	$ 500.00	5	$ 500.00
21	Show Room = # cars in stock x $100 ea	5	$ 500.00	6	$ 600.00	6	$ 600.00
22	Facilities						
23	# tables used x $15 ea	4	$ 60.00	4	$ 60.00	4	$ 60.00
24	# Tool Fixtures used x $10 ea	5	$ 50.00	0	$ -	0	$ -
25	# Tool material totes used x $5 ea	5	$ 25.00	0	$ -	0	$ -
26	**Total of CAPITAL CHARGES =**		**$ 1,635.00**		**$ 1,260.00**		**$ 1,260.00**
27							
28	EVA = Sales - COGS - Capital Charges						
29	**Earned Value =**		**$ 5,005.00**		**$ 5,380.00**		**$ 5,370.00**
30	**Gross Margin =**		**50.1%**		**53.8%**		**53.7%**

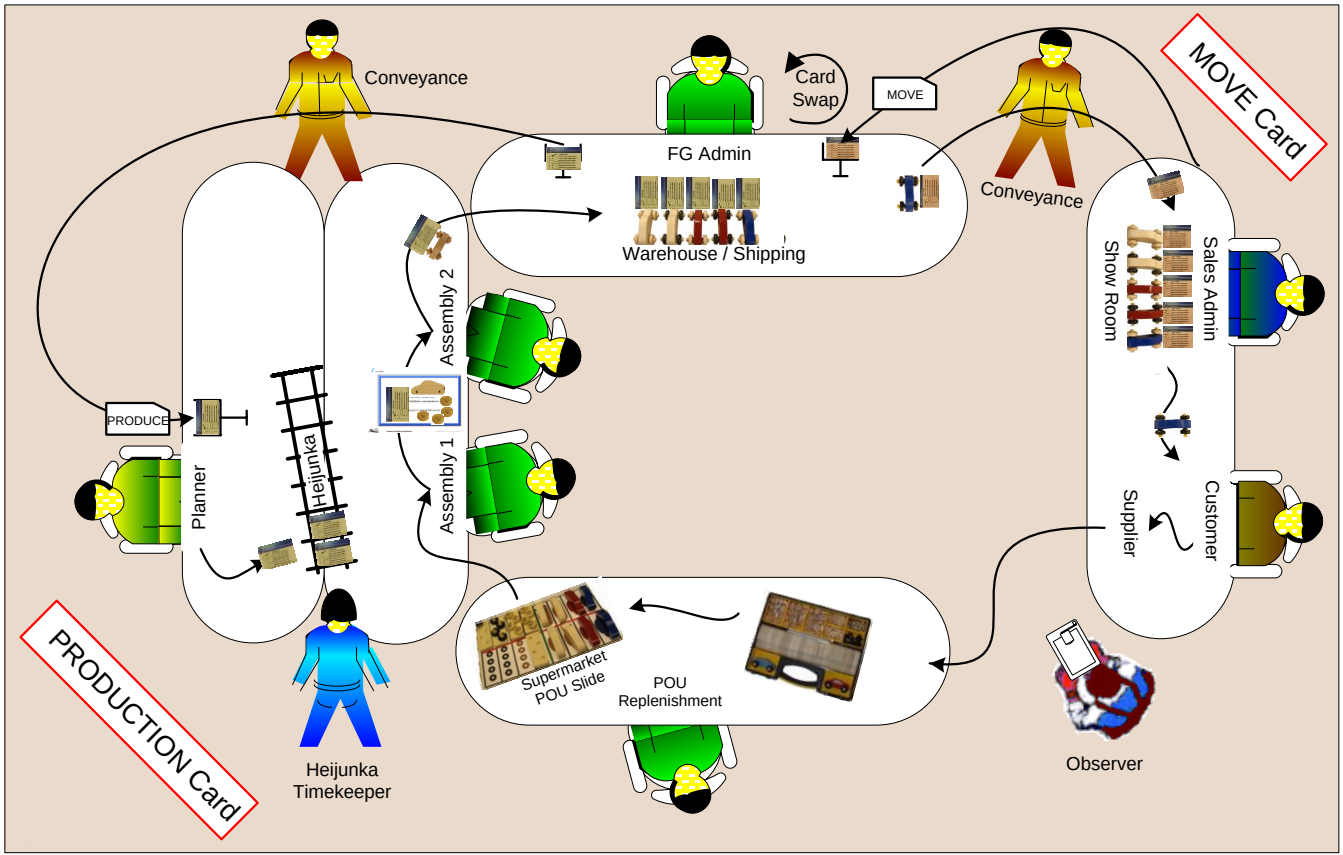
Facilitator: Stop the 3rd event and have the operators freeze movement.

Go around to each operator and count the work-in-progress inventory, capital equipment, and resources at each process location and fill in the Financial Chart and the Inventory Chart Excel worksheets.

Discuss the observation notes taken during the event with the team and how the use of a heijunka box has affected the bottom line EV and Margin.

Participants are encouraged to observe and comment on the heijunka ability to level the production build even in the face of unpredictable demand.

Suggested room set up – 3rd exercise



Exercise Number 3 – Heijunka Control – with Finished Goods Buffer.

- The purpose of this third round of simulation is to address the uneven flow caused by random orders of mixed models with different process cycle times. We will introduce participants to the affect of Heijunka planning on unpredictable customer demand when producing a mixed mode product. The warehouse may be utilized to hold extra completed cars as planning deems necessary to act as a buffer stock to support customer demand.

- We will add a Heijunka Box which the Planner will use to control the sequence of build based on the product mix and work cell capacity. Participants are encouraged to observe and comment on the heijunka ability to level the production build even in the face of unpredictable demand. The Heijunka schedule used in this simulation exercise to load the box is based on the Heijunka Calculation Chart method.

- The team then discusses the pros and cons of this system, such as how well did the Heijunka system level the work flow and provide a prioritization system. Also discuss the use of the warehouse as a buffer inventory to offset the possible roll of the die selecting two long lead car types in sequence. The discussion is augmented by team observers performing the 10 Second Test to compare results of the first two simulation exercises.

