Investigation of Modifying Part A, B and C Production Process for SM Electronics

CSI4124/SYS5110 – Foundations of Modelling and Simulation

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1.Problem Description

1.1 Problem Statement

1.1.1 Description of Part A, B and C Production Process

For the production process of Part A, B, and C in SM Electronics, there are four production lines (Line 1, 2, 3, and 4). Line 1, 2, and 3 have consistent performance for producing almost-finished Part A, B and C. Moving on, all three almost-finished parts will go through an input conveyor before being processed in Line 4 to get corresponding finished parts. Line 4 and the input conveyor have a limited capacity and will increase the operation cost for the production process both due to delayed time and lost parts.

1.1.2 Problems to be Investigated

When an almost-finished part arrives to the fully occupied input conveyor, the Line produces that specific almost-finished Part will be temporally shut down and reopened when there's space available in the input conveyor. In this case we will find out the operation cost for lost parts caused by the shut down process of Line 1, 2, and 3. At the same time, two approaches to reduce lost parts cost will be investigated joint and separately. The lost cost as well as cost saving from each approaches will be calculated. The first one is to add extra pallets within Line 4 and the second one is to add extra conveyors before Line 4. The modification approach that has the lowest lost cost /highest cost saving will be clarified in this research. Recommended solution may include one approach of the approaches or, a combination of both.

1.2 SUI Details

SM Electronics is a small manufacturer that produces electronic parts used by a variety of other manufacturers. The demand mix for these three products (Parts A, B, and C) has changed slowly over time. The department is almost fully automated and consists of four lines (Line 1, 2, 3, and 4). Line 1, 2, and 3 produce almost-finished Part A, B and C. Moving on, all three almost-finished parts will go through an input conveyor before being processed in Line 4 to get corresponding finished parts.

The operation time is limited to five days in a week and sixteen hours in a day. All lines will shut down at the end of each day and the incomplete parts will be left in the system until they restart in the next working day. As described above, the process after almost-finished parts leave Line 1, 2, 3, and 4 and the input conveyor area is the main system that will be investigated in this project.

1.2.1 Structural Description

Below is the structural description of Line 4. Fig 1.1 shows the setup of how plant and, in particular, how Line 4 is organized in Part A, B and C production processed. This is schematic of how lines are organized, it shows the placement of cells and direction of flow of parts from one point to another.

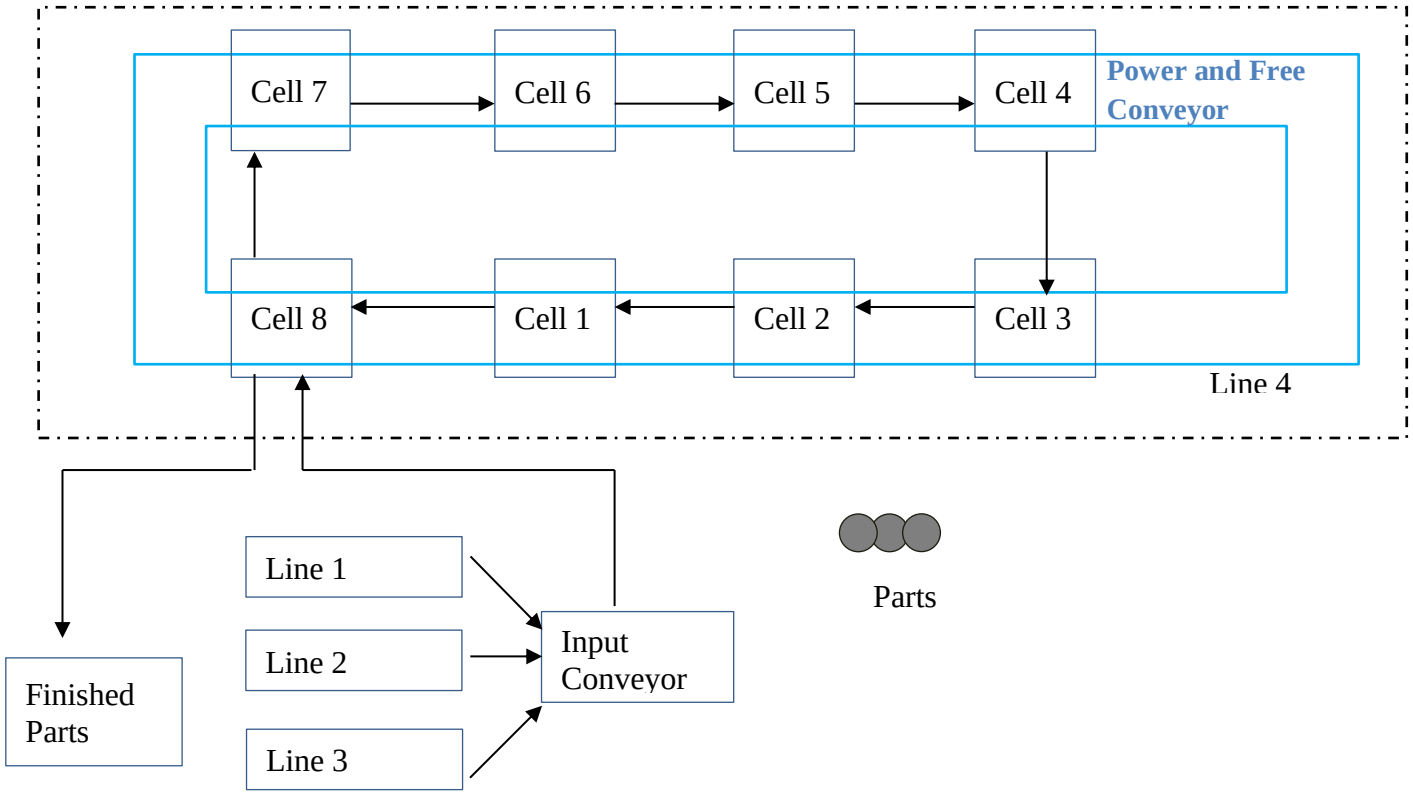


Fig. 1.1 Lines for processing Parts A, B and C.

1. Production Lines: Three production lines (Line A, Line B, Line C) produce each partially completed parts A, B, C respectively.
2. Input Conveyor: The input conveyor located at the the merge point to where the parts enter Line 4. The maximum parts capacity of the input conveyor is 40 and no specific distribution pattern in the input conveyor is observed.
3. Parts: For the parts processing process, the almost finish keeps arriving to the input conveyor continuously. When the input conveyor is full, the incoming part will turn into lost part and the cost for a lost part is $0.89, $0.63, and $0.72 for Parts A, B, and C, respectively.
4. Pallets: A special pallet in Line 4 will hold the part as it travels through the line. Presently, there are 40 pallets in the system and each pallet requires 2 feet of space.
5. Work Cells:
   1) Loading/ Unloading Work Cell: Cell 8, loads arriving part onto pallets, and unloads completed parts from pallets.
   2) Operation Work Cell: Work Cells 1, 3, 4, 5, and 6 are automated operations. The operation time is for automatic Work Cells is shown in Table one. Work Cells 2 and 7 are manual operations and the triangular distribution is shown in the data model section.
6. Power and Free Conveyor: Power and free conveyor moves pallets containing parts from one work cell to the other around the line.

1)The distance between two of successive work cells is 18ft and each work cell will take two feet space on the power and free conveyor so does the pallets. Therefor the maximum pallets can be hold between two work cells is 8.
2)The total space in the power and free convey or is 72 and 8 of them is used to hold work cells. The maximum amount of work cells that can be held in line 4 is 72 (it is 40 in the current system), while each of the work cells is holding one pallet in it
3) The travel time between two work cells (9 positions) is 15 seconds.

1.2.2 Behavioural Description of Processing Parts

1.2.2.1 Line 1, 2, and 3

Line 1, 2, and 3 feed Line 4 with almost finished parts with their varying arrival rates. The normal arrival interval for the three parts are: Part A, every 2.8 minutes; Part B, every 1.4 minutes and Part C, every 2.0 minutes. But jams can occur in each line to perturb the arrivals of parts.

1.2.2.2 Inputting Parts to Line 4

For the original system, when there is no buffer batch input conveyor at the end of each Line 1, 2, and 3, the parts came from Line 1, 2, and 3 go directly into the input conveyor as long as there is space on the input conveyor.

When there is one buffer batch input conveyor at the end of each Line 1, 2 and 3, the parts will enter corresponding batch input conveyor first then release into the input conveyor in batches. Parts will be released into Line 4 through the input conveyor.

1.2.2.3 Power and Free Conveyor

The 8 work cells in Line 4 are connected by the power and free conveyor around it. A pallet that carries a Part will be moved through Cell 8 to Cell 1, 2, 3, 4, 5, 6, and 7 then back to Cell 8 by the power and free conveyor. When a pallet (with a part on it) reaches a work cell, the pallet will be locked within the cell but it is still on the conveyor. During the time that the Part was being process in the cell, the incoming parts from the upstream cells will accumulate behind the work cell till the part in the cell has finished the processing process and left the cell. As the part moves out of the cell the part behind it can move into the cell.

1.2.2.4 Loading and Unloading Cell (Cell 8)

A pallet with a finished part will be unloaded at Cell 8, then a new part from input conveyor will be loaded onto this empty pallet. The loading and unloading Time is 25 seconds. This loaded pallet will be moved by the power and free conveyor to entering Cell 1. The distance between Cell 8 and Cell 1 can hold up to 8 pallets, which provides a buffer area. When this area is full, in other words, when there are 8 pallets between Cell 8 and Cell 1, the loaded pallet can not move out of Cell 8 and it will block Cell 8 thus stops the loading and unloading process. he pallet remains in Cell 8 and it will block Cell 8. Loading/Unloading Time is 25 seconds.

1.2.2.5 Automatic Operated Work Cells

When a pallet enters an automated work cell (cell 1, 3, 4, 5, and 6), a scanner reads the part type on that pallet and if there is a change to the type of the part, the work cell requires a reset process (with corresponding reset time as shown in table 1.1) to continue on processing the part. For example, when a Part A enters into Cell 1 after having processed either a Part B or Part C, Cell 1 will start the reset process in order to work on Part A.

The operation time for every automatic operated work cell depends on the part type as shown in table 1.2. There are no jams or failures occur at Work Cells 1 through 7.

Table 1.1. Setup Time (sec) for Automatic Operated Work Cells

Arriving Part Type	Cell 1	Cell 3	Cell 4	Cell 5	Cell 6
Part A	25	52	35	29	11
Part B	20	21	22	14	19
Part C	17	34	24	37	17

Table 1.2. Operation Time (sec) for Automatic Operated Work Cells

Part Type	Cell 1	Cell 3	Cell 4	Cell 5	Cell 6
Part A	37	39	41	33	31
Part B	46	27	38	41	24
Part C	39	23	47	35	51

1.2.2.6 Manual Operated Work Cells

For the manually operated work cells, Cell 2 and Cell 7, there is no reset operation required at the manually operated cells. The operation time for each manually operated work cell depends on the type of the part type.

1.2.3 Modification Proposals

1.2.3.1 Add Pallets

The first modification is adding extra pallets in Line 4. There are two type of cost for this modification. The first on is the fixed cost of 17,000 to modify Line 4, which will make it able to add extra pallets in on top of the 40 pallets in the current system. The second type of cost is the incremental cost of adding pallets to the system. It will cost $3,000 for every pallet being added into the system.

1.2.3.2 Add Input Conveyor

The second modification is to add three buffer conveyor, one at end of each Line and each of the first three lines would insert their parts into their own buffer conveyor. Each conveyor can hold up to 10 parts. Parts can be released in batches from 2 to 10. This modification will allow these parts to be released in batches to the existing buffer conveyor (limited to 40 parts). This will be able to reduce the setup time at each of the automated operation work cell. The modification cost is $56000 (including the equipment cost, installation cost, and the development of release logic is required). The modification is shown as below.

