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Intuitive dispatching method to handle the 450 mm wafer and prioritize jobs in a conveyor of semiconductor industry

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ABSTRACT

An effective material handling system can help factories meet the transportation demands for new wafer size since the size increases from 300 mm to 450 mm. With advantages proved, conveyor-based automated materials handling system (AMHS) is chosen as the next generation transport system. However, this transport system also faces with the problems about traffic jams when having so much lot in loop and loading or unloading procedures. Besides, a higher priority lots should enjoy greater transportation privileges than those with a lower priority. Thus, one good dispatching rule is very helpful for an AMHS. This research proposes restructuring loop configurations for conveyor-based AMHS and develops an effective dispatching rule, named rota-caster in heuristic preemptive dispatching method (R-HPD). Simulation results demonstrate that the R-HDP can provide better performances than the best existed method (DPD). The R-HPD rule reduces the average delivery time by 49.4% for hot lots and 50.5% for normal lots. Moreover, the average delivery time of normal lot is not affected so much when bay loading and hot lot ratio increase.

1. Introduction

The semiconductor industry has been increasing the size of wafers about every 10 years (Duncan, 2002). Increases in wafer sizes have been a natural evolution and manufacturing efficiency improvement for the semiconductor industry for decades, as shown in the Fig. 1.

The proposed revision in the timing targets for the 450 mm generation semiconductor manufacturing and foundry pilot lines, which are now delayed about 2 years (2015–16, versus the previous 2013-14 target made by the ITRS in 2009) (ITRS, 2012). By 2015-16, Intel Corp (INTC), Global foundries Inc., Samsung Electronics Co. Ltd. and Taiwan Semiconductor Manufacturing Co. Ltd. (TSM) will have 450 mm wafer fabs constructed and equipment installed. While these are only a handful of fabs so far, they represented 34% of the revenues of the entire semiconductor industry in 2012.

To transport items, wafer factory uses automated materials handling system (AMHS), including automatic guided vehicle (AGV), rail-guided vehicles (RGV), overhead shuttle system (OHS), and overhead hoist transport (OHT), conveyor, and so on (Nguyen and Tran, 2016).

Widely recognized as the main transport system for 300 mm fabs, OHT system is currently used not only for intra-bay transport but also inter-bay or factory wide transport. That is an automated transport system that travels on the overhead track and "directly" accesses the load port of the stocker or process equipment by the belt driven hoisting mechanism. The efficiency of an OHV-based AMHS is highly dependent on the vehicles' characteristics and control mechanism. An AMHS with a small number of vehicles will cause long delays for lots waiting to be transported. On the other hand, an excess of vehicles can cause traffic congestion in the interbay and intrabay systems because each of these units will frequently block other transporters that are traveling on the same path.

However, in the 450 mm semiconductor fab, lots are heavier and process time increased, the OHT system is no longer adequately suitable for transportation. Thus, some researchers confer on conveyor transport as the main transport tool. Pettinato and Pillai (2005) proposed the use of continuous flow transporters (CFT) as the primary AMHS for 450 mm wafer fabs since this technology provides high transport capacity, short and predictable delivery times, and low costs. CFT can also provide local buffering of material closer to the

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processing tool, possibly reducing the need for large stockers or larger process tool footprints.

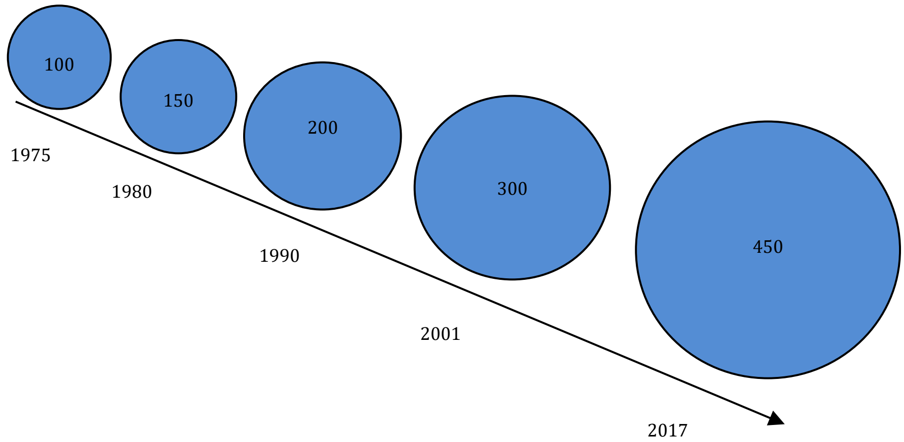

Fig. 1: Wafer size (in mm) development over time (from extremetech.com)