- Note: depending on your room setup and table size, the Heijunka Box may require the addition of a second table as shown to provide the working space needed by the planner.

Customer: Exercise #3 [same as #1 and 2]

Initial Conditions

- Hold the 1st order until at least 3 cars have been delivered to the showroom

a b c d e f

Tasks

- Task1: order 1 car every two minutes by picking randomly from the showroom inventory, or sales photo. Try to keep the selection mixed, i.e. there are only a few of the color car bodies so order them infrequently.
- OPTIONAL Task 2: The simulation may be run in loop mode to provide sufficient materials to support an extended simulation period. If true, then as each car is delivered disassemble it into its component parts. Use the ergonomic wheel extractor tool and peg finger guard as needed.
- Send the components to the Stockroom. Note that it is particularly important the color car body parts are returned immediately due to the few number of them available.

  (if distance is involved, call Conveyance transport the materials.)

Constraints

- Only one Car order can be placed every two minutes.
- On-Time delivery as advertised is under two minutes.
- As the team becomes efficient, the facilitator may decrease the time between orders.

Ergonomic Assembly Tool

To remove a tight wheel assembly, gently slide the wheel extraction tool under the wheel and around the axle peg.

Slowly pry up against the underside of the wheel or disk, with the tip of the tool centered with the peg, to bring the peg straight out of the hole.

Gently rock the axle back and forth while pressing downward on the extraction tool handle. Use care not to flip the wheel and disk into the air. Do not bend the tool – press slowly and rock the peg loose.

Exercise #3
Customer Order Sequence

Random Demand

Use a wet-erase marker to check off the orders as they are placed, and again as they are delivered.

This is a random sequence so metrics are to some extent Random between competing Teams, unless a single die is used to run both teams. Therefore TAKT time will vary Dependent upon the roll of the die.

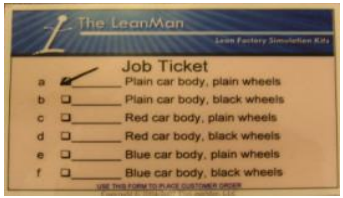
Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 1					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 2					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 3					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 4					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 5					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 6					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 7					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 8					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Note: if actual Heijunka Box is used with only 5 rows, place cards for type a and b in the same row.

Showroom: Exercise #3 [same as #1 and #2]

Initial Conditions



- The showroom receives 1 each of the 6 models, with a **Move Card** attached to each (use Job Ticket Card as the Move Kanban).

Tasks

- Task 1: As the Customer demands a car model, remove its **Move Card** and deliver the car from inventory to the customer. The customer may order only 1 car every two minutes by picking randomly from the available showroom inventory, or by sales photo (a thru f). If the car is not yet available, record the time the order is placed and the time the car is delivered.
- Task 2: accept completed cars from the warehouse along with its **Move Card**.
- Send the **Move Card** removed from the delivered car to the Warehouse for replenishment. (if distance is involved, call Conveyance to transport the card.)

Constraints

- Only one Customer order can be placed every two minutes, or as determined by efficiency.
- Customer can only choose from available showroom stock.

Metrics Option

- The back of the Job Ticket Card can be used to record factory cycle time by recording the time the order is placed to the Warehouse and then again as the car is delivered to the Showroom. Goal is less than two minutes.
- Record the exercise time in minutes, the total number of cars delivered and the cycle time for each. Use Little's Law to calculate average WIP.

TH (avg) = WIP (avg) x Cycle Time (avg)

Exercise #3
Order Delivery Metrics

Random Demand

Use a wet-erase marker to check off the orders as they are placed, and again as they are delivered.

Any order delivered two minutes or more after the customer places the order is considered late.

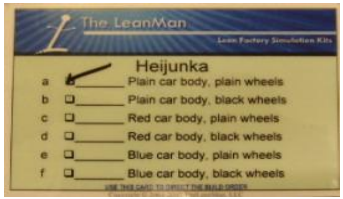
Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 1					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 2					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 3					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 4					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 5					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 6					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 7					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 8					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Finished Goods Warehouse: Exercise #3

Initial Conditions

- Initial start up conditions: finished goods inventory holds 1 each of the 6 models, with a **Production Card** attached to each (use Heijunka Card).
- At start up, the planner will issue six Move Cards to the warehouse to act as orders from the Showroom. Fill the orders as cars are available.



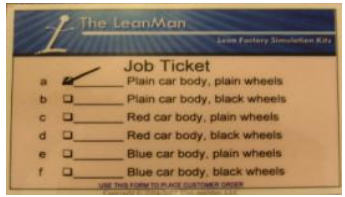
Production Card

Tasks

- Task 1: Accept order requests from the Showroom. This will be via a **Move Card** with the specific car body, color and wheel choice marked.
  If a match exists in the warehouse Inventory, swap the **Production Card** from the car with the **Move Card**, and send the car with **Move Card** to the Showroom. (if distance is involved, call Conveyance to transport the material.) If no match exists, set the **Move Card** aside until manufacturing delivers a car to match.
- Task 2: Accept the completed car and **Production Card** from Assembly 2. Check to see if a **Move Card** is waiting for a match request from the Show Room, and if true swap the **Production Card** and **Move Card** and send the car and **Move Card** to the Showroom.
  (if distance is involved, call Conveyance to transport the card or car as appropriate.)
- If no open order exists, send the car and **Production Card** to the warehouse FG inventory.

Constraints

- Only one Showroom order can be placed every two minutes. However, if efficiency makes it possible, a shorter period may be used.
- Factory lead time goal is under two minutes in any case.