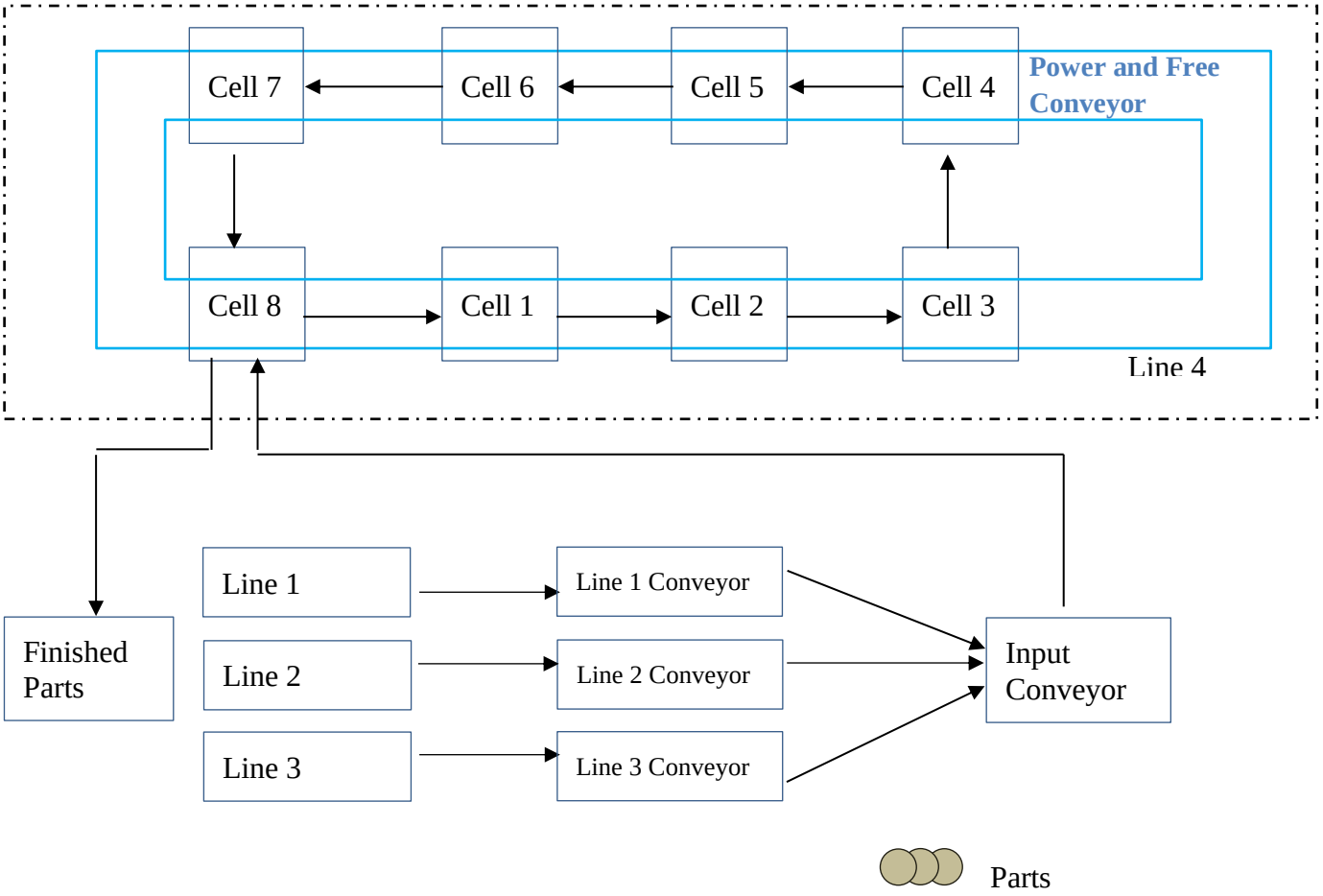


Fig. 1.2 Part A, B and C production process with the second modification by adding Line 1, 2, and 3 batch input conveyor.

2. Project Goals

2.1 Description

Our goal is to find the lost cost, and find out if changing the number of pallets or adding the buffer conveyor or both of the proposed modifications modification or, a combination of two modifications that will help to reduce the lost cost.

2.1.1 Lost Part and Lost Cost

After a part leaves Line 1, 2, or 3, if the input conveyor is full, that part will not enter the input conveyor and that part will be considered as a lost part and will introduce the lost cost.

The cost of lost part is computed as:

Cost = 0.89a + 0.53b + 0.72c

where, a = number of part A lost;
b = number of part B lost;
c = number of part C lost;

when the parts cannot enter the Line 4 (the input conveyor is full).

2.1.2 Downtime

Since the Line 1, 2, and 3 will keep generating parts and attempt to deliver to the input conveyor after the system reach its steady state, any downtime in Line 4 will increase the amount of lost part and thus the lost cost.

We define downtime in the system as the time when Cell 8 is not able to take in new parts. There are two reasons when cell 8 is not able to take in new parts. The first one is when there is no pallet for the Cell 8 to load the new part on it. The second one is when there is no space between Cell 8 and Cell 1 for the already loaded pallet to leave the system thus it can not take the new part.

Generally speaking, when a part is being processed inside a work cell, the pallet form the the upstream side will stop after this work cell and if there are more pallets coming behind this pallet, they will all accumulate in the space between the current work cell and the upstream work cell. When this space is full (with 8 pallets on it), this the pallet form the upstream work cell can not leave that cell, and thus block the pallet behind it. When the pallets are accumulating in the system by one or some slow work cells, it could cause both type of delays. One is when all work cells are accumulated in the system anywhere above Cell 7 (Cell 7, 5,4,3,2, and 1) in system, there is no pallet to get into Cell 8 to load a new part. The second one is when the space between cell 8 and cell 1 is full, the loaded pallet can not leave cell 8.

The first modification will increase the number of pallet in the system thus it should be able to provide more pallet to get into cell to load a new part. On the other hand, with the increasing number of extra pallets in the system, it might slow down the processing speed. The increasing number of pallets will

reduce the buffer space in the system and at some point the process speed of system 4 will be limited one cell. Thus in this project, we will try to get the proper amount of pallet that will be added into Line 4 that will reduce the lost cost.

The second modification by let the Parts enter the system in batches will reduce the reset time for the automatic work cell thus reduce the cell accumulation problem in the system. This will be able to reduce the accumulation between Cell 1 and Cell 8 thus reduce the downtime. This will reduce the average processing time thus will bring more pallet from Cell 7 to Cell 8 to intake new part to reduce the downtime. In this case we will investigate the the number of parts that should be release into the input conveyor can reduce the lost cost by the most among all experiments we conducted in this project.

2.2 Parameters

addNumPallets: The additional number of pallets in Line 4. The data range is [0, 32]. The data range is [0,32]. there is a physical limitation for the number of pallets we can incorporate in the system. For the current system, between cells there are 16 feet of buffer space on the power and free conveyor and the cells occupy 2 feet on the conveyor. Thus the maximum amount of pallets that can be held in between each pair of successive work cells is 8. There are 8 pair of successive work cells, and 8 work cells, which can hold one part in each cell, so the maximum amount of pallets in Line 4 is 72. The current system has 40 pallets leaves the maximum addNumPallets to be 32. When addNumPallets is 0, it represents that no pallet was added into the system.

addBuffer: Describe if it is necessary to add a buffer between Line A, Line B, Line C and input conveyor leading toLine 4. The data range is {true, false}. When TRUE, add the three additional buffers before the input conveyor leading to line 4. When FALSE, arriving parts are placed directly into the input conveyor.

numInputRelease: When the addBuffer is TRUE, this integer parameter will be introduced. Is is the Batch size of parts from buffer conveyor to input conveyor. The data range is [1,10]. Ten is maximum because a buffer conveyor can accommodate only 10 parts.

2.3 Experimentation

2.3.1 Experimentation

Four steps listed below shall be investigated to determine the cost of 4 separate configurations. The main goal is to find a configuration that has the lowest cost (defined in detail of how to compute cost in each step).

1. Simulate the current system's operation:

addBuffer = *false;* addNumPallets = *0*; numInputRelease = *0*;

This presents the cost of the current configuration.

2. Add pallets to existing Line 4 at a time:

addBuffer = *false;* addNumPallets = *range(1,24)*; numInputRelease = 0;

This is going to find the value of addNumPallets, which reduces the most number of parts lost. The cost of this configuration will be cost of lost parts + 17000 + n*3000 where n is the number of pallets added. Select the configuration which reduces the most lost cost.

3. Add input buffer between Line A, Line B, Line C and Line 4:

addBuffer = *true;* addNumPallets = *0*; numInputRelease = *range[2,10]*;

This is going to find the value of numInputRelease, which is the number of parts the buffer conveyor will release at one time. The cost of this solution is cost of lost parts + 56000. Select the configuration which reduces the most lost cost.

4. Add input buffer and pallets (one at a time) at the same time, and find out the number of pallets:

addBuffer = *true;* addNumPallets = *range(1,24)*; numInputRelease = *range[2,10]*;

This is going to find the (addNumPallets, numInputRelease), which a combination of number of pallet that is being added into the system and the number of parts the buffer conveyor will release at one time. The cost of this solution is cost of lost parts + 17000 + n*3000 +56000. Select the configuration which reduces the most lost cost.

5. Compare cost of each configuration obtained in each of the four steps and select the configuration with the lowest cost.

2.3.2 Study

In this experimentation, the operation lines do not reset after the shutdown at the end of each day, and the parts remain in the system as is; when the system starts the next day, operation resumes from the point it was stopped. The operation lines keep working on the parts, thus, this is a steady state study.

2.3.3 Observation Interval

The simulation will provide a steady state analysis after the warm-up period and the observation interval will be determined during experimentation

2.4 Output

totalLostCost: Lost Cost is the cost of lost parts during the experimentation observation interval. We get the lost cost from every observation interval. So in this case, it is a simple scalar output variable (SSOV).

2.5 Data Models

The data used in the SM projects is:

1. Data to be analyzed before parts A, B and C enter Line 4 is shown below.

Arrival Time: Arrivals of Parts A, B and C arrive into the input conveyor with constant rate as shown in Table 2.1.

Delay due to Jams: the above constant arrival times are perturbed by the delay due to occasional jams, which are modeled as triangular distributions (parameter values shown are min, peak, max). The parameters' units for the distributions are in seconds.

Table 2.1. Parts Arrival Time to input conveyor.

Part	Arrival Rate (min)	Delay Due to Jams	
		Probability (%)	Triangular Distribution (seconds)
A	1.8	2.00	(5, 15, 60)
B	2.4	1.75	(5, 20, 55)
C	1.0	0.50	(5, 20, 65)

2. Probability models of Line 4 are shown in Table 2.2.

Jam probability: The time to clear the jam is modelled as in the Unload/load process is modeled as a triangular distribution (parameter values shown are min, peak, max) with parameters, the unit is in seconds.

Table 2.2. Probability models of Work Cell 8.

Unload/Load Process Jam Probability	1%
Triangular Distribution (seconds) for Clearing Jams(min, peak, max)	(5,15,75)
Unload/load Processing Time(seconds)	25

3. The description of manually operated cells is shown in Table 2.3.

Table 2.3. Operation Time (sec) in Triangular Distribution for Automatic Operated Work Cells

Part Type	Work Cell 2 (min, peak, max)	Work Cell 7 (min, peak, max)
Part A	36,45,52	27,35,41
Part B	21,32,39	31,39,43
Part C	32,36,42	22,27,38

3. ABCmod Conceptual Model

3.1 High Level Conceptual Model

3.1.1 Assumptions

1. Parts A, B and C keep arriving to input conveyor, if conveyor is full, the arriving part is considered as lost part and leaves the system.

3.1.2 Simplifications

1. The time for the input conveyor to move the parts to Cell8 is considered negligible.
2. The accelerate time of the pallet form 0 to the power and free conveyor's speed is negligible. In other words, the pallet is either not moving or moves at a constant speed.