Nowadays, conveyor-based AMHS are emerging as alternative to existing vehicle-based AMHS for providing high-speed, high-throughput deliveries. With vehicle-based AMHS, a wafer carrier needs to wait for a considerable amount of time at the tool port to be picked up by an unloaded, unassigned vehicle (Miller et al., 2011). These waiting times are highly variable due to the high levels of congestion that most vehicles encounter while traveling in the AMHS tracks. However, because of continuous conveyor flow in the conveyor-based AMHS, the wafer carrier can leave the tool port faster and at a near constant speed once. Thus, the waiting time is virtually eliminated. Another benefit of conveyor-based AMHS is that it provides higher storage capabilities near the processing equipment, therefore reducing the need for large stocker units and increasing the flow rate of wafers into the processing equipment (Nazzal and El-Nashar, 2007).

The conveyor-based AMHS has two main parts: the first one is an interbay transfer loop between production centers; the second is intrabay transfer loops within a production center. The interbay material handling system is set in the center of factory and connected to all intrabay. The transport equipment is conveyor, which always moves with one direction. The intrabay is connected to the intrabay by curve-conveyor. The get-out sensor is used at the end of intrabay to determine the lot finished process operation or not; then the control system will drive the lot corresponding the sensed results (Johnson et al., 2009). The lot is loaded to machine or unloaded to the conveyor by the AMHS load ports. The AMHS load ports are assembled for each machine. Now, the load port for 450 mm wafer size production machine is already standardized (ITRS, 2012). The conveyor handles the lot from the start to the end of interbay after completing the process operation for each intrabay.

Wafer handling is a challenge for the migration from 300 mm to a 450 mm production. Because the 450 mm wafers are heavier and bigger, operators cannot move them easily. The effective material handling practices are significant contributors to reduced wafer cycle time. The design of an AMHS must not only be capable of meeting numerous complex material handling requirements, but it must also simplify control and reduce capacity loss.

In semiconductor foundry manufacturing, some products are very urgent and important, demanding a short cycle time and on-time delivery. These high-priority products are typically called hot lots, which are given precedence over normal lots (Wertz et al., 2008). The traffic jams occur frequently in load and unload processes because conveyor will continuous move along the single direction. A lot will block the delivery of other lots behind it when it is loaded to the empty machine or is unloaded back to conveyor. Furthermore, the traffic jams also occur when so many lots in the intrabay (high Bay loading). The lots frequently block each other in the intrabay transfer loop (Wu et al., 2011).

The purpose of this research is to develop an effective heuristic dispatching policy that provides good transport services for lots in a 450 mm wafer fabrication. The objective of this rule is to minimize the transport delay of lots. Higher priority lots should enjoy their privilege of preemptive transportation against those with lower priority. Therefore, we propose method to expedite the movement of the hot lots with the least impact to normal lots delivery. This study simplifies systems in principle, and uses simulations to test the efficiency of this rule.

2. Methodology

Rotacaster is a multi-directional driven installation based on interlacing 125 mm and 48 mm wheels 90 degrees offset to one another (Rotacaster, 2014). This allowed the shafts for both wheels to cross one another without interfacing while creating a common surface plane.

Because of the multi-directional design of the wheels, when for instance the 125 mm wheels are transferring the product along their primary direction of rotation, the product is transferred across the perpendicular rollers of the 48 mm wheels. Likewise, when the 48 mm wheels are driving the product, it rolls across the 125 mm wheel rollers without much resistance. While this solution delivered a 90 degree change of direction, more complex programming would enable the product to change direction across a progressive curve or even more complex pathways.

Compared to other driven multi-directional transfer solutions, Rotacasters deliver the significant advantage of simplicity. This solution can simply be dropped into an existing conveyor installation.

2.1. Changing structure of the fabrication

In an intrabay (as Fig. 2), conveyor moves along the single direction. Thus, all of lots will need to complete the entire length of the intrabay, causing traffic jams when lot ratio high. To cutting down quickly the amount of lot in the intrabay, this study proposes coupling two lines of Intrabay and using Rotacaster to move lot directly from line 1 to line 2 if necessary. In the way, the delivery time of lot in intrabay is severely reduced because of reducing the length of the road and blocked time. Let's suppose intrabay has n machines in all and stipulate that "quick" area includes machines from Mj to Mn.