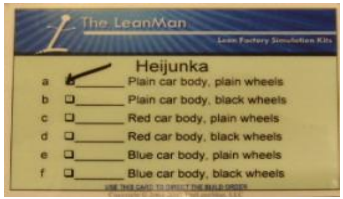


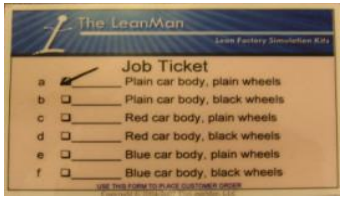
Move Card

Planning Dept: Exercise #3

Initial Conditions

- Place the assembled Heijunka Box between the planner and the Assembly 1 person. Each should comfortably reach the kanban cards on their side of the box.
- If not already set in place from exercise #1, the Showroom and finished goods each hold 1 each of the 6 models, so to start create 6 kanbans, one of each car type. The completed cars will have a **Production Card** attached to each (use Heijunka Card).
- Create 6 Move Cards, 1 for each of the 6 models, and call conveyance to deliver them to the Finished Goods Warehouse to be processed.
- Insert each of the 6 kanbans into the Heijunka Box to begin the simulation.





Tasks

- Task 1: Accept **Production Card** from the warehouse and verify the card is clearly marked with a car body and wheel color selection.
  (if the wet erase marker has smudged, make it readable)
- Insert the **Production Card** into the Heijunka Box for processing by the Assembly 1 department to initiate the manufacturing cycle.

Constraints

- The factory lead time goal is less than two minutes.
- Planner may utilize the warehouse as a buffer stock if appropriate.

Timekeeper: Exercise #3

Keep time for the simulation event, provide the time stamps used for metrics, and maintain the "drum beat" used to regulate the flow.

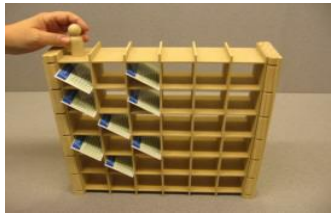
Timekeeping

- Start the simulation event and the stopwatch. Time the overall event and run for at least 20 total minutes (40 if event time permits), then call stop.
- At time zero, start the planner setting Heijunka kanban cards into the Heijunka box pitch 1 to create one of each model. Some of the team waits idle while you allow two minutes for this head start to filling the warehouse. The planner then continues to load pitch 2 with "forecast" cars.
- Anytime a team member calls out "time stamp" reply with the time reading off the stopwatch in minutes and seconds. Avoid excess word like "2 minutes 15 seconds" and use "2 15" instead.
- The timekeeper maintains the "beat" for the assembly team by using the Timekeeper marker – a simulation only device placed on top of the "pitch in operation" column of the Heijunka Box, and moved to the next pitch on 5 minute intervals.

  In actual practice, the pitch is typically a half-day, or a shift change or some period such as a break horn sounding that is easily recognized across the value stream as a "drum beat."

Timekeeper

- At the 5 minute mark, call start for the customer to begin placing orders and place the Timekeeper on top of pitch 2 column of the Heijunka box to indicate the "pitch" is active. The Timekeeper is moved one column over at the stroke of each additional 5 minute mark on the stopwatch. At the end of the last column, move the Timekeeper back to the first column and repeat at the 5 minute mark until the simulation is finished.
- The simulation operation will run for a total of 20 minutes (or 40) on the stopwatch. Call "all stop" to end the simulation. You may allow conveyance to continue for another minute until all cars in process are delivered and metrics are complete.



Stockroom: Exercise #3 [same as #2]

Initial Conditions

- Stock tray with wheels, pegs, disks and bodies available, Supermarket Slide point of use (POU) inventory located within reach of the assembly 1 person, and the slide is loaded with components.

Tasks

- TASK 1: maintain the POU inventory levels on the slide as materials are withdrawn by the Assembly 1 person. Retrieve materials out of the stock tray as needed.

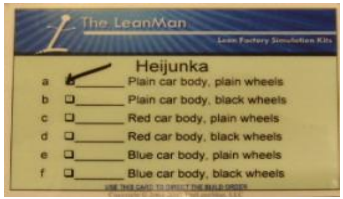
  OPTIONAL: if simulation is run as a loop, receives component materials from the Supplier and replenishes the stock tray.

Constraints

- The color car bodies are few in number and should take precedence to replenish as soon as they become available.

Assembly 1: Exercise #3

Initial Conditions



- Locate the kanban square between Assembly 1 and Assembly 2, and both stations should be located within arms reach of the kanban square for easy hand-off of materials.

Tasks

- TASK 1: Pull **Production Card** from Heijunka Box, starting with top left corner, working down the column, then to the top of the next column. Repeat until finished with the last column and start over. Withdraw the necessary materials as specified on the **Production Card** from the POU slide. Note color choice for car body and wheels. See constraint below.
- Task 2: Place the car body and **Production Card** on the Kanban Square. Assemble each Axle, Wheel and Brake subassembly and place onto the kanban square as each is completed.
- Repeat step 1 and 2 for the next **Production Card** in the sequence received from the planner.
  Note: do not place any material onto the kanban square until the previous job has been completely removed by Assembly 2.

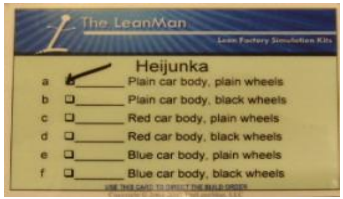
Constraints

- If used, wait until the Timekeeper is moved to the next pitch column, and repeat again. If finished early, stop until the Timekeeper is moved. If finished late, work to catch up to the correct pitch.

Timekeeper

Assembly 2: Exercise #3

Initial Conditions



- Locate ergonomic peg insertion tool at station. Insert pegs with a slight twist as you push the peg into the hole. Remove with a slight twist as you pull the peg from the hole.

Tasks

- TASK 1: Remove the car body and the **Production Card** from the Kanban Square, and assemble each Axle/Wheel/Brake subassembly (4) onto the car body as they are placed into the square.
- TASK 2: Perform inspection and rework as necessary. Wheels should rotate freely, adjust as needed. Wheels and car body should be the correct color per the **Production Card**.
- If the car has black wheels, delay the car for 5 seconds, if Red with black wheels, delay 10 seconds, and if Blue with black wheels delay 15 seconds. (this simulates a labor variation in the models)

  During this waiting time you are not to perform any other task.
- Send the completed car and **Production Card** to the Finished Goods Warehouse input.