3.1.3 Structural View

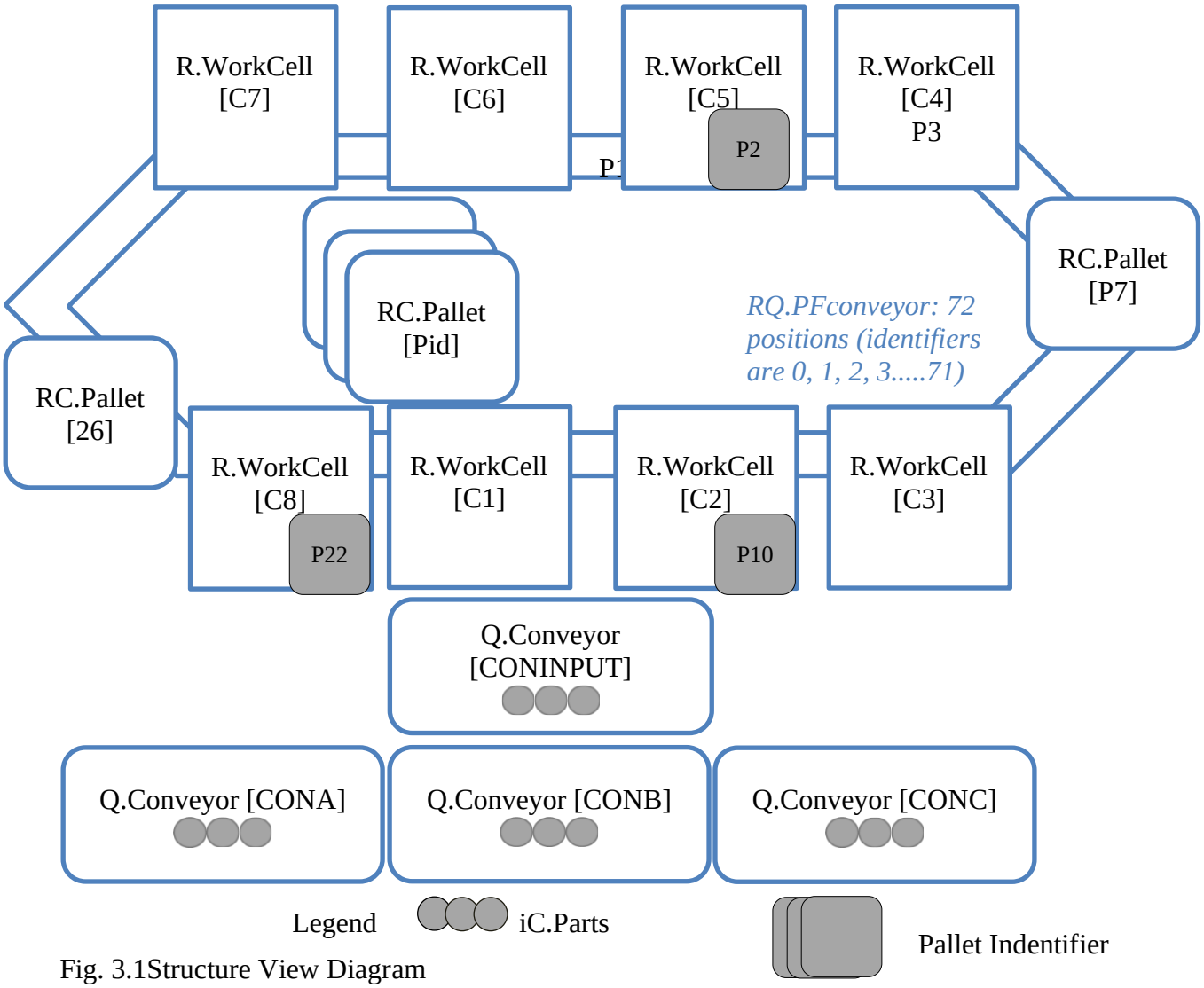


Fig. 3.1Structure View Diagram

Entity Categories:

1. Q.Conveyor: The set of queue entity that represents the four input conveyor in the system. The number 1,2,3,4 are used to identify the different conveyor. The attribute *ubatch* is used to define if it is the batch release conveyor.

   Role = Queue and Scope = Set (N=4) represent the four conveyor in the system.

   a. Batch input conveyor after Line 1: Q.Conveyor [CONA]
   b. Batch input conveyor after Line 2: Q.Conveyor [CONB]
   c. Batch input conveyor after Line 3: Q.Conveyor [CONC]
   d. Non-Batch input conveyor in the original system: Q.Conveyor [CONINPUT]

2. RQ.PFConveyor: A single resource entities represents the power free conveyors performing the transportation of parts between the successive work cells and it is also a first in first out conveyor. There are 72 positions (identifiers are 0, 1, 2, 3…..71).

   Role = Queue and Resource, and Scope = Unary represent the only power and free conveyor in Line 4.

3. R.WorkCell: The set of resource entities represents the set of work cells performing processing parts. There are 2 types of work cell: manual and automatic. Cells are distinguished using the Part attribute *uCType*. The 8 work cells located on the power and free conveyor on the following position as shown in table 3.1.

   Role = Resource and Scope = Set (N = 8) represents the eight work cell Line 4.

   Table 3.1 Work Cell Location on the Power and Free Convwyor

Work Cell	Indentifier	Position on the Power and Free Conveyor
1	C1	0
2	C2	9
3	C3	18
4	C4	27
5	C5	36
6	C6	45
7	C7	54
8	C8	63

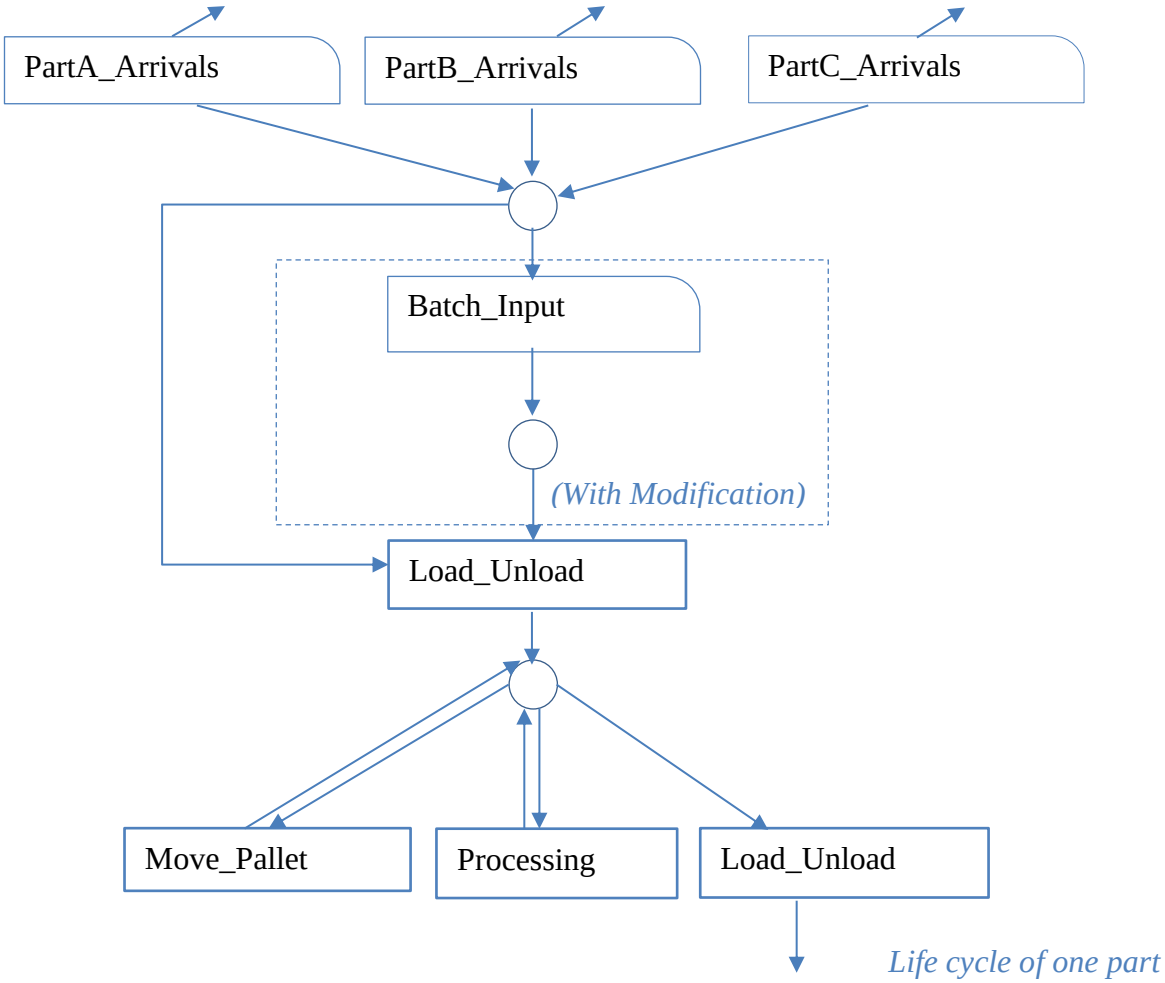
4. iC.Parts: A consumer entity category that represents the parts that required to be processed in the system. There are 3 types of parts: A, B and C. Parts are distinguished using the Part attribute *uType*.

   Role = Consumer and Scope=Class represents the collection of parts that required to be processed in the system.

5. RC.Pallets: A resource and consumer entity that represents the pallets in Line 4.

   Role = Resource and Consumer and Scope =Set[numPallets], that is the parameter determines the number of pallets in the mode. The ID = {P0,P1,P3,…PN-1}is used to identify the pallets in the system.

3.1.4 Behavioural View



Actions:

Scheduled Action constructs:

PartA_Arrivals: Part A is produced and send to the input conveyor. We classify these as scheduled actions because Part A has their own arrival rate.
PartB_Arrivals: Part B is produced and send to the input conveyor. We classify these as scheduled actions because Part B has their own arrival rate.

PartC_Arrivals: Part C is produced and send to the input conveyor. We classify these as scheduled actions because Part C has their own arrival rate.

Conditional Action constructs:

Batch_Input: Only functional when parameter addBuffer is TRUE. The new added batch input conveyor keeps sending Parts A, B, C in batches to the input conveyor while it is not full and when the batch input conveyor has no less than the amount of Parts need to be released at one time. While the input conveyor is full or when there are not enough parts to be released at one time, the BATCH_INPUT input port will pause until there is more room and enough parts to be released to the input conveyor.

Activity:

Load_Unload: Take parts from Q.Conveyor[CONINPUT] to add them to a pallet after removing the completed part (if any) from the pallet. The condition of the starting event is when there is a both a finished part (on a pallet) and a new part (from the input conveyor and without a pallet) arrives at cell 8, and the finish event is a scheduled event since it takes 25 second to unload/load.

Move_Pallet: move pallets by one position on the power and free conveyor. The conditions to move a pallet by one position are there is a pallet to move and an empty position on the power and free conveyor to move into.The finish event is a scheduled event since it takes 15/9 second to move one position.
Processing: The cell 1 to cell 7 process the parts. The condition for the starting event is when the work cell is not busy and has a part inside to be processed. The finished event is scheduled.

3.1.5 Input

Exogenous Input (Entity Stream)			
Variable	Description	Domain Sequence	Range Sequence
uAPArr	Input entry stream variable of Part A	RVP.DuAPArr()	One A part arrives
uBPArr	Input entry stream variable of Part B	RVP.DuBPArr()	One B part arrives
uCPArr	Input entry stream variable of Part C	RVP.DuCPArr()	One C part arrives
Endogenous Input (Semi-Independent)			
variable	Description	Values	
uMProcTime	Processing time in work cells, depends on the part type. It includes the reset time for automatic work cells. (CId = C1, C2, C3, C4, C5, C6 and C7).	RVP.uCProcTime(CId, type)	
uLProcTime	Loading and unloading time in cell 8, including the time to clear jams.	RVP.uLProcTime	

3.2 Detailed Conceptual Model

3.2.1 Structural Components

Constants		
Name	Description	Value
CONA, CONB, CONC, CONINPUT	Identifier for set categories Q.Conveyor.	0, 1, 2, 3
MOVE_TIME	The time for power and free conveyor to move one position.	25.0/9.0 seconds
COST_PARTA, COST_PARTB, COST_PARTC	The lost cost for one Part A, B or C	$0.89, $0.63, and $0.72
CELLPOS8	Positions of the work cells 8 on the Power and Free conveyor	0
C1, C2, C3, C4, C5, C6, C7, C8	Identifier for set categories R.WorkCell	0, 1, 2, 3, 4, 5, 6, 7
CELLPOS	An list of work cell (1-8) positions on the power and free conveyor.	{9,18,27,36,45,54,63,0}
NONE	When an list is empty	-1
Parameters		
Name	Description	Value
addNumPallets	The additional number of pallets in Line 4	0 to 32
addBuffer	Value TRUE add a buffer batch input conveyor between Line A, Line B, Line C and Line 4.	TRUE, FALSE
numInputRelease	The amount of parts that are released by one batch input conveyor the at one time. Valid if addBuffer is TRUE	2 to 10

Consumer Class: Parts	
Parts processed by the factory.	
Attributes	**Description**
type	Set to PA, B or C to reflect the type of component and NO_PART when there is no part on the pallet.

Queue Set [4]: Conveyor	
The four input conveyors in the model. CONA, CONB, CONC, and CONINPUT are the four identifiers for the conveyors.	
Attributes	**Description**
n	The number of Parts on the conveyor.
list	The list of part entities on the conveyor.
length	The length of the conveyor. It is used to describe what's the max amount it can hold. 10 in CONA, B C, and 40 in CONINTPUT

Resource Queue: PowerAndFreeConveyor	
The power and free conveyors transports pallets between the work cells within Line 4.	
Attributes	**Description**
list	The list of positions on the power and free conveyor. There are total 72 positions, Pos = {0,1,2,…71} in the Line 4, each contains a RC. Pallet identifier or NO_PALLET if no pallet exists in the position. Discipline: first in first out (FIFO).

Resource Set[8]: WorkCell	
The 8 work cells in the system. C1, C2, …, C8 are the 8 identifiers of the work cell.	
Attributes	**Description**
auto	Set to TRUE when it is automatic work cell (C1, C3, C4, C5, C7, C8)and FALSE to the rest.
busy	Set to TRUE when the work cell is processing a part and FALSE otherwise.
prtConfig	Set to PA, B, or C to indicate for automatic work cells of part the cell is configured. Set to N to manual work cells, Cell 2 and Cell 7.