In each intrabay, we place a rotacaster behind each machine of conveyor line 1 to move item to conveyor line 2. This rotacaster is connected to $Conveyor_{k+1}$ ("D2" distance from machine M_j so that it is easy for programming). Basically, we take advantage of HPD and develop some of algorithm with Rotacaster (as in Fig. 3).

2.2. Setting rules of wafer transportation in the conveyor

First of all, this study defines a transport job as a macro of transfer commands, embracing four steps as follow. Firstly, an empty machine sends a request signal to an unprocessed lot. The second step, the unprocessed lot will be delivered to the empty machine by conveyor. The lot will be loaded to machine. After processing, the lot will be unloaded back to conveyor to deliver. The third step, the interbay turnout sensor checks if the lot has been completely processed or not. Finally, if the lot was completely processed, it will be released to the interbay. Otherwise, it will keep moving in the intrabay, while waiting for the completion of processing and release.

By presenting the literature review and empirical data from lot handling operations, this study finds six major points can be changed. These changes are described as follow:

uN: unprocessed normal lot — uN

uH: unprocessed hot lot — uH

pN: processed normal lot — pN

pH: processed hot lot — pH

1. If there are any unprocessed hot lot behind the unprocessed normal lot follows the moving direction, this hot lot will be made reservation at the nearest empty machine and the normal lot will keep moving, because hot lot is higher priority lot, it needs to process first (Fig. 4).
2. If there is more than one unprocessed hot lot within a distance D1 before the empty machine, the last unprocessed hot lot is served at this machine. The D1 equals to the average conveyor speed multiplied by the loading time since the loading procedure of the unprocessed hot lot in front will clutter movement of the rear hot lots (Fig. 5).