  (if distance is involved, call Conveyance to transport the material.)

Constraints

- The total factory lead time goal is less than two minutes, all models.

Ergonomic tool in use

Assembly 2: Exercise #3: Results

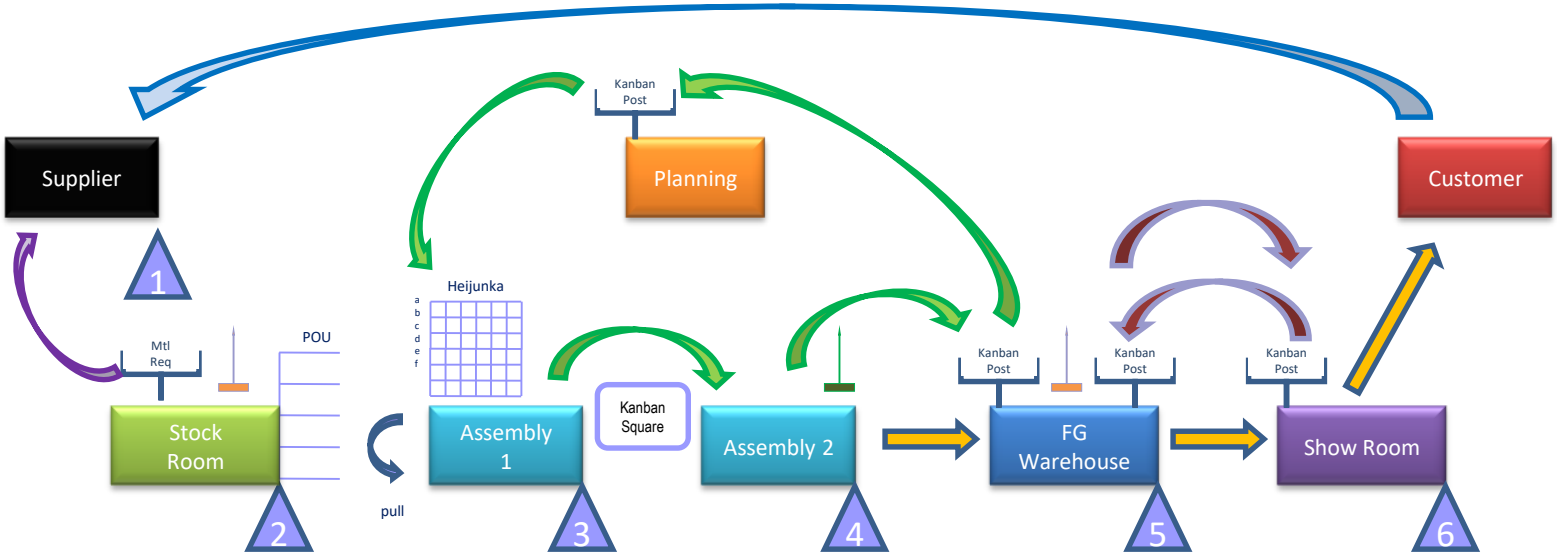
Check off each type of car ordered as the Die is rolled.

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 1					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 2					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 3					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 4					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 5					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 6					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 7					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 8					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Exercise #4

Kanban Dual Card Method w/Heijunka & Near-Zero FG Inventory



Dual Kanban configuration.

Lean improvement is further implemented by reducing the waste of Finished Goods Inventory by using the synchronized flow system to hold FGI at zero or near-zero levels.

Kanban Dual Card Method w/Heijunka & Near-Zero FG Inventory

The Supplier takes in completed cars and disassembles them into piles of components. Upon receiving a Material Requisition Card from the Stock Room gathers the requested components into a tote bin and calls Conveyance to deliver the item to the Stock Room.

The Stock Room manages inventory, and when a component level is low, raises the kanban Signal Flag and places a Material Requisition Card with the needed items checked into the output area by the flag. The Stock Keeper monitors the Assy1 area POU levels and fills as appropriate.

The Assembly 1 person Pulls the Production Kanban Cards from the heijunka box in sequence, left column first going top to bottom, picks the necessary component materials from the POU inventory and assembles the 4 subassembly items, placing each into Kanban Square located between Assembly 1 and Assembly 2 positions along with the car body and Production Kanban Card. Note: The Assembly 1 operator may only move materials into the kanban square when it is empty. If the Assembly 2 person has not yet cleared the square, then wait.

The Assembly 2 operator pulls the material from the square and completes the car, waits any required time delay (if black wheels) and then placing the car at the output along with the Production Kanban Card, and raises the Kanban Signal Flag for Conveyance to deliver the product to the Finished Goods Warehouse. The Assembly 2 operator may only retrieve material from the kanban square after delivering any current car in process. To simulate labor variation, plain models with black wheels require a 5 second delay at assembly 2, Red models with black wheels delay 10 seconds, and Blue models with black wheels delay 15 seconds before passing to finished goods. No other work can be performed while waiting out the delay.

Facilitator Option: The Detail person, if used, can be added in after Assembly 2. In this case, the detail person delivers the car to the warehouse via conveyance.

The Warehouse receives replenishment orders from the Show Room as a Move Kanban Card. If a matching car is in stock, the Warehouse Administrator sends the car and the Move Kanban Card to the Showroom, and returns the Production Kanban Card taken from the car to the Planner for replenishment. If no match yet exists, the Admin holds the Move card until a matching car arrives. A kanban signal flag may be used to initiate a Conveyance move. Note: the warehouse is typically at zero inventory except that short period where a car exchange is taking place as the replenishment cars are received from the factory.

The Show Room sells cars either from on-hand stock or by photo. As a car is delivered, the Show Room removes the Move Kanban Card and sends it to the FG Warehouse for replenishment. Delivery for all cars is on-time if done in under two minutes.