Consumer Resource Set[addNumPallets+ 40]: Pallets	
The pallets hold and transport the parts among work cells in Line 4. P0, P1, P2…P addNumPallets + 39 are the identifiers for the pallets.	
Attributes	**Description**
processed	Set to TRUE when the work cell is processing a part on it and FALSE otherwise.
part	References a Part entity on the pallet. Set to NO_PART to indicate part is not present in the pallet.
moving	References if a pallet is moving or not. Set to TRUE indicate the pallet is moving, FALSE otherwise.

3.2.2 Behavioral Components

Time Unit and Observation Interval
Time unit: Seconds, unless specified

Action: Initialise	
TimeSequence	<0.0>

Event SCS	FOR cId C1, C3, C4, C5, C6, C8
	R.WorkCell [cId].auto ←TRUE
	R.WorkCell [cId].busy←FALSE
	IF(cId == C2 || C7)
	R. WorkCell [cId]. auto ← FALSE
	R.WorkCell [cId].busy←FALSE
	ENDFOR
	(set up automatic work cells)
	FOR CId C1 to C8,
	R.WorkCell[cId].busy ← FALSE
	(set up all work cells to not busy)
	ENDFOR
	FOR Pid P0 toP addNumPallets+ 39,
	RC.Pallets[pid].processed ← FALSE
	RC.Pallets[pid].part ←NO_PART
	RC.Pallets[pid].moving← FALSE
	ENDFOR
	(set up the length and attributes of the pallets)
	Add pallet before load cell
	FOR pos from 71-38- addNumPallets to 71
	(set up the length and attributes of Power and Free conveyor and the pallet position)
	FOR CONA, CONB, CONC, CONINPUT
	Q.Conveyor[conId].n ← 0
	ENDFOR
	FOR CON,CONB,CONC, CONINPUT:
	IF it is not CONINPUT
	Q.Conveyor[conId].length ← 10
	ELSE
	Q.Conveyor[conId]. length ← 40
	ENDFOR
	(set up the length and attributes of four conveyors)

Output Construct

Output	
Simple scalar output variable (SSOV)	
Name	**Description**
totalLostCost	The cost of lost parts during the experimentation observation interval.

Input Construct

Action: PartA_Arrivals		
Arrival of a part A.		
Time Sequence	RVP.DuAPArr(),	

Event	iC.Part ←SP.Derive(Part)
	iC.Part.type ← PA
	IF(addBuffer =FALSE AND
	Q.Conveyor[CONVINPUT].n < Q.Conveyor[CONVINPUT].length)
	SP.InsertQu(Q.Conveyor[CONVINPUT], iC.Part)
	ELSE IF(addBuffer = TRUE AND
	Q.Conveyor[CONA].n < Q.Conveyor[CONA].length)
	SP.InsertQu(Q.Conveyor[CONA], iC.Part)
	ELSE *(no room in input queue - lost part)*
	lostPart ← COST_PARTA
	ENDIF	

Random Variate Procedures		
Name	**Description**	**Data Model**
DuAPArr	Return the next arrival time for Part A	interarrival time 2.8 minutes + delayed time caused by Jam (Jam probability 2% and Triangular Distribution for delayed time (min, peak, max):(5,15,60))

Action: PartB_Arrivals	
Arrival of a part B.	
Time Sequence	RVP.DuBPArr(),

Event	C.Part <-- SP.Derive(Part)
	iC.Part.uType <-- B
	IF(addBuffer = FALSE AND
	Q.Conveyor[CONVINPUT].n<Q.Conveyor[CONVINPUT].length)
	SP.InsertQu(Q.Conveyor[CONVINPUT], iC.Part)
	ELSE IF(addBuffer = FALSE AND
	Q.Conveyor[CONB].n < Q.Conveyor[CONB].length)
	SP.InsertQu(Q.Conveyor[CONB], iC.Part)
	ELSE *(no room in input queue - lost part)*
	lostPart←COST_PARTB
	ENDIF

Random Variate Procedures		
Name	**Description**	**Data Model**
DuBPArr	Return the next arrival time for Part B	interarrival time 1.4 minutes + delayed time caused by Jam (Jam probability 1.75% and Triangular Distribution for delayed time (min, peak, max):(5,20,65))

Action: PartC_Arrivals	
Arrival of a part C.	
Time Sequence	RVP.DuCPArr,

Event	iC.Part ←SP.Derive(Part)
	iC.Part.uType ← C
	IF(addBuffer = FALSE AND.
	Conveyor[CONVINPUT].n<Q.Conveyor[CONVINPUT].length)
	SP.InsertQu(Q.Conveyor[CONVINPUT], iC.Part)
	ELSE IF(addBuffer = FALSE AND
	Q.Conveyor[CONC].n < Q.Conveyor[CONC].length)
	SP.InsertQu(Q.Conveyor[CONC], iC.Part)
	ELSE *(no room in input queue - lost part)*
	lostPart ←COST_PARTC
	ENDIF

Random Variate Procedures		
Name	**Description**	**Data Model**
DuCPArr	Return the next arrival time for Part C	interarrival time 2.0 minutes + delayed time caused by Jam (Jam probability 0.5% and Triangular Distribution for delayed time (min, peak, max):(5,15,65))

Behavior Constructs

Action: Batch_Input	
The new added batch input conveyor sends Parts A, B, C in batches to the input conveyor while it is not full.	
Precondition	UDP. CanMoveBatch ≠ NONE
Event SCS	UDP.MoveBatch(UDP.CanMoveBatch())
User-Defined Procedures	
Name	**Description**
UDP.CanMoveBatch()	Get the batch conveyor ID (bId), if add buffer is true and there is room in the CONINPUT (Q.Conveyor[CONINPUT].n < Q Conveyor[CONINPUT].length – numInputRelease), then cycle through the three batch input conveyors starting at startBid and find the Bid of the conveyor that has enough parts to release Q.Conveyor [bId]. n>= numInputRelease).
Name	**Description**
UDP.MoveBatch(bid)	Move numInputRelease parts from the batch conveyor with [bId] to the input conveyor then set startBid to the next batch conveyor. To move parts (SP.InsertQue(Q.Coneyor[CONINPUT].Parts) SP.RemoveQue(Q.Coneyor[bId].parts)) Update startBid (StartBid ←bId)

Activity: Load_Unload	
The work cell 8 take new parts from conveyors and take out the finished parts from the Line 4.	
Precondition	Q.Conveyor[CONINPUT].n > 0) (*There are parts in the input conveyor to b loaded into Line 4)*, AND RQ.PFConveyor.list[CELLPOS[C8]] ≠ NON_PALLET*(There is a pallet in C8)* AND RC.Pallet[RQ.PFConveyor.list[CELLPOS[C8]].processed = FALSE] AND*(Either there is no pallet on the pallet or it is not a part has just been loaded on cell 8, in both case the pallet being processed are false)* Cell[C8].moving← FALSE (*Cell 8 is not busy processing)*
Event SCS	R.WorkCell[C8].busy ← TRUE(*Work Cell becomes busy)* iC.Part ← SP.RemoveQu(Q.Conveyor[CONINPUT]) (*the first part on the input conveyor had been removed)* pid ← R.PowerFreeConveyor.list[CELL8]
Duration	uLProcTime
Event SCS	RC.Pallet[pid]part ← iC.Part (*The old part on cell 8 left and new part has been loaded on Cell 8)* Cell 8(RC.Pallet[pid]processed ← TRUE) (*This is the new part that has just been loaded onto)* R.WorkCell[CELLPOS[C8]]busy ← FALSE*(Work cell is not busy)*

Random Variate Procedures		
Name	**Description**	**Data Model**
uLProcTime	Processing time in WorkCell[C8].	25s loading_unloading time + additional time to clean Jam (Jam probability 1% and Triangular Distribution for Cleaning Jams(min, peak, max):(5,15,75))

Activity: Move_Pallets	
Move Pallet by one position on the power and free conveyor	
Precondition	For pos ition, 0-71, UDP. CanMovePallet() ≠ None*(Search the power and free conveyor to find a pallet that is ready to move)*
Event SCS	StartMoving()
Duration	MOVE_TIME

Event SCS	IF position 71 in movePos:
	temPPid ← pid
	ENDIF
	FOR checkPos in pos:
	pid ← PalleIdAtPosition (pos)
	(Get the pallet id of the pallet that is ready to move)
	RQ.PFConveyor.list[(movePos+1)mod72] ← RQ.PFConveyor.list[movePos]
	(The pallet moved by one position)
	(RQ.PFConveyor.list[movePos] ←NO_PALLET *(The pallet leaves it current position empty)*
	(RQ.PFConveyor.list[(movePos+1)mod72].moving ← FALSE) *(pallet stops moving)*
	RC.Pallet[MovePid].processed ← FALSE
	ENDFOR
	IF position 71 in pos:
	The pallet moved by one position(RQ.PFConveyor.list[(71+1)mod72] ← TempPid.
	ENDIF

User-Defined Procedures	
Name	**Description**
CanMovePallet()	1) Find a pallet (RQ.PFConveyor.list [palletPos] ≠ NO_PALLET.) 2) see if the pallet is in a work cell (palletPos == CELLPOS), **either** I. if the pallet is in the work cell, **either** a) the processing should be completed (RC.Pallet[RQ.PFConveyor.list[Pos]].processed = TRUE) **OR** b) it is in a work cell other than the loading_unloading (cell8) **AND** there is no pallet on it on the pallet (palletPos != Constants.CELLPOS8RC.Pallet[RQ.PFConveyor.list[palletPos]] .part == null; II. it is not in a work cell AND a) the pallet is not in moving state (RC.Pallet[RQ.PFConveyor.list[palletPos]]).moving = FALSE

	AND b) a. the next position should be empty(RQ.PFConveyor.list[(palletPos+1) mod 72] = NO_PALLET) **OR** b. The pallet on the next position is moving(RC.Pallet[RQ.PFConveyor.list[palletPos+1] mod 72]).moving = TRUE).
StartMoving()	Scan the PFconveyor from the last position (position 71) to the first position (position 0) twice: 1) Find a pallet that can be moved (canMovePallet ≠ NO_PALLET). 2) Add this pallet position to the pos list and get the pallet id. 3) Change the pallet to moving state.

Activity: Processing		
The work cell processes the inside parts		
Precondition	UDP.CellReadyForProcessing() ≠ NONE	
Event SCS	cid ← UDP.CellReadyForProcessing() (*Get the cell id that is ready to process a part)* type ← C.Pallets[RQ.PFConveyor.list[CELLPOS[cid]].part.type *(Get the part type that the cell will process)* pid = RQ.PFConveyor.list[CELLPOS[cid]] R.WorkCell[cid].busy ← TRUE (*this work cell will be busy)*	
Duration	RVP.uMProcessTime(cId, type)	
Event SCS	R.WorkCell[cid].busy ← FALSE*(The work cell is no longer busy)* RC.Pallets[RQ.PFConveyor.list[CELLPOS[cid]].processed ← TRUE] *(The part on the pallet has been processed by by this workcell)* *If it is automic* R.WorkCell[cid].prtconfig ←part *(work cell has been configured to the part type that has just processed)*	
Random Variate Procedures		
Name	**Description**	**Data Model**
uMProcessTime (cid, type)	Processing time for WorkCell(cid, type)	1)For manual work cells (R.WorkCell[cid].auto = FALSE): Use Triagular (min, peak, max) where paramters are defined for the part type, which can be found in RC.Pallet[RQ.PFConveyor.list[POS[cid]]].part.type, and cid set of C2/C7: tyep/Cell C2 C7 A 36, 45, 52 27, 35, 41 B 21, 32, 39 31,39,43 C 32,36,42 22,27,38 2)For automatic work cells (R.WorkCell[cid].auto = TRUE): Reset Time + processing time When RC.Pallet[RQ.PFConveyor.list[POS[cid]]].part.type ≠ R.WorkCell[cId].prtConfig, add a time from the following table for

		the part type (RC.Pallet[RQ.PFConveyor.list[POS[cid]]].part.type) and the cell type (cid) type/Cell C1 C3 C4 C5 C6 A 25 52 35 29 11 B 20 21 22 14 19 C 17 34 24 37 17 R.WorkCell[cid].prtConfig == (RC.Pallet[RQ.PFConveyor.list[POS[cid]]].part.type Add to the processing time to the reset time, the time to process the part according to the part type and the cell type: type/Cell C1 C3 C4 C5 C6 A 37 39 41 33 31 B 46 27 38 41 24 C 39 23 47 35 51

User-Defined Procedures	
Name	**Description**
CellReadyForProcessing()	Find the (cid)of the a work cell when: 1) There is a pallet in the cell (RQ.PFConvery.list.[CELLPOS[cid]]≠ NO_PALLET) 2) The work cell is not busy (R.WorkCell [cid].busy = FALSE) 3) Pallet has not been processed (R.Pallet[QR.PRConveyor.list[CELLPOS[cid]]].processed =FALSE) 4) Threre is a part on the pallet (R.Pallet[QR.PRConveyor.list[CELLPOS[cid]]].part ≠NO_PART)

3.2.3 Design of Validation Experimentation

Given the simplicity of the model, it is possible to validate the model using a trace log as described below. The model shall be validated for both the base case and the alternate case.