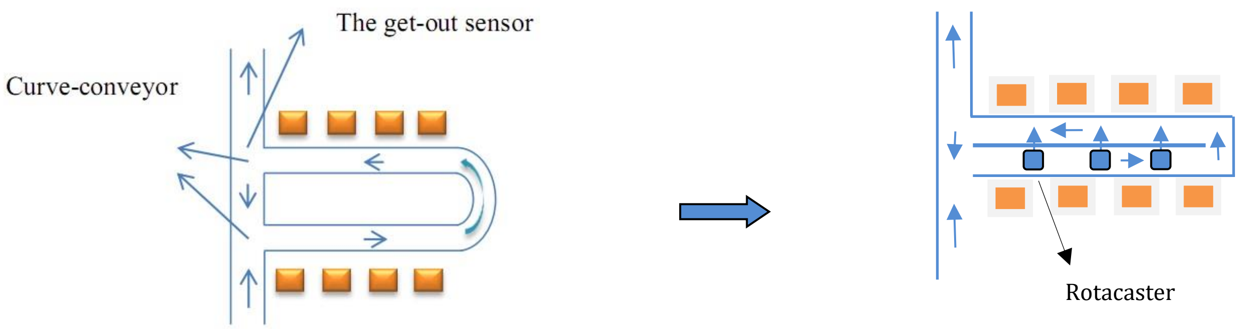

Fig. 2: Coupling two lines of each intrabay

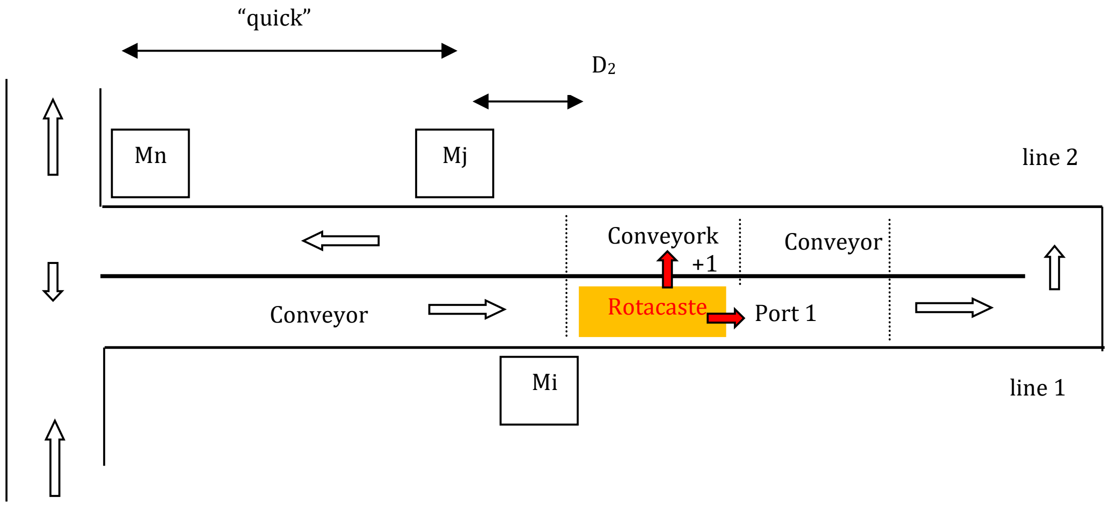

Fig. 3: Establishing position of rotacaster in an intrabay

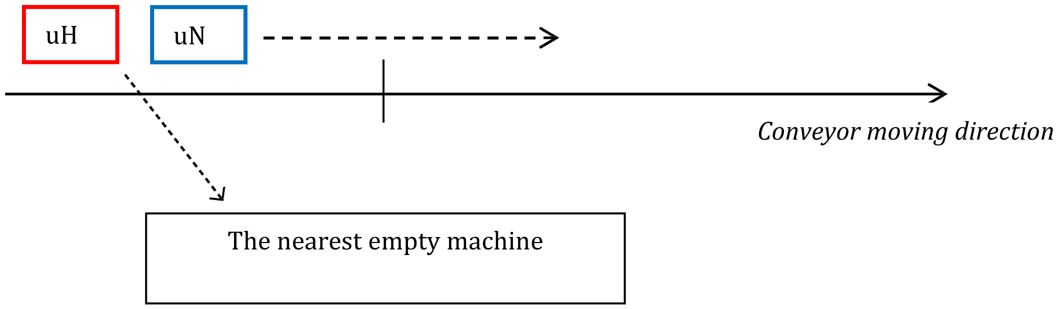

Fig. 4: R-HPD - Rule 1

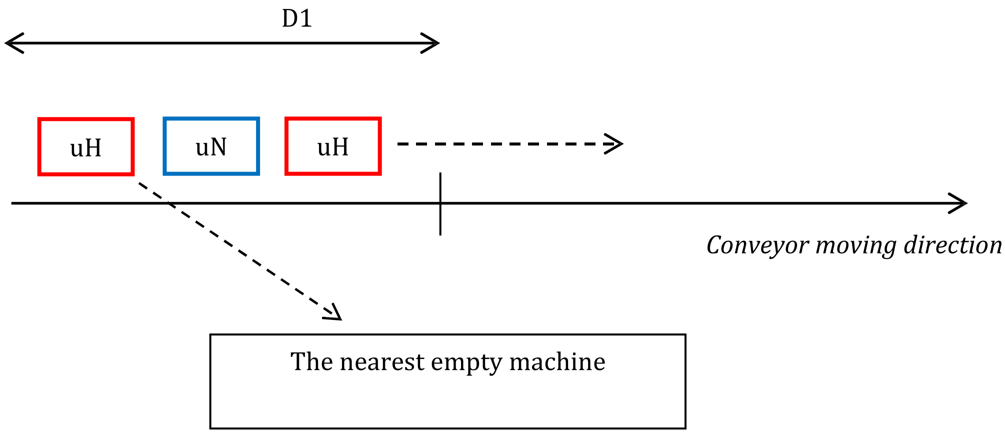

Fig. 5: R-HPD – Rule 2

3. If there is more than one unprocessed normal lot within a distance D1 in front of the empty machine and the number of empty machine is more than one, the second unprocessed normal lot is served at the nearest empty machine and the first one keep going to other empty machine. (Because the loading process of the first unprocessed normal lot is the cause of congestion of other unprocessed normal lot) (Fig. 6).

If not, the first unprocessed normal lot will be served (Fig. 7).

4. If there are any processed hot lots within a distance D2, the unloading procedure will be stopped. Distance D2 is defined as the average conveyor speed multiplied by the unloading time. (Because the unloading procedure will delay the delivering of processed hot lot) (Fig. 8).
5. If all of conditions hereunder are satisfied simultaneously:

- There are any processed hot lots within D1.
- There are any unprocessed normal lots in front of the processed hot lot.
- The machine is an empty machine.
- There are not any unprocessed hot lots within this intrabay.

The unprocessed normal lot keeps moving. (Because of the loading process of unprocessed normal lot will block the movement of processed hot lots) (Fig. 9).

6. When a lot passing rotacaster, it will be handled to conveyor line 2 if (Fig. 10):

- This lot is processed hot lot or processed normal lot.
- Or this lot is unprocessed hot lot and there are emty machine in "quick" area.