The Customer orders one car every two minutes at random. Upon delivery sends the Car to the Supplier for disassembly back into components.

The Conveyance person(s) moves material as requested, either by hearing “conveyance” being called out by an operator or by observing the presence of a raised kanban flag.

Kanban Dual Card Method w/Heijunka & Near-Zero FG Inventory

The Planner receives Production kanbans from the warehouse and initiates replenishment by loading the cards into the heijunka box according to level loading calculations. See adjacent chart. Each model type requires a fixed number of seconds as detailed in the chart. Each heijunka column is 300 seconds in duration, and the planner's task is to receive Production kanban cards, match each to it's allotted time in seconds, and calculate the next available position in the heijunka box which both produces the car as soon as practical and works to keep the total number of seconds to total as close as possible but not to exceed 300. The task of the planner is to stay ahead of the factory by at least one pitch interval, but preferably two, while keeping warehouse inventory near-zero.

Facilitator: the base number of minutes for all cars is 60 seconds. The cars with black wheels each have additional delay time added for purposes of simulating labor variation. The 60 second baseline is an opportunity for improvement. In order to maintain on-time delivery to the customer with near-zero finished goods inventory will require the team to achieve a reduced cycle-time in the factory. Have the team work on improving upon this 60 second baseline. The task for the planner is to slowly reduce the 60 second plan parameter while observing the on-time delivery metric. As the 60 is reduced to 55 (remove 5 seconds for all models) and then to 50, and then to 45. This results in more cards per pitch. At some point you will observe the balance point where the system is synchronized to achieve desired metrics. Note: other balance opportunities may present themselves in the factory flow as the baseline time is reduced. The time between customer orders may also need to be reduced.

The Timekeeper is a method of keeping the system schedule on time. The Timekeeper person places the time keeper device at the top T1 column of the box. At the stroke of 5 minutes, move the time keeper to the T2 column. Do this at each 5 minute mark.

Kanban Dual Card Method w/Heijunka & Near-Zero FG Inventory

	A	B	C	D	E	F	G	H	I
1	Financial Chart		Single Kanban System		Dual Kanban System		Dual Kanban System Heijunka		Dual Kanban Heijunka Zero FGI
2		#	$	#	$	#	$	#	$
3	Sales								
4	# Delivered x $500 ea	20	$ 10,000.00	20	$ 10,000.00	20	$ 10,000.00	20	$ 10,000.00
5	**Total SALES =**		**$ 10,000.00**		**$ 10,000.00**		**$10,000.00**		**$10,000.00**
7	COGS: Cost of goods sold								
8	Sales Raw Mtl = # sold x $100 ea	20	$ 2,000.00	20	$ 2,000.00	20	$ 2,000.00	20	$ 2,000.00
9	Labor = # workers x $165 ea	8	$ 1,320.00	8	$ 1,320.00	8	$ 1,320.00	8	$ 1,320.00
10	Labor OT = total # minutes OT x $40 ea	0	$ -	0	$ -	0	$ -	0	$ -
11	Overhead = # tables used x $10 ea	4	$ 40.00	4	$ 40.00	5	$ 50.00	5	$ 50.00
12	Scrap = # rejects x $100 ea	0	$ -	0	$ -	0	$ -	0	$ -
13	**Total of COGS =**		**$ 3,360.00**		**$ 3,360.00**		**$ 3,370.00**		**$ 3,370.00**
15	Capital Charges								
16	Work in Progress: WIP								
17	Stockroom = #kits in bags x $100 ea	3	$ 300.00	0	$ -	0	$ -	0	$ -
18	Assembly 1 = # assembled subs x $10 ea	8	$ 80.00	4	$ 40.00	4	$ 40.00	4	$ 40.00
19	Assembly 2 = # of partial cars x $60 ea	2	$ 120.00	1	$ 60.00	1	$ 60.00	1	$ 60.00
20	Warehouse = # cars in stock x $100 ea	5	$ 500.00	5	$ 500.00	5	$ 500.00	0	$ -
21	Show Room = # cars in stock x $100 ea	5	$ 500.00	6	$ 600.00	6	$ 600.00	6	$ 600.00
22	Facilities								
23	# tables used x $15 ea	4	$ 60.00	4	$ 60.00	4	$ 60.00	4	$ 60.00
24	# Tool Fixtures used x $10 ea	5	$ 50.00	0	$ -	0	$ -	0	$ -
25	# Tool material totes used x $5 ea	5	$ 25.00	0	$ -	0	$ -	0	$ -
26	**Total of CAPITAL CHARGES =**		**$ 1,635.00**		**$ 1,260.00**		**$ 1,260.00**		**$ 760.00**
28	EVA = Sales - COGS - Capital Charges								
29	**Earned Value =**		**$ 5,005.00**		**$ 5,380.00**		**$ 5,370.00**		**$ 5,870.00**
30	**Gross Margin =**		**50.1%**		**53.8%**		**53.7%**		**58.7%**

Facilitator: Stop the 4th event and have the operators freeze movement.