Trace Logging

The state of the simulation model is monitored by tracking the list of Q.Conveyor[CONINPUT] and RQ.PFConveyor and the state of the work cells presented as follow:

```
Clock: xxxxxxx
```
(where the xxxxxxx is replaced with the current value of the clock.)

```
Q.Conveyors[CONA].n: xx
Q.Conveyors[CONB].n: xx
```

Q.Conveyors[CONC].n: xx
Q.Conveyors[CONINPUT].n: xx
where the *xx* are replaced with the number of parts on each conveyor, -1 represents that the batch input has not been added into the system.

Q.Conveyors[CONTINPUT].list: x x x x x x x x x x x
where the *xx* are replaced with the list of parts on the input conveyor, it will be empty when there are no parts on the input conveyor.

RQ.PFConveyor.list:

C8	1	2	3	4	5	6	7	8	C1	10	11	12	13	14	15	16	17
xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
C2	19	20	21	22	23	24	25	26	C3	28	29	30	31	32	33	34	35
xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
C4	37	38	39	40	41	42	43	44	C5	46	47	48	49	50	51	52	53
xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
C6	55	56	57	58	59	60	61	62	C7	64	65	66	67	68	69	70	71
xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

where the *xxx* are replaced with the list of parts on the power and conveyor, it is either Pid or NP if there is no pallet at that position and EP if it is an empty pallet.

CId	auto	busy	prtConfig
C1	TRUE	xxxx	x
C2	FALSE	xxxx	Null
C3	TRUE	xxxx	x
C4	TRUE	xxxx	x
C5	TRUE	xxxx	x
C6	TRUE	xxxx	x
C7	FALSE	xxxx	Null
C8	TRUE	xxxx	Null

where the *xxxx* are replaced with the either TRUE or FALSE to depends in the cell is busy or not; where *x* are replaced by A, B or C.

4. Simulation Model

4.1 Design of Simulation Model and Program

The simulation model is implemented in the class Manufacturing (an extension of the ABSmod/J class `AOSimulation` model) and a number of other classes used to implement the various constructs from the ABCmod conceptual model. All Java classes that make up the Java SMElectronics simulation model are placed in the Java package `Electronics`.
The following table shows how the various ABCmod entity structures are mapped to Java classes and how objects instantiated from these classes are reference by the Manufacturing class.
The following table shows how the various ABCmod entity structures are mapped to Java classes and how objects instantiated from these classes are reference by the Manufacturing class.

Entity Structures		
ABCmod Construct	**Java Class**	**Object References**
Q.Conveyor	`Conveyor` and `ArrayList (`stansard Java class) Note: • The various methods available in the `Conveyor` class provide the implementation of the various ABCmod procedures, such as SPInsertQue (), SPRemveQue () • The attribute length is implemented by int to demonstrate how many parts it can carry at maximum. • The attribute n is maintained within the `ArrayList` object (adjusted automatically when `ArrayList` methods are called). The method conveyor.getN() provides the value of the Q.Conveyor.n attribute.	`Manufactruing.qConveyor[CONid]`
RQ.PFConveyor	PFConveyor Note: • The attribute list is used to hold what is on the power and free conveyor.	`Manufactruing.rPowerAndFreeConveyot`
R.WorkCell	WorkCell Note: • The attribute auto and busy is used to demonstrate if the work cell is auto machine and if it is process parts. • prtConfig is used to demonstrate which type of parts is processing.	`Manufactruing.rWorkCell`
iC.Parts	Parts Note: • use `uType type` to limit the part type • use attribute type to describe the part type that has been removed or insert queue or processed.	Typically by the reference variable `ic.Parts` in the various methods that manipulate Parts objects.
RC.Pallets	Pallets Note: • attribute processed and moving is used to suggest the pallet state and their default value are false. • Attribute Parts is used to demonstrate the part on it.	`Manufactruing.rcPallets[pid]`

The following table provides mapping between the conceptual model Action/Activities to Java classes.

Actions/Activities	
ABCmod Constructs	**Java Classes**
PartA_Arrivals	`PartAArrivals`
PartB_Arrivals	`PartBArrivals`
PartC_Arrivals	`PartCArrivals`
Batch_Input	`Batch_Input`
Load_Unload	`Load_Unload`
Move_Pallet	`Move_Pallet`
Processing	`Processing`

Other classes that make up the SMElectronics ABSmod/J simulation model include:

- `RVPs` (referenced by `Electronics.RVPs`): Contains the Java methods used to implement the CM RVP's.
- `UDPs` (referenced by `Electronics.UDPs`): Contains the Java methods used to implement the CM UDP's
- `Output` (referenced by `Electronics.Outputs`): Contain the SSOV.
- `Seeds`: The class used to pass seeds for random number generators used in implementing the various RVPs.

The package `Electronics` provides public access to the following:

- The constructor `Manufacturing` to allow creation and initialisation of a `Manufacturing` object.
- The Method `getLostCost()` to allow access the value of the output variable `lostCost`.
- All public methods provided by the class `AOSimulation` (e.g. `runsimulation`) for supporting experimentation.

4.2 Results of the Validation Experimentation

Base Case (addBuffer = *false;* addNumPallets = *0*; numInputRelease = *0*)

Start of log shows the proper initialization and start of the model execution.

At the beginning, the there is no batch conveyor in the system so there is no part on CONA, B and C.

At the beginning, the there are no parts in the system so there is no part on CONINPUT

```
Case 1 - no additional pallets; no batch conveyor
Clock =     0.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty
```

40 Empty Pallet (EP) are in the system at the beginning

```
   RQ.PFConveyor.list:
-------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP
-------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------
```

```
-------------------------------------
CID      auto      busy      prtConfig
-------------------------------------
C1       true      false       null
C2       false     false       null
C3       true      false       null
C4       true      false       null
C5       true      false       null
C6       true      false       null
C7       false     false       null
C8       true      false       null
-------------------------------------
```

Work Cell 1, 3, 4, 5, 6, and 8 are automatic work cells. 2 and 7 are not.

All work cells are not busy and not being configured.

```
------------SBL----------
TimeStamp:84.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:120.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------
```

Scheduled actions have been properly scheduled.

No Lost Cost at the beginning.

```
Total Lost Cost:     0.0

>--------------------------------------------------------------------<
```

After the first part arrived:

```
Clock =    84.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty
```

At Clock = 84.0000, a Part B arrives to the system.

At the beginning, the there is no batch conveyor in the system so there is no part on CONA, B and C. There is no part on CONINUP because the loading_unloading started immediately.

Work cell 8 still has empty pallet because the loading/unloading process has not completed.

```
   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
-------------------------------------
CID      auto      busy      prtConfig
-------------------------------------
C1       true      false       null
C2       false     false       null
C3       true      false       null
C4       true      false       null
C5       true      false       null
C6       true      false       null
C7       false     false       null
C8       true      true       null
-------------------------------------
```

The loading_unloading work cell (C8) is busy

```
------------SBL----------
TimeStamp:109.0 Activity/Action: Electronics.Load_Unload
TimeStamp:120.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
```

The terminating event for loading_unloading process has been scheduled.

The losading_unloading processed has completed:

```
Clock =   109.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty
```

A part B has been loaded on the pallet in work cell 8.

```
   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
B  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
```

```
--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      false        null
--------------------------------------
```

The loading_unloading process has completed so work cell 8 in no longer busy

```
------------SBL----------
TimeStamp:111.77777777777777 Activity/Action: Electronics.Move_Pallet
TimeStamp:120.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0
```

The precondition of Move_Pallet has met, it starts immediately and the terminating event has been scheduled.

Pallets have been moved to the next position:

```
Clock =   111.7778
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty
```

All the pallets that can be moved have been moved by one position.

```
   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP   B  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      false        null
---------------------------------------
```

All work cells are not busy

There are still pallets can move, so the terminating event of Move_Pallet has been scheduled

```
------------SBL----------
TimeStamp:114.55555555555554 Activity/Action: Electronics.Move_Pallet
TimeStamp:120.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
```

After pallets move by one position:

```
Clock =   114.5556
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty
```

Only the pallet with a part B has been moved by one position because the empty pallet is waiting at Cell 8 to get load a part.

```
   RQ.PFConveyor.list:
-------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------
EP  NP   B  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP
-------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------


--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      false        null
--------------------------------------
```

Cell 8 is not busy because there is no part to load.

```
------------SBL----------
TimeStamp:117.33333333333331 Activity/Action: Electronics.Move_Pallet
TimeStamp:120.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>--------------------------------------------------------------------------<
```

when the next part arrives:

```
Clock =   120.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty
```

```
   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP   B  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      true         null
---------------------------------------

------------SBL----------
TimeStamp:120.11111111111109 Activity/Action: Electronics.Move_Pallet
TimeStamp:145.0 Activity/Action: Electronics.Load_Unload
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------



Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
```

Cell 8 is busy.

The next part arrives to the system and the loading_Unoading process has immediately started. The terminating event for Loading/Unloading had been scheduled.

Right before the first part reaches Work Cell 1:

```
Clock =   131.2222
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
```

```
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP   B  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP
-------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------
```

Part B is in work position 8 and will move to position 9, where work cell 1 in the next time instance

```
---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      true         null
---------------------------------------

------------SBL----------
TimeStamp:133.99999999999994 Activity/Action: Electronics.Move_Pallet
TimeStamp:145.0 Activity/Action: Electronics.Load_Unload
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>--------------------------------------------------------------------<
```

Work Cell 8 is busy so the new part in not shown in the power and free conveyor yet.

The first part moves to the position where Work Cell 1 is:

```
Clock =   134.0000
```

```
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP   B  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      true         null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      true         null
---------------------------------------

------------SBL----------
TimeStamp:145.0 Activity/Action:
Electronics.Load_Unload
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:199.99999999999994 Activity/Action: Electronics.Processing
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
```

Once the part is in Work Cell 1, the it starts the processing process (includes configuration if need), work cell 1 busy. The prtConfig will change state once the processing activity has completed.

The terminating event has been scheduled and the time is 46s processing time and 20s configure time, total is 66s, which is consistent as the time scheduled by the system.

When the first part shows on CONINPUT:

```
Clock =   168.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      1

   Q.Conveyors[CONTINPUT].list:
 B

   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP   C   B  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      true         null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      true         null
---------------------------------------

------------SBL----------
TimeStamp:193.0 Activity/Action: Electronics.Load_Unload
TimeStamp:199.99999999999994 Activity/Action: Electronics.Processing
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:252.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
When Work Cell 1 finishes processing:
Clock =   200.0000
```

There is a Part B on the input conveyor because the loading_unloading work cell is busy

```
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP   A  NP  NP  NP  NP  NP   C   B  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      false          B
C2       false     false       null
C3       true      false       null
C4       true      false       null
C5       true      false       null
C6       true      false       null
C7       false     false       null
C8       true      true        null
--------------------------------------

------------SBL----------
TimeStamp:201.33333333333331 Activity/Action: Electronics.Move_Pallet
TimeStamp:202.77777777777771 Activity/Action: Electronics.Move_Pallet
TimeStamp:220.77777777777777 Activity/Action: Electronics.Load_Unload
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:252.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
>-------------------------------------------------------------------------<
```

Work cell 1 has completed the processing and had been configured to process Part B

When B has moved to the next position:

```
Clock =   202.7778
   Q.Conveyors[CONA].n:          0
```

```
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP   A  NP  NP  NP  NP  NP   C   B  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      true          B
C2       false     false       null
C3       true      false       null
C4       true      false       null
C5       true      false       null
C6       true      false       null
C7       false     false       null
C8       true      true        null
--------------------------------------

------------SBL----------
TimeStamp:204.1111111111111 Activity/Action: Electronics.Move_Pallet
TimeStamp:205.5555555555555 Activity/Action: Electronics.Move_Pallet
TimeStamp:220.77777777777777 Activity/Action: Electronics.Load_Unload
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:252.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:258.7777777777777 Activity/Action: Electronics.Processing
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>---------------------------------------------------------------------<
```

The Pallet on position 8 has moved into work cell at the same time when B has moved out of the work Cell.

The terminating event for processing event has been scheduled and the time is consistent with the data model (39 s processing time and 17 s configuration time).