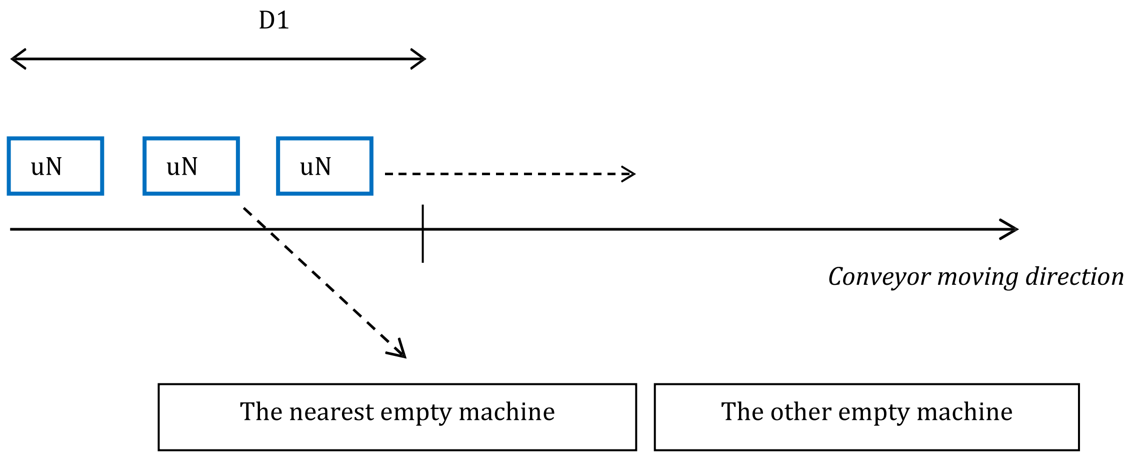

Fig. 6: R-HPD - Rule 3_condition 1

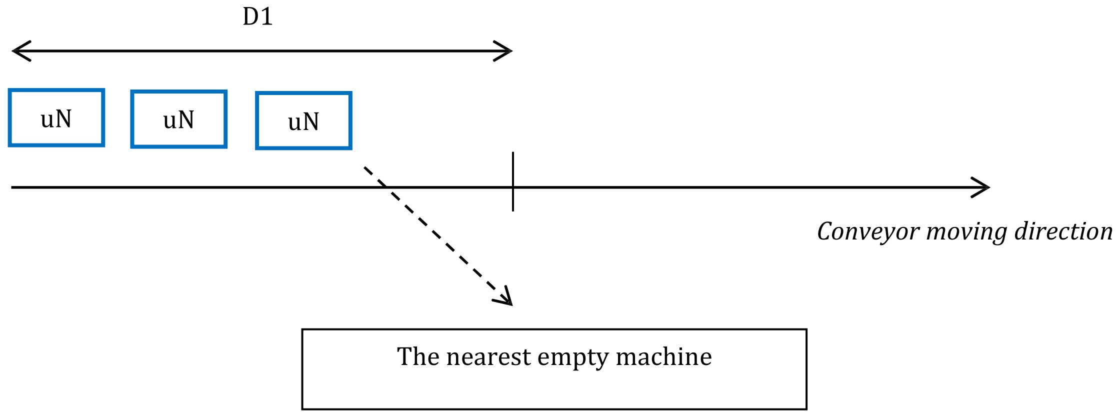

Fig. 7: R-HPD – Rule 3_condition 2

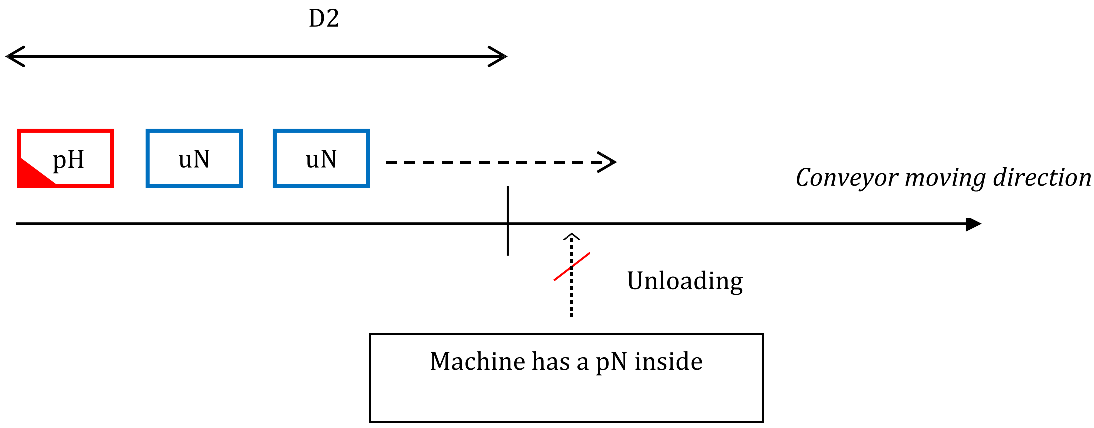

Fig. 8: R-HPD – Rule 4

Easily understanding way, Rotacaster plays normal conveyor to handle items, however it is developed more some algorithms to change direction of item.

Figs. 11 and 12 illustrate the proposed algorithm, and the details are described below. We implement algorithm in C Language.

First of all, AMHS controller checks all machine in the corresponding intrabay to find out the nearest empty machine. After that, the lot is tested as an unprocessed hot lot or an unprocessed normal lot.

If this lot is an unprocessed hot lot, it will be made reservation at the nearest empty machine. Even in process of movement, if another empty machine occurs closer to this hot lot than the originally reserved empty machine, AMHS controller changes the reservation to this new machine. Before the loading procedure is happened, AMHS controller will check the total of unprocessed hot lot in a distance D1 in front of the empty machine. The distance D1 equals to the average conveyor speed multiplied by the loading time. If there is more than one unprocessed hot lot within D1, the machine is served to the last unprocessed hot lot. If not, this hot lot is loaded to this empty machine and unloaded back to the conveyor to handle after processed.