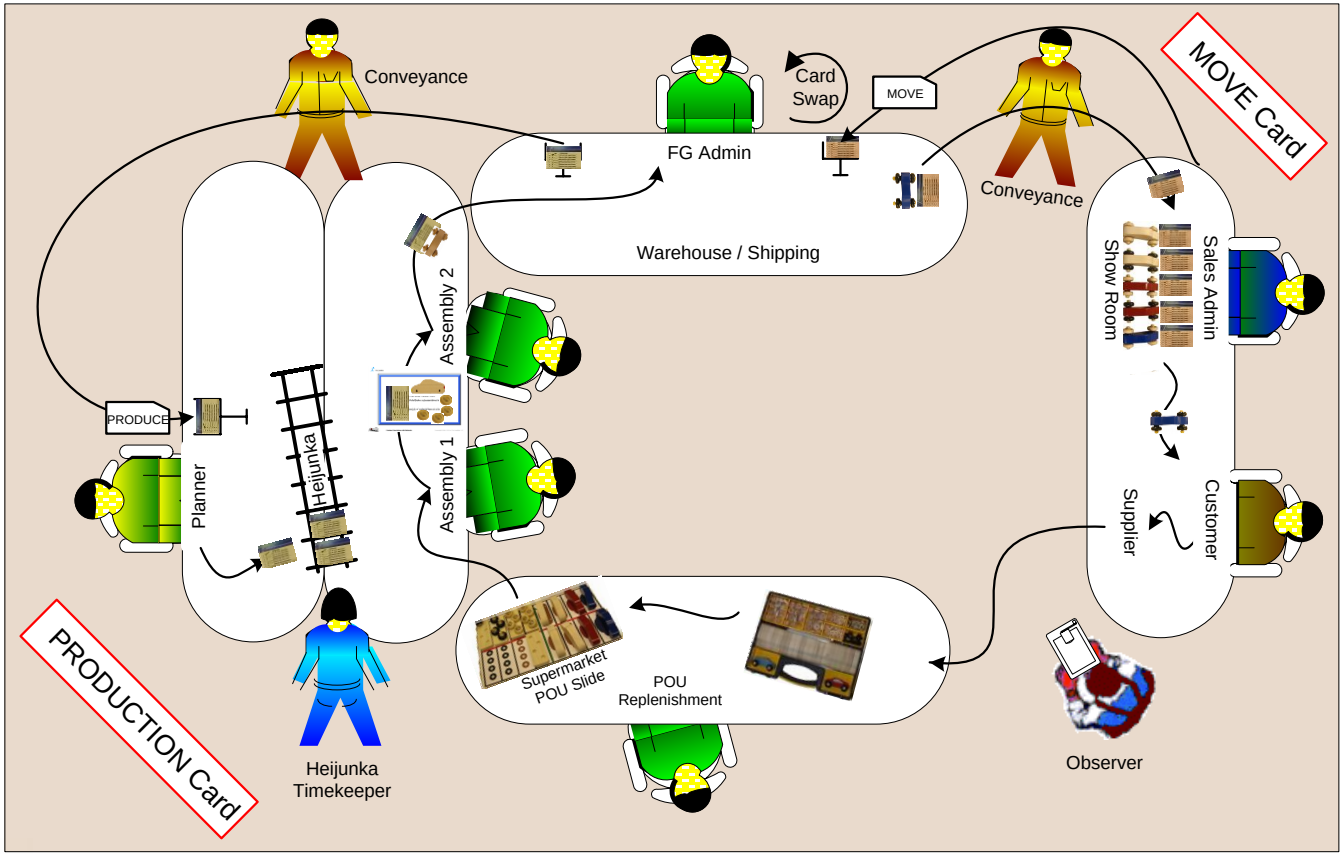
Go around to each operator and count the work-in-progress inventory, capital equipment, and resources at each process location and fill in the Financial Chart and the Inventory Chart Excel worksheets.

Discuss the observation notes taken during the event with the team and how holding near-zero FGI has affected the bottom line EV and Margin.

Participants are encouraged to observe and comment on the heijunka ability to manage cycle-time and On-Time metrics.

Suggested room set up – 4th exercise

4



Exercise Number 4 – Heijunka Control – with zero Finished Goods Buffer.

- The purpose of this fourth round of simulation is to address the high level of working capital investment caused by carrying a full set of finished goods inventory. We will the Heijunka planning to level flow and reduce working capital. The Showroom will attempt to maintain a full stock, but the advertised lead time of two minutes will also be utilized to assure on-time to the customer while lowering inventory investment.

- Participants are encouraged to observe and comment on the heijunka ability to level the production build while maintaining an acceptable on-time delivery metric. The Heijunka schedule used in this simulation exercise to load the box is based on the Heijunka Calculation Chart method.

- The team then discusses the pros and cons of this system, such as how well did the Heijunka system level the work flow and provide a prioritization system. The discussion is augmented by team observers performing the 10 Second Test to compare results of the first two simulation exercises.

- Note: depending on your room setup and table size, the Heijunka Box may require the addition of a second table as shown to provide the working space needed by the planner.

Customer: Exercise #4 [same as #1, 2 and 3]

Initial Conditions

- Hold the 1st order until at least 3 cars have been delivered to the showroom

a b c d e f

Tasks

- Task1: order 1 car every two minutes by picking randomly from the showroom inventory, or sales photo. Try to keep the selection mixed, i.e. there are only a few of the color car bodies so order them infrequently.
- OPTIONAL Task 2: The simulation may be run in loop mode to provide sufficient materials to support an extended simulation period. If true, then as each car is delivered disassemble it into its component parts. Use the ergonomic wheel extractor tool and peg finger guard as needed.
- Send the components to the Stockroom. Note that it is particularly important the color car body parts are returned immediately due to the few number of them available.
  (if distance is involved, call Conveyance transport the materials.)

Constraints

- Only one Car order can be placed every two minutes, or as determined by the facilitator as efficiency improvements are made.
- On-Time delivery as advertised is under two minutes.

Ergonomic Assembly Tool

To remove a tight wheel assembly, gently slide the wheel extraction tool under the wheel and around the axle peg.

Slowly pry up against the underside of the wheel or disk, with the tip of the tool centered with the peg, to bring the peg straight out of the hole.

Gently rock the axle back and forth while pressing downward on the extraction tool handle. Use care not to flip the wheel and disk into the air. Do not bend the tool – press slowly and rock the peg loose.

Exercise #4
Customer Order Sequence

Random Demand

Use a wet-erase marker to check off the orders as they are placed, and again as they are delivered.

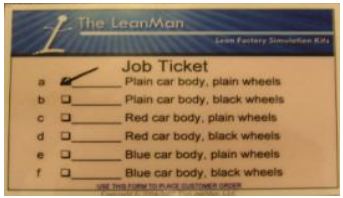
This is a random sequence so metrics are to some extent Random between competing Teams, unless a single die is used to run both teams. Therefore TAKT time will vary Dependent upon the roll of the die.