The moment B has arrived to Work Cell 2

```
Clock =   225.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP   B  NP  NP  NP  NP  NP  NP   A   C  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
 B  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
NP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1      true      true          B
C2      false     true        null
C3      true      false       null
C4      true      false       null
C5      true      false       null
C6      true      false       null
C7      false     false       null
C8      true      false       null
---------------------------------------

------------SBL----------
TimeStamp:226.33333333333331 Activity/Action: Electronics.Move_Pallet
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:252.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:253.34149160157617 Activity/Action: Electronics.Processing
TimeStamp:258.7777777777777 Activity/Action: Electronics.Processing
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0
```

The terminating event for processing event has been scheduled and the time is consistent with the data model (triangular distribution 21, 32, 39).

```
>-------------------------------------------------------------------------<
```

When work cell 1 finished processing C

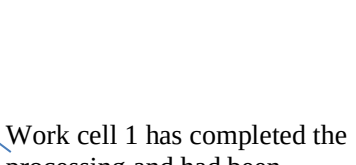
```
Clock =   258.7778
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      1

   Q.Conveyors[CONTINPUT].list:
 B

   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP   B   A   C  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP   B  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
NP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1      true      false         C
C2      false     false        null
C3      true      false        null
C4      true      false        null
C5      true      false        null
C6      true      false        null
C7      false     false        null
C8      true      true         null
---------------------------------------

------------SBL----------
TimeStamp:258.89704715713174 Activity/Action: Electronics.Move_Pallet
TimeStamp:261.5555555555555 Activity/Action: Electronics.Move_Pallet
TimeStamp:265.0 Activity/Action: Electronics.Load_Unload
TimeStamp:336.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:360.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------
```



```
Total Lost Cost:     0.0

>-------------------------------------------------------------------<
```

Work Cell 1 starts to process Part A:

```
Clock =   261.5556
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      1

   Q.Conveyors[CONTINPUT].list:
 B

   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP   B   A   C  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP   B  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
NP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------

--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1      true      true          C
C2      false     false        null
C3      true      false        null
C4      true      false        null
C5      true      false        null
C6      true      false        null
C7      false     false        null
C8      true      true         null
--------------------------------------

------------SBL----------
TimeStamp:261.6748249349095 Activity/Action: Electronics.Move_Pallet
TimeStamp:264.33333333333326 Activity/Action: Electronics.Move_Pallet
TimeStamp:265.0 Activity/Action: Electronics.Load_Unload
TimeStamp:323.5555555555555 Activity/Action: Electronics.Processing
TimeStamp:336.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:360.0 Activity/Action: Electronics.PartCArrivals
```

The terminating event for processing event has been scheduled and the time is consistent with the data model (37 s processing time and 25s configuration time).

```
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>--------------------------------------------------------------------<
```

B reaches to Work Cell 3

```
Clock =   278.3415
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP   C  NP  NP  NP   B   A  NP  NP  NP  NP  NP  NP   C  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP   B  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
NP  NP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1      true      true          C
C2      false     false        null
C3      true      true         null
C4      true      false        null
C5      true      false        null
C6      true      false        null
C7      false     false        null
C8      true      true         null
---------------------------------------

------------SBL----------
TimeStamp:278.88888888888886 Activity/Action: Electronics.Move_Pallet
TimeStamp:280.9999999999999 Activity/Action: Electronics.Move_Pallet
TimeStamp:292.77777777777777 Activity/Action: Electronics.Load_Unload
```

```
TimeStamp:323.5555555555555 Activity/Action: Electronics.Processing
TimeStamp:326.34149160157614 Activity/Action: Electronics.Processing
TimeStamp:336.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:360.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:      0.0

>----------------------------------------------------------------------<
```

The terminating event for processing event has been scheduled and the time is consistent with the data model
(21 s processing time and 27s configuration time).

Similarly, we have checked that the model is working consistent with the data model, and we will validation if there will not be any configuration time when it process the same parts in a row later in the case when there are batch input in the system.

Right before there is a lost cost in the system:

```
Clock =  4746.7352
   Q.Conveyors[CONA].n:           0
   Q.Conveyors[CONB].n:           0
   Q.Conveyors[CONC].n:           0
   Q.Conveyors[CONINPUT].n:       40

   Q.Conveyors[CONTINPUT].list:
 A  B  C  B  A  C  B  B  C  A  B  C  B  A  C  B  B  C  A  B
 C  B  A  B  C  B  A  C  B  C  B  A  B  C  B  A  C  B  B  C
   RQ.PFConveyor.list:
-----------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-----------------------------------------------------------------------
 B   C   B   A   C   B   B   C   A   B  NP  NP  NP  NP  NP  NP  NP  NP
-----------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-----------------------------------------------------------------------
 C  NP  NP  NP  NP  NP  NP  NP  NP   B   A  NP  NP   C   B   B   C   A
-----------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-----------------------------------------------------------------------
 B  NP  NP  NP  NP  NP  NP  NP  NP   C  NP  NP  NP  NP  NP   B   A   B
-----------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-----------------------------------------------------------------------
 C  NP   B   C   A   B   B   C   A   B   C   B   A   C   B   B   C   A
-----------------------------------------------------------------------


--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      true         C
C2       false     false        null
C3       true      true         A
C4       true      true         C
C5       true      true         B
C6       true      true         B
```

The input Conveyor is full and there is no empty pallet in the system.

```
C7      false     true        null
C8      true      false        null
-------------------------------------

------------SBL----------
TimeStamp:4746.795040843538 Activity/Action: Electronics.PartAArrivals
TimeStamp:4748.535336077584 Activity/Action: Electronics.Move_Pallet
TimeStamp:4749.512940850228 Activity/Action: Electronics.Move_Pallet
TimeStamp:4757.999999999998 Activity/Action: Electronics.Processing
TimeStamp:4762.480303165547 Activity/Action: Electronics.Processing
TimeStamp:4768.386035931331 Activity/Action: Electronics.Processing
TimeStamp:4793.757558299807 Activity/Action: Electronics.Processing
TimeStamp:4802.60825815355 Activity/Action: Electronics.Processing
TimeStamp:4817.113149660522 Activity/Action: Electronics.PartBArrivals
TimeStamp:4829.058990223533 Activity/Action: Electronics.Processing
TimeStamp:4863.442342313155 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>--------------------------------------------------------------------<
```

A part A is scheduled to arrive the system.

When there is lost cost in the system.

```
 Clock =  4746.7950
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      40

   Q.Conveyors[CONTINPUT].list:
 A  B  C  B  A  C  B  B  C  A  B  C  B  A  C  B  B  C  A  B
 C  B  A  B  C  B  A  C  B  C  B  A  B  C  B  A  C  B  B  C
   RQ.PFConveyor.list:
-----------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-----------------------------------------------------------------------
 B   C   B   A   C   B   B   C   A   B  NP  NP  NP  NP  NP  NP  NP  NP
-----------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-----------------------------------------------------------------------
 C  NP  NP  NP  NP  NP  NP  NP  NP   B   A  NP  NP   C   B   B   C   A
-----------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-----------------------------------------------------------------------
 B  NP  NP  NP  NP  NP  NP  NP  NP   C  NP  NP  NP  NP  NP   B   A   B
-----------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-----------------------------------------------------------------------
 C  NP   B   C   A   B   B   C   A   B   C   B   A   C   B   B   C   A
-----------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
```

The input Conveyor is full and there is no empty pallet in the power and free conveyor.

```
C1      true      true         C
C2      false     false       null
C3      true      true        PA
C4      true      true         C
C5      true      true         B
C6      true      true         B
C7      false     true        null
C8      true      false       null
-------------------------------------

-----------SBL----------
TimeStamp:4748.535336077584 Activity/Action: Electronics.Move_Pallet
TimeStamp:4749.512940850228 Activity/Action: Electronics.Move_Pallet
TimeStamp:4757.999999999998 Activity/Action: Electronics.Processing
TimeStamp:4762.480303165547 Activity/Action: Electronics.Processing
TimeStamp:4768.386035931331 Activity/Action: Electronics.Processing
TimeStamp:4793.757558299807 Activity/Action: Electronics.Processing
TimeStamp:4802.60825815355 Activity/Action: Electronics.Processing
TimeStamp:4817.113149660522 Activity/Action: Electronics.PartBArrivals
TimeStamp:4829.058990223533 Activity/Action: Electronics.Processing
TimeStamp:4863.442342313155 Activity/Action: Electronics.PartCArrivals
TimeStamp:4914.795040843538 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.89

>--------------------------------------------------------------------<
```

Part A turns into lost part and generates a lost cost of $0.89.

When there are more lost part/lost cost in the system:

```
Clock =  5978.3533
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      40

   Q.Conveyors[CONTINPUT].list:
 C  B  A  B  C  B  A  C  B  C  B  A  B  C  B  A  C  B  B  C
 B  C  B  C  B  A  B  C  B  C  B  C  B  C  B  B  C  B  A  B
   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
 B   A   C   B   B   C   A   B   C   B  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
 A  NP  NP  NP  NP  NP  NP  NP  NP   C   B   B   C   A   B   C   B   A
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
 B  NP  NP  NP  NP  NP  NP  NP  NP   C  NP  NP  NP  NP  NP  NP   B   A
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
```

```
 C  NP   B   B   C   A   B   C   B   A  NP   C   B   B   C   A   B   C
-------------------------------------------------------------------------


--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1      true      true         A
C2      false     true        null
C3      true      true         B
C4      true      true         C
C5      true      true         B
C6      true      true         B
C7      false     false        null
C8      true      false        null
--------------------------------------

------------SBL----------
TimeStamp:5981.131067349553 Activity/Action: Electronics.Move_Pallet
TimeStamp:5984.386035931324 Activity/Action: Electronics.Processing
TimeStamp:5985.1902524724055 Activity/Action: Electronics.Processing
TimeStamp:6013.555555555546 Activity/Action: Electronics.Processing
TimeStamp:6016.0959997785285 Activity/Action: Electronics.Processing
TimeStamp:6018.608258153543 Activity/Action: Electronics.Processing
TimeStamp:6026.380287163106 Activity/Action: Electronics.Processing
TimeStamp:6059.104972106677 Activity/Action: Electronics.PartBArrivals
TimeStamp:6063.442342313155 Activity/Action: Electronics.PartCArrivals
TimeStamp:6090.795040843538 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     9.389999999999999

>-------------------------------------------------------------------------<
```

The lost cost is accumulating over time.

When there is more lost cost in the system:

```
Clock =  7197.2749
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      40

   Q.Conveyors[CONTINPUT].list:
 C  B  C  B  C  B  A  B  C  B  C  B  C  B  C  B  B  C  B  A
 B  B  A  C  B  C  B  C  B  C  A  C  A  C  B  C  B  B  A  B
   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
 B   B   C   A   B   C   B   A   B   C  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
 B  NP  NP  NP  NP  NP  NP  NP   C   A   B   C   B   A   B   C   B   A
-------------------------------------------------------------------------
```

```
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
 C  NP  NP  NP  NP  NP  NP  NP  NP   B  NP  NP  NP  NP  NP  NP   B  NP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
 C  NP  NP   A   B   C   B   A   C   B   B   C   A   B   C   B   A   B
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      true        B
C2       false     true       null
C3       true      true        B
C4       true      true        B
C5       true      true        B
C6       true      true        A
C7       false     true       null
C8       true      false      null
---------------------------------------

------------SBL----------
TimeStamp:7200.0 Stop Notification
TimeStamp:7200.052702597977 Activity/Action: Electronics.Move_Pallet
TimeStamp:7200.386035931317 Activity/Action: Electronics.Processing
TimeStamp:7203.03400772965 Activity/Action: Electronics.Processing
TimeStamp:7213.052702597977 Activity/Action: Electronics.Processing
TimeStamp:7214.333333333316 Activity/Action: Electronics.Processing
TimeStamp:7221.608258153536 Activity/Action: Electronics.Processing
TimeStamp:7230.386035931317 Activity/Action: Electronics.Processing
TimeStamp:7263.442342313155 Activity/Action: Electronics.PartCArrivals
TimeStamp:7264.88781579985 Activity/Action: Electronics.Processing
TimeStamp:7272.553690799925 Activity/Action: Electronics.PartBArrivals
TimeStamp:7280.738525009873 Activity/Action: Electronics.PartAArrivals
----------------------

Total Lost Cost:     18.000000000000004

>-------------------------------------------------------------------------<
```

The lost cost is accumulating over time.