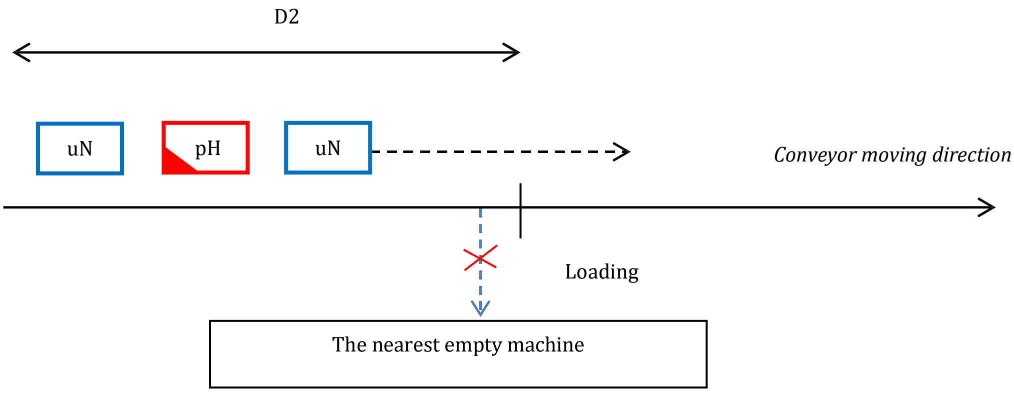

Fig. 9: R-HPD – Rule 5

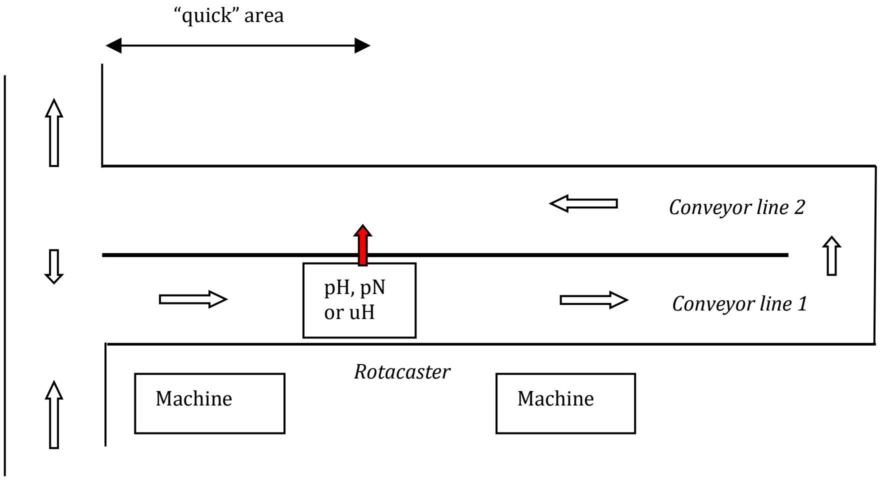

Fig. 10: R-HPD – Rule 6

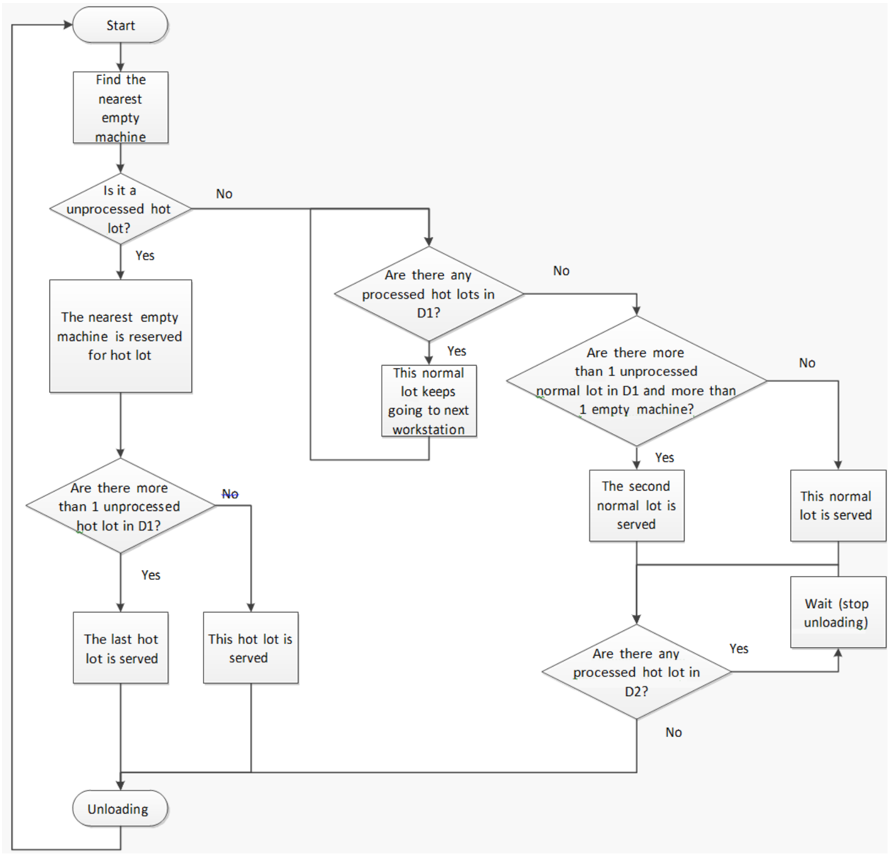

Fig. 11: Flowchart for normal conveyors

On the other hand, if this lot is an unprocessed normal lot, it may be reserved at the nearest empty machine after some inspection procedures. Firstly, AMHS controller will calculate the total of processed hot lot within a distance D1 before the empty machine. If there are any processed hot lots here, the unprocessed normal lot keeps delivering to next workstation. If not, AMHS will check the total of empty machine in this intrabay and the total of unprocessed normal lot within a distance D1. If both of them are greater than one, the second unprocessed normal lot is directed into the nearest empty machine. Otherwise, the first unprocessed normal lot is served. After the lot is processed, AMHS controller will check the total of processed hot lot within a distance D2 in front of the empty machine. The distance D2 equals to the average conveyor speed multiplied by the unloading time. If there are any processed hot lots within this distance, the unloading procedure is stopped. The processed normal lot is controlled to stay in the machine until the unloading condition is satisfied. Then, it is unloaded back to the conveyor to deliver to other intrabay. The encoding process is shown as in Fig. 13 which is typically in the Flexsim software.

When a lot is delivered to rotacaster, AMHS controller will check to know which kind of lot this is. If this is unprocessed normal lot, it will be kept moving along the original direction (port 1). If this is processed hot lot or processed normal lot, output of $Conveyor_k$ will be closed and lot is handled to $Conveyor_{k+1}$ (port 2). After that movement of $Conveyor_k$ will go on. Stopping $Conveyor_k$ has little or no effect on delivery time of other lots because speed of Rotacaster is quickly (just only 0.5 ft/s).

If this lot is unprocessed hot lot, AMHS controller will check to find the nearest empty machine in intrabay and "quick" area. "Quick" area includes machines from Mj to Mn. If there are any empty machine in "quick" area, lot is reserved at this empty machine and changed direction to handle to conveyor line 2 (port 2) in similar way as above. Otherwise, it will keep moving (port 1) to the next empty machine if have.