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 1					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 2					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 3					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 4					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 5					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 6					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 7					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 8					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Showroom: Exercise #4 [same as #1, 2, and 3]

Initial Conditions



- The showroom receives 1 each of the 6 models, with a **Move Card** attached to each (use Job Ticket Card as the Move Kanban).

Tasks

- Task 1: As the Customer demands a car model, remove its **Move Card** and deliver the car from inventory to the customer. The customer may order only 1 car every two minutes by picking randomly from the available showroom inventory, or by sales photo (a thru f). If the car is not yet available, record the time the order is placed and the time the car is delivered.
- Task 2: accept completed cars from the warehouse along with its **Move Card**.
- Send the **Move Card** removed from the delivered car to the Warehouse for replenishment. (if distance is involved, call Conveyance to transport the card.)

Constraints

- Only one Customer order can be placed every two minutes. This can be adjusted as efficiency grows.
- Customer can only choose from available showroom stock.

Metrics Option

- The back of the Job Ticket Card can be used to record factory cycle time by recording the time the order is placed to the Warehouse and then again as the car is delivered to the Showroom. Goal is less than two minutes.
- Record the exercise time in minutes, the total number of cars delivered and the cycle time for each. Use Little's Law to calculate average WIP.

TH (avg) = WIP (avg) x Cycle Time (avg)

Exercise #4
Order Delivery Metrics

Random Demand

Use a wet-erase marker to check off the orders as they are placed, and again as they are delivered.

Any order delivered two minutes or more after the customer places the order is considered late.

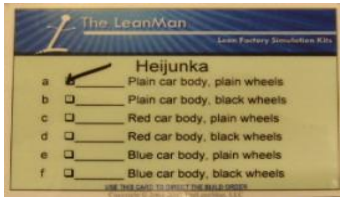
Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 1					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 2					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 3					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 4					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 5					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 6					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 7					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 8					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Finished Goods Warehouse: Exercise #4

Initial Conditions

- Finished goods inventory is held at or near zero, and product received from the factory is generally shipped immediately to the Showroom. Inventory is held short term pending order matchup.



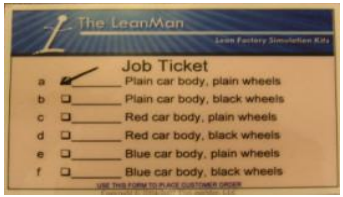
Production Card

Tasks

- Task 1: Accept order requests from the Showroom. This will be via a **Move Card** with the specific car body, color and wheel choice marked.
  If a match exists in the warehouse Inventory, swap the **Production Card** from the car with the **Move Card**, and send the car with **Move Card** to the Showroom. (if distance is involved, call Conveyance to transport the material.) If no match exists, set the **Move Card** aside until manufacturing delivers a car to match.
- Task 2: Accept the completed car and **Production Card** from Assembly 2. Check to see if a **Move Card** is waiting for a match request from the Show Room, and if true swap the **Production Card** and **Move Card** and send the car and **Move Card** to the Showroom.
  (if distance is involved, call Conveyance to transport the card or car as appropriate.)
- If no open order exists, send the car and **Production Card** to the warehouse FG inventory.

Constraints

- Only one Showroom order can be placed every two minutes.
- Factory lead time goal is under two minutes.

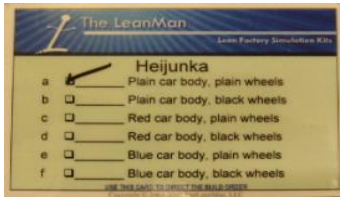


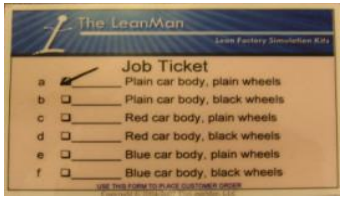
Move Card

Planning Dept: Exercise #4

Initial Conditions

- Place the assembled Heijunka Box between the planner and the Assembly 1 person. Each should comfortably reach the kanban cards on their side of the box.
- If not already set in place from exercise #1, the Showroom and holds 1 each of the 6 models, so to start create 6 kanbans, one of each car type. The completed cars will have a **Production Card** attached to each (use Heijunka Card).
- Create 6 Move Cards, 1 for each of the 6 models, and call conveyance to deliver them to the Finished Goods Warehouse.
- Insert each of the 6 kanbans into the Heijunka Box to begin the simulation.





Tasks

- Task 1: Accept **Production Card** from the warehouse and verify the card is clearly marked with a car body and wheel color selection.
  (if the wet erase marker has smudged, make it readable)
- Insert the **Production Card** into the Heijunka Box for processing by the Assembly 1 department to initiate the manufacturing cycle.

As viewed by planner

Constraints

- The factory lead time goal is less than two minutes.

Planner Heijunka Process

Receive periodic orders for cars from the customer for the 6 models available and produce them assuring accurate on-time delivery while managing a level production work load.

Scheduling

- Calculate order acceptance time for each job order card received from customer, basing the time on visual observation of the Heijunka Box and the next available pitch increment time for the model ordered. The time is obtained from the timekeeper's stopwatch by calling out "time stamp" and adding the appropriate additional time for the pitch increment where the order is expected to be planned. The Timekeeper will respond in minutes and seconds. Record the TimeStamp on the back of the Job Ticket card.

- On-time is defined as TimeStamp plus 90 seconds per car. Record the due time on the card by adding 1 minute 30 seconds to the recorded TimeStamp, less the early delivery window of 15 seconds.

  Example: a 1 pc order is due in TimeStamp+1 min 15 sec

- Create the Heijunka kanban card from the job order card, and send the Job Order Card to Finished Goods / Shipping.
- The Heijunka Card is created using the plan rules for each model as defined by the team for the Heijunka and flow selected. Insert the Heijunka Card into the proper pitch and row of the Heijunka Box, leveling the work for each pitch. Note: you will be working the Box right to left as you load from the back side, while the assembler pulls left to right.