Modification Case when add pallets to the system.

```
Case 2 - Case 4 addBuffer = true; addNumPallets = false 4; numInputRelease = 0;


Clock =     0.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty
```

```
   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
```

There are 42 pallets in the power and free conveyor now.

```
--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      false        null
--------------------------------------

------------SBL----------
TimeStamp:84.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:120.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
```

Check another time instance:

```
Clock =  5321.8305
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      39

   Q.Conveyors[CONTINPUT].list:
 B  C  B  A  C  B  B  C  A  B  C  B  A  B  C  B  A  C  B  C
```

```
 B  A  B  C  B  A  C  B  B  C  B  C  B  C  B  A  B  C  B


RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
 C   C   B   B   C   A   B   C   B   A   B  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP   C  NP  NP  NP  NP  NP   B  NP  NP   A   C   B   B   C   A
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
 B  NP   C  NP  NP  NP  NP  NP  NP   B  NP  NP  NP  NP   A   C   B   B
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
 C  NP   A   B   C   B   A   B   C   B  NP   C   A   B   B   C   A   B
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      true        B
C2       false     false      null
C3       true      true        A
C4       true      true        C
C5       true      false       B
C6       true      true        A
C7       false     true       null
C8       true      true       null
---------------------------------------

------------SBL----------
TimeStamp:5321.941591486882 Activity/Action: Electronics.Move_Pallet
TimeStamp:5323.833415714696 Activity/Action: Electronics.Move_Pallet
TimeStamp:5324.555555555549 Activity/Action: Electronics.Move_Pallet
TimeStamp:5324.608258153547 Activity/Action: Electronics.Move_Pallet
TimeStamp:5336.922690401673 Activity/Action: Electronics.Processing
TimeStamp:5343.442342313155 Activity/Action: Electronics.PartCArrivals
TimeStamp:5346.777777777772 Activity/Action: Electronics.Load_Unload
TimeStamp:5352.031159575573 Activity/Action: Electronics.Processing
TimeStamp:5376.386035931328 Activity/Action: Electronics.Processing
TimeStamp:5383.777777777772 Activity/Action: Electronics.Processing
TimeStamp:5387.871817310957 Activity/Action: Electronics.Processing
TimeStamp:5405.113149660522 Activity/Action: Electronics.PartBArrivals
TimeStamp:5418.795040843538 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------


Total Lost Cost:     4.6499999999999995
>-----------------------------------------------------------------------<
```

All work cell with indicator in busy have parts in it.

The lost cost is accumulating over time.

Modification Case when add batch input to the system.

```
Case 3 addBuffer = true; addNumPallets = 0; numInputRelease = 2.

The time instance before there are two same parts in the system:

Clock =   120.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          1
   Q.Conveyors[CONC].n:          1
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1      true      false        null
C2      false     false        null
C3      true      false        null
C4      true      false        null
C5      true      false        null
C6      true      false        null
C7      false     false        null
C8      true      false        null
---------------------------------------

------------SBL----------
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------
```

Another Part B will arrive at t = 168.0

```
Total Lost Cost:     0.0

>-------------------------------------------------------------------<

When Part B Arrives:
Clock =   168.0000
   Q.Conveyors[CONA].n:          1
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          1
   Q.Conveyors[CONINPUT].n:      1

   Q.Conveyors[CONTINPUT].list:
 B

   RQ.PFConveyor.list:
-----------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-----------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-----------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-----------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP  EP
-----------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-----------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-----------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-----------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-----------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      true         null
---------------------------------------

------------SBL----------
TimeStamp:193.0 Activity/Action: Electronics.Load_Unload
TimeStamp:240.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:252.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:7200.0 Stop Notification
----------------------
Total Lost Cost:     0.0

>-------------------------------------------------------------------<
```

Two Part B moves into the input conveyor from the batch input conveyor immediately.

Loading_unloading starts and the terminating event has been scheduled

when an automatic work cell has already configured to the part it is going to process the next:

```
Clock =   284.4444
   Q.Conveyors[CONA].n:          1
   Q.Conveyors[CONB].n:          1
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP   C   B   B  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1       true      false        B
C2       false     false       null
C3       true      false       null
C4       true      false       null
C5       true      false       null
C6       true      false       null
C7       false     false       null
C8       true      true        null
---------------------------------------

------------SBL----------
TimeStamp:286.7777777777777 Activity/Action: Electronics.Move_Pallet
TimeStamp:287.2222222222222 Activity/Action: Electronics.Move_Pallet
TimeStamp:292.77777777777777 Activity/Action: Electronics.Load_Unload
TimeStamp:336.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:360.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
----------------------
```

Work cell 1 had been configured to process Part B and it just finished processing B. The next pallet is going to move into work cell 1.

```
Total Lost Cost:     0.0

>-------------------------------------------------------------------------<

Clock =   286.7778
   Q.Conveyors[CONA].n:          1
   Q.Conveyors[CONB].n:          1
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP   C  NP   B   B  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      true         B
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      true         null
--------------------------------------

------------SBL----------
TimeStamp:287.2222222222222 Activity/Action: Electronics.Move_Pallet
TimeStamp:289.5555555555555 Activity/Action: Electronics.Move_Pallet
TimeStamp:292.77777777777777 Activity/Action: Electronics.Load_Unload
TimeStamp:332.7777777777777 Activity/Action: Electronics.Processing
TimeStamp:336.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:360.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
```

When the next B moves into Work Cell 1, the terminating event of the processing process has been scheduled, and it is consistent with the data model with only processing time of 46s.

```
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
```

Modification Case when add both pallets and batch input to the system.

```
Case 4 addBuffer = true; addNumPallets = 4; numInputRelease = 4;

Clock =     0.0000
   Q.Conveyors[CONA].n:          0
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          0
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


---------------------------------------
CID      auto      busy      prtConfig
---------------------------------------
C1      true      false        null
C2      false     false        null
C3      true      false        null
C4      true      false        null
C5      true      false        null
C6      true      false        null
C7      false     false        null
C8      true      false        null
---------------------------------------

------------SBL----------
TimeStamp:84.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:120.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:168.0 Activity/Action: Electronics.PartAArrivals
```

There are 44 empty pallets in the system.

```
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<
```

When parts are releasing in batches:

```
Clock =   252.0000
   Q.Conveyors[CONA].n:          1
   Q.Conveyors[CONB].n:          3
   Q.Conveyors[CONC].n:          2
   Q.Conveyors[CONINPUT].n:      0

   Q.Conveyors[CONTINPUT].list:
     Input Conveyor Is Empty


   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------


--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      false        null
--------------------------------------

------------SBL----------
TimeStamp:336.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:360.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:7200.0 Stop Notification
```

A part B is scheduled to arrive next

```
----------------------

Total Lost Cost:     0.0

>-------------------------------------------------------------------------<


Clock =   336.0000
   Q.Conveyors[CONA].n:          1
   Q.Conveyors[CONB].n:          0
   Q.Conveyors[CONC].n:          2
   Q.Conveyors[CONINPUT].n:      3

   Q.Conveyors[CONTINPUT].list:
 B  B  B

   RQ.PFConveyor.list:
-------------------------------------------------------------------------
C8  01  02  03  04  05  06  07  08  C1  10  11  12  13  14  15  16  17
-------------------------------------------------------------------------
EP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP
-------------------------------------------------------------------------
C2  19  20  21  22  23  24  25  26  C3  28  29  30  31  32  33  34  35
-------------------------------------------------------------------------
NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  NP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C4  37  38  39  40  41  42  43  44  C5  46  47  48  49  50  51  52  53
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
C6  55  56  57  58  59  60  61  62  C7  64  65  66  67  68  69  70  71
-------------------------------------------------------------------------
EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP  EP
-------------------------------------------------------------------------
```

When a part B arrives to the system, four part B has been released into the input conveyor and the loading_unloading process has started immediately.

```
--------------------------------------
CID      auto      busy      prtConfig
--------------------------------------
C1       true      false        null
C2       false     false        null
C3       true      false        null
C4       true      false        null
C5       true      false        null
C6       true      false        null
C7       false     false        null
C8       true      true         null
--------------------------------------

------------SBL----------
TimeStamp:354.07607504708244 Activity/Action: Electronics.PartAArrivals
TimeStamp:360.0 Activity/Action: Electronics.PartCArrivals
TimeStamp:361.0 Activity/Action: Electronics.Load_Unload
```

Loading_unloading work cell is busy

```
TimeStamp:420.0 Activity/Action: Electronics.PartBArrivals
TimeStamp:7200.0 Stop Notification
----------------------

Total Lost Cost:     0.0

>------------------------------------------------------------------------<
```

4.3 Report on Verification and Validation

In the verification and validation experiment we have tested the model for both its logic, data model and output. The way the model behaves is consistent with the SUI. Thus we confirm that the model is working properly.

5. Experimentation and Analysis

5.1 Steady State Observation Interval

For a steady state study, the selection of the observation interval is made to accommodate a warm up time and an end time for generating appropriate confidence intervals. First we consider the warm up time by applying Welch's method on the base case, when there were no modifications in the system. Then develop some experimentation to define a suitable right hand side (end time) of the observation interval.

The Java class `Warmup` contains the experimentation software required to determine the warm up time. It uses the `ABSmod/J` class `WelchAverage` to apply Welch's moving average method to data collected within time cells.

Ten simulation runs are used with 60 intervals of one hour. One matrices, `totalLostCost` and is used to collect the total lost cost for each of the intervals during the simulation runs. The matrices are then used with the class `WelchAverage` to apply the moving average method to the collected data. The results of the method are then printed out in comma delimited form such that a graph may be generated using Excel.

The following shows the resulting graphs for the `totalLostCost` output variable with window sizes of 0, 1, 3 and these results are shown below.

```
Base case: addBuffer = false; addNumPallets = 0; numInputRelease = 0
```

Table 5.1 Warmup Test Result

Total Lost Cost ($)				
t	w = 0	w = 1	w = 3	w = 5
1	0	0	0	0
2	18.264	14.893	14.893	14.893
3	26.415	23.54666667	19.1578	19.1578
4	25.961	25.84166667	21.73714286	21.73714286
5	25.149	26.337	25.85171429	23.21266667
6	27.901	27.17333333	27.23571429	24.11063636
7	28.47	28.391	27.48657143	26.64118182
8	28.802	28.408	27.79671429	27.61009091
9	27.952	28.30833333	28.18057143	27.782
10	28.171	28.085	28.32642857	27.91081818
11	28.132	28.04633333	28.303	28.20036364
12	27.836	28.29666667	28.09957143	28.23581818

13	28.922	28.35466667	28.15414286	28.18336364
14	28.306	28.202	28.17128571	28.19936364
15	27.378	28.006	28.13714286	28.19309091
16	28.334	28.001	28.30028571	28.19190909
17	28.291	28.17266667	28.15185714	28.20490909
18	27.893	28.38733333	28.13071429	28.25136364
19	28.978	28.25133333	28.25885714	28.12790909
20	27.883	28.33966667	28.26071429	28.08290909
21	28.158	28.10533333	28.15685714	28.12618182
22	28.275	28.26	28.14514286	28.12790909
23	28.347	28.062	27.98457143	28.131
24	27.564	27.90733333	28.05171429	28.13818182
25	27.811	27.743	28.07557143	28.06627273
26	27.854	28.006	28.03228571	28.12763636
27	28.353	28.17733333	28.00942857	28.16263636
28	28.325	28.21666667	28.15142857	28.09436364
29	27.972	28.16133333	28.256	27.98563636
30	28.187	28.239	28.20885714	28.01245455
31	28.558	28.42933333	28.03714286	28.06390909
32	28.543	28.20833333	27.97057143	28.12163636
33	27.524	27.73933333	28.02842857	28.10618182
34	27.151	27.51133333	28.07157143	28.11727273
35	27.859	27.79566667	28.018	28.15572727
36	28.377	28.24166667	28.00428571	28.15681818
37	28.489	28.34966667	28.12871429	28.18263636
38	28.183	28.373	28.27842857	28.05736364
39	28.447	28.34166667	28.41885714	28.188
40	28.395	28.347	28.24571429	28.29090909
41	28.199	28.47866667	28.31314286	28.36090909
42	28.842	28.06866667	28.32742857	28.307
43	27.165	28.32266667	28.35342857	28.22290909
44	28.961	28.13633333	28.26614286	28.23536364
45	28.283	28.62433333	28.17542857	28.18145455
46	28.629	28.232	28.10085714	28.16845455
47	27.784	27.99233333	28.19928571	28.16272727
48	27.564	27.88933333	28.098	28.07172727
49	28.32	27.91266667	28.077	28.199
50	27.854	28.142	27.96442857	28.16854545
51	28.252	28.08066667	28.076	28.16518182

52	28.136	28.07633333	28.22771429	28.12909091
53	27.841	28.18066667	28.21714286	28.19645455
54	28.565	28.344	28.27114286	28.32336364
55	28.626	28.479	28.31014286	28.32363636
56	28.246	28.368	28.42785714	
57	28.232	28.33433333	28.49671429	
58	28.525	28.57233333		
59	28.96	28.60266667		
60	28.323			