- The planner should stay well ahead of the work team, preferably at least one pitch period.

Constraints

- Each order for plain cars can be between 1 and 2 cars per job order, but typically they will be 1 pc batch orders.
- Each order for color car bodies can only be 1 pc jobs and the same color car can only be placed for only 1 car of the same color in the same pitch interval.

Timekeeper: Exercise #4

Keep time for the simulation event, provide the time stamps used for metrics, and maintain the “drum beat” used to regulate the flow.

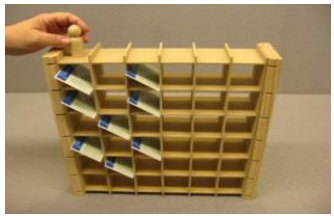
Timekeeping

- Start the simulation event and the stopwatch. Time the overall event and run for 20 total minutes (40 if event time permits), then call stop.
- At time zero, start the planner setting Heijunka kanban cards into the Heijunka box to build 1 of each of 6 models. The assembly team begins building while the customer waits idle for this head start.
- Anytime a team member calls out “time stamp” reply with the time reading off the stopwatch in minutes and seconds. Avoid excess word like “2 minutes 15 seconds” and use “2 15” instead.
- The timekeeper maintains the “beat” for the assembly team by using the Timekeeper marker – a simulation only device placed on top of the “pitch in operation” column of the Heijunka Box, and moved to the next pitch on two minute intervals.

  In actual practice, the pitch is typically a half-day, or a shift change or some period such as a break horn sounding that is easily recognized across the value stream as a “drum beat.”

Timekeeper

- At the 5 minute mark, call start for the customer to begin placing orders and place the Timekeeper on top of pitch 2 column of the Heijunka box to indicate which “pitch” is active. The Timekeeper is moved one column over at the stroke of each additional 5 minute mark on the stopwatch. At the end of the last column, move the Timekeeper back to the first column and repeat until the simulation is finished.
- The simulation operation will run for a total of 20 minutes on the stopwatch (or 40). Call “all stop” to end the simulation. You may allow conveyance to continue for another minute until all cars in process are delivered and metrics are complete.



As viewed by Assembly

Stockroom: Exercise #4

Initial Conditions

- Stock tray with wheels, pegs, disks and bodies available, Supermarket Slide point of use (POU) inventory located within reach of the assembly 1 person, and the slide is loaded with components.

Tasks

- TASK 1: maintain the POU inventory levels on the slide as materials are withdrawn by the Assembly 1 person. Retrieve materials out of the stock tray as needed.

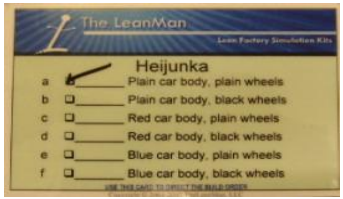
  OPTIONAL: if simulation is run as a loop, receives component materials from the Supplier and replenishes the stock tray.

Constraints

- The color car bodies are few in number and should take precedence to replenish as soon as they become available.

Assembly 1: Exercise #4

Initial Conditions



- Locate the kanban square between Assembly 1 and Assembly 2, and both stations should be located within arms reach of the kanban square for easy hand-off of materials.

Tasks

- TASK 1: Pull **Production Card** from Heijunka Box, starting with top left corner, working down the column, then to the top of the next column. Repeat until finished with the last column and start over. Withdraw the necessary materials as specified on the **Production Card** from the POU slide. Note color choice for car body and wheels. See constraint below.
- Task 2: Place the car body and **Production Card** on the Kanban Square. Assemble each Axle, Wheel and Brake subassembly and place onto the kanban square as each is completed.
- Repeat step 1 and 2 for the next **Production Card** in the sequence received from the planner.
  Note: do not place any material onto the kanban square until the previous job has been completely removed by Assembly 2.

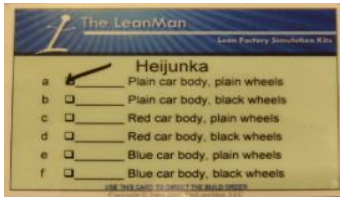
Constraints

- If used, wait until the Timekeeper is moved to the next pitch column, and repeat again. If finished early, stop until the Timekeeper is moved. If finished late, work to catch up to the correct pitch.

Timekeeper

Assembly 2: Exercise #4

Initial Conditions



- Locate ergonomic peg insertion tool at station. Insert pegs with a slight twist as you push the peg into the hole. Remove with a slight twist as you pull the peg from the hole.

Tasks

- TASK 1: Remove the car body and the **Production Card** from the Kanban Square, and assemble each Axle/Wheel/Brake subassembly (4) onto the car body as they are placed into the square.
- TASK 2: Perform inspection and rework as necessary. Wheels should rotate freely, adjust as needed. Wheels and car body should be the correct color per the **Production Card**.
- If the car has black wheels, delay the car for 5 seconds, if Red with black wheels, delay 10 seconds, and if Blue with black wheels delay 15 seconds. (this simulates a labor variation in the models)

  During this waiting time you are not to perform any other task.
- Send the completed car and **Production Card** to the Finished Goods Warehouse input.

  (if distance is involved, call Conveyance to transport the material.)

Constraints

- The total factory lead time goal is less than two minutes, all models.

Ergonomic tool in use

Assembly 2: Exercise #4: Results

Check off each type of car ordered as the Die is rolled.

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 1					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 2					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 3					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 4					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			

Customer Demand - Random toss of die					
Seq			Car	Wheels	Details
Pitch 5					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 6					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 7					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐			
Pitch 8					
1	a	☐ ☐			
2	b	☐ ☐			
3	c	☐ ☐			
4	d	☐ ☐			
5	e	☐ ☐			
6	f	☐ ☐