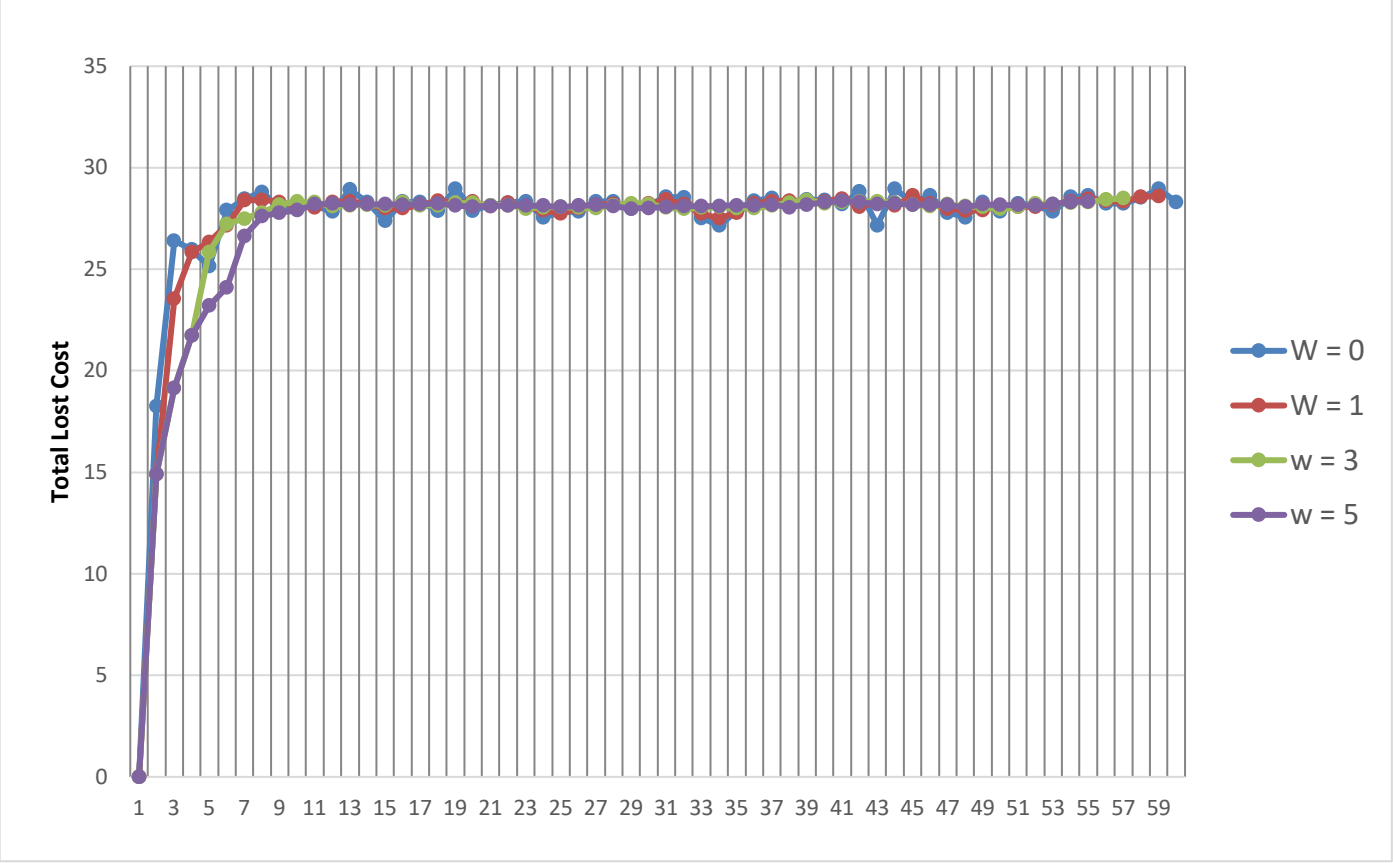


Fig. 5.1 Welch's method applied to total lost cost.

As we can see from Fig 5.1, the lost cost has reached a relatively steady value after 8 hour. As we are measuring the weekly lost cost, we will set the warm up to one week.

To define a suitable end time for the observation interval. The Java class Credibility was designed to examine the effect of using a 2 weeks, 4 weeks, and 8 weeks' observation interval with number of simulation runs ranging from 10 runs to 100 runs. We choose observation interval f 4 weeks and 20 runs for our experiment.

Base Case CI = 90%

Base Case											
tf:	2 weeks				4 weeks				8 weeks			
n	yb(n)	s(n)	z(n)	z(n)/yb(n)	yb(n)	s(n)	z(n)	z(n)/yb(n)	yb(n)	s(n)	z(n)	z(n)/yb(n)
10	2248.383	6.500	4.650	0.0021	2253.333	3.399	2.431	0.0011	2254.016	2.183	1.562	0.0007
20	2253.207	7.636	3.574	0.0016	2253.683	3.593	1.682	0.0007	2254.772	2.328	1.090	0.0005
30	2254.358	7.026	2.623	0.0012	2254.494	3.743	1.398	0.0006	2255.038	2.409	0.900	0.0004
40	2254.453	6.742	2.156	0.0010	2254.965	3.961	1.267	0.0006	2255.472	2.503	0.800	0.0004
60	2254.070	7.549	1.950	0.0009	2255.000	4.000	1.033	0.0005	2255.363	2.534	0.655	0.0003
80	2254.242	7.093	1.579	0.0007	2255.412	4.121	0.917	0.0004	2255.672	2.605	0.580	0.0003
100	2254.652	7.289	1.446	0.0006	2255.503	4.035	0.801	0.0004	2255.695	2.605	0.517	0.0002

5.2 Experimentation

There four steps to carry out our experiment as described before and we have conducted all four steps with the output result (Total lost lost, $) shown below:

NUM_BATCH_RELEASE	2	3	4	5	6	7	8	9	10	False
ADD_PALLET_NUMBER: 0	1702.03	1407.69	1249.26	1147.77	1078.08	1029.40	1012.88	971.70	966.27	2250.78
ADD_PALLET_NUMBER: 1	1702.33	1407.93	1249.26	1148.25	1077.66	1029.31	1012.59	969.50	966.27	2255.16
ADD_PALLET_NUMBER: 2	1702.33	1407.48	1249.50	1148.25	1077.42	1028.61	1012.10	968.46	966.27	2249.22
ADD_PALLET_NUMBER: 3	1702.33	1407.48	1249.50	1148.25	1077.42	1028.67	1013.06	962.27	966.27	2249.22
ADD_PALLET_NUMBER: 4	1702.33	1407.48	1249.50	1148.25	1077.42	1028.67	1011.44	960.06	966.27	2249.22
ADD_PALLET_NUMBER: 5	1702.03	1407.69	1249.05	1147.77	1078.32	1029.47	1013.38	964.88	966.27	2246.00
ADD_PALLET_NUMBER: 6	1702.27	1407.90	1249.05	1148.01	1078.08	1028.83	1012.11	967.22	966.27	2248.99
ADD_PALLET_NUMBER: 7	1702.33	1407.90	1248.63	1147.80	1078.08	1028.91	1012.37	962.08	966.27	2249.08
ADD_PALLET_NUMBER: 8	1702.33	1407.42	1248.63	1147.59	1078.29	1028.59	1012.15	962.91	966.27	2250.50
ADD_PALLET_NUMBER: 9	1702.27	1407.90	1248.87	1147.59	1078.05	1029.36	1011.69	963.58	966.27	2252.91
ADD_PALLET_NUMBER: 10	1702.03	1407.69	1249.08	1148.46	1077.36	1029.30	1011.47	965.67	966.27	2249.23
ADD_PALLET_NUMBER: 11	1702.27	1407.93	1249.71	1148.25	1077.57	1028.80	1011.54	961.22	966.27	2250.57
ADD_PALLET_NUMBER: 12	1702.33	1407.93	1249.71	1148.25	1077.33	1029.18	1012.43	964.74	966.27	2254.58
ADD_PALLET_NUMBER: 13	1702.33	1407.69	1249.71	1148.49	1077.57	1028.80	1012.05	959.14	966.27	2252.46
ADD_PALLET_NUMBER: 14	1702.57	1407.90	1249.71	1148.70	1077.36	1029.31	1011.39	961.94	966.27	2248.64
ADD_PALLET_NUMBER: 15	1702.27	1407.21	1249.50	1148.49	1077.36	1028.91	1013.40	959.73	966.27	2254.65
ADD_PALLET_NUMBER: 16	1702.03	1407.42	1249.50	1148.25	1077.36	1029.40	1011.74	960.87	966.27	2249.31
ADD_PALLET_NUMBER: 17	1702.54	1407.69	1248.63	1148.25	1077.39	1029.24	1013.50	964.60	966.27	2248.74
ADD_PALLET_NUMBER: 18	1702.33	1407.48	1249.08	1148.25	1077.39	1028.67	1010.99	963.02	965.41	2250.88
ADD_PALLET_NUMBER: 19	1702.24	1407.72	1248.84	1148.04	1077.42	1029.30	1012.05	963.00	968.77	2258.43
ADD_PALLET_NUMBER: 20	1702.24	1407.72	1249.71	1147.80	1077.42	1028.40	1013.17	965.43	970.84	2255.06
ADD_PALLET_NUMBER: 21	1702.57	1407.48	1249.47	1147.59	1077.45	1029.09	1011.63	962.97	969.94	2251.54
ADD_PALLET_NUMBER: 22	1702.27	1407.69	1249.47	1147.83	1078.32	1029.48	1011.78	962.23	969.89	2247.61
ADD_PALLET_NUMBER: 23	1702.54	1407.00	1249.50	1148.25	1078.29	1029.69	1011.76	965.39	974.55	2245.70
ADD_PALLET_NUMBER: 24	1702.24	1407.21	1249.26	1148.49	1078.29	1029.02	1011.76	968.97	979.62	2253.55
ADD_PALLET_NUMBER: 25	1702.27	1407.45	1249.05	1147.83	1078.50	1029.98	1012.79	969.58	984.19	2253.25
ADD_PALLET_NUMBER: 26	1702.54	1407.48	1248.63	1149.15	1078.02	1030.58	1014.61	972.90	996.54	2258.26
ADD_PALLET_NUMBER: 27	1702.81	1407.48	1249.50	1150.50	1078.95	1032.33	1018.25	986.25	1018.82	2253.93
ADD_PALLET_NUMBER: 28	1702.54	1407.69	1250.19	1156.77	1083.18	1038.76	1029.18	1008.11	1072.79	2255.41
ADD_PALLET_NUMBER: 29	1702.57	1408.83	1258.74	1188.51	1096.53	1067.14	1061.50	1071.02	1167.12	2252.58
ADD_PALLET_NUMBER: 30	1704.57	1416.24	1305.51	1327.14	1146.45	1191.21	1175.99	1201.11	1306.65	2267.86
ADD_PALLET_NUMBER: 31	1776.70	1533.03	1512.51	1580.86	1352.34	1389.73	1351.79	1350.87	1486.95	2338.67
ADD_PALLET_NUMBER: 32	5392.35	5392.35	5392.35	5392.35	5392.35	5392.35	5392.35	5392.35	5392.35	5392.35

5.3 Output Analysis

5.3.1 Base Case

As we can see in the experimentation result table, for the base case, when there are no pallets added into the system, the lost cost for one week is $2250.78.

5.3.2 Add Pallets

As we can see in the experimentation result table, the last column represents when there are 0-32 pallets added into the system. The lost cost did not change much and the lowest cost lost is $2245.70. It can reduce the lost cost by $5.08 per week when add 23 pallets to the system.

5.3.3 Add Buffer Conveyor

As we can see in the experimentation result table, the first column represents when the buffer conveyors are added. The number of parts that will release at one time is from 2-10. The lowest lost cost is $966.27 when the buffer conveyor release 9 parts at one time. It can reduce the lost cost by $1284.51 per week.

5.3.4 Add Buffer Conveyor and Pallets

As we can see in the experimentation result table, the lowest total cost is $959.14 when 13 buffers added into the system and the buffer conveyors are releasing 9 parts at one time. It can reduce the lost by $1291.64 per week.

5.3.5 Total Cost for Modification

1. For the add pallets modification, as we can see from 5.3.2, the lost cost reduced is negligible comparing to the modification cost by adding pallets to the system, which is $ 17,000.00 fixed cost plus 23* $3000 (for per pallet), comes to the total of $125,000.00. This cost will take about 470 years to get paid back. In this case this modification will not be considered.

2. For the add buffer conveyor modification, the modification cost is $56,000.00. This modification will take less than one year (43.60 weeks) to get paid back.

3. For the add buffer and batch conveyor, the modification for add 13 pallets and buffer conveyor is $112,000.00. This modification will take about 86 years to get paid pack. Also the difference of lost cost between the add buffer conveyor and add both buffer conveyor and pallets is not significant ($7.13/week).

5.4 Conclusions

5.4.1 Current System

The weekly cost lost for the current system is $2250.78.

5.4.2 Modifications Result

1. Add extra pallet only has minor affection to reduce the lost cost, also the modification cost is too high thus it is not recommended.
2. Add buffer conveyor will reduce the lost cost and when is releasing 10 at a time, the total lost cost had reduced by 57.0%. So it is recommended.
3. Add both buffer conveyor and pallets will reduce the lost cost by 57.3%. Considering the insignificant difference between the add buffer conveyor modification and the significant modification cost difference, this modification is not recommended.

5.4.3 Modification Proposal

According to the above study, we recommend to add three buffer conveyors to Line 1, 2, and 3. Set the it to release 10 part at a time. This modification will get paid back in 44.5 weeks.