2.3. Simulation and optimization process

As mentioned in ITRS 2012 Update Overview, the 450 mm wafer size transition is taking full advantage of the work previous done to standardize the 300 mm wafer transport by having already adopted the same whole automation scheme with only minor upgrades, thus placing the 450 mm silicon standards and automation schedule ahead of the corresponding 300 mm wafer size conversion schedule with respect both to automation and also to silicon material standards.

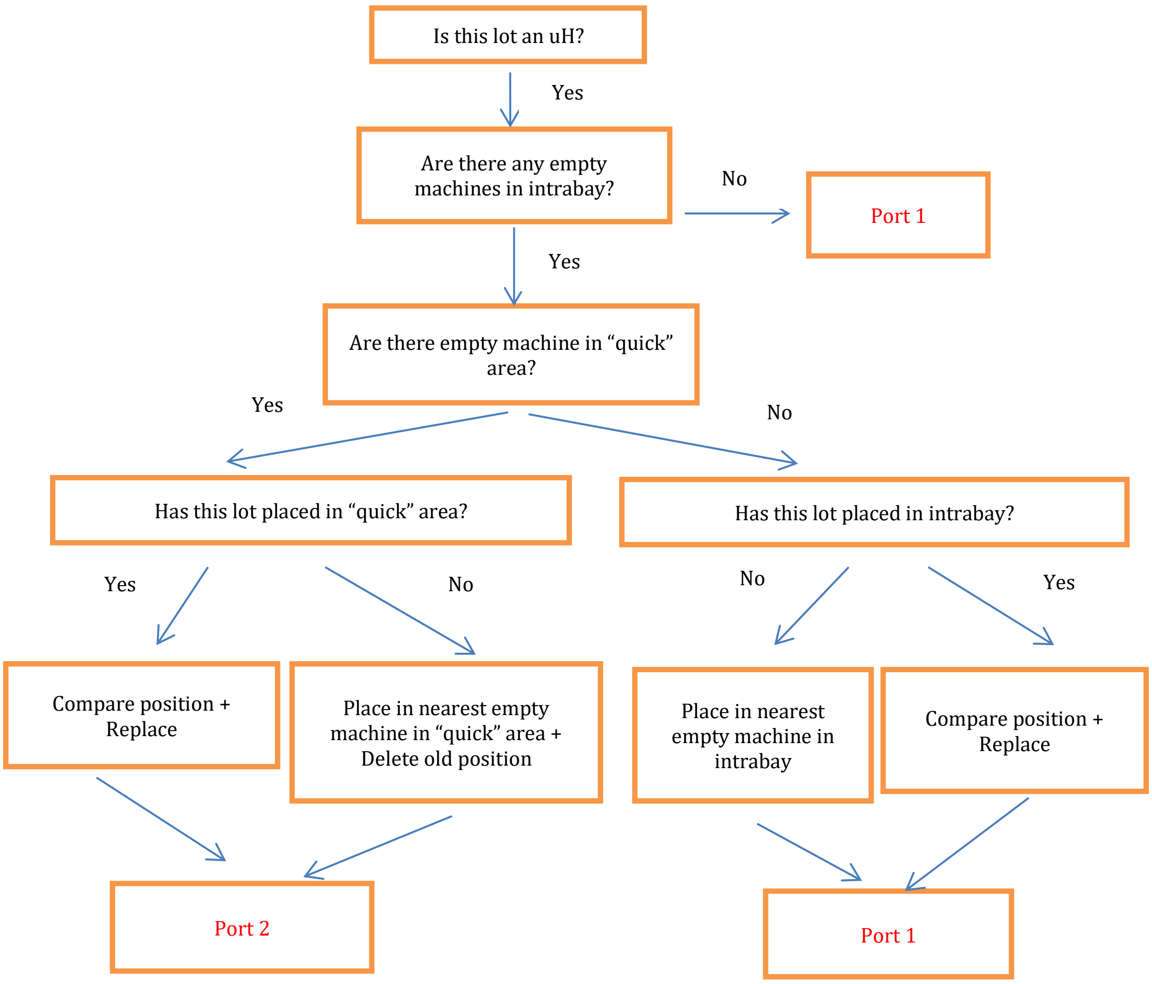

Fig. 12: Flowchart for Rotacaster

```
// There is at least one path from Start to Unloading
// Start
Define variables and constants is used in this program
Define tables which is used in this program
The type of hot lot is an even number from 2
The type of normal lot is an odd number from 1
D1 = the loading time * the average conveyor speed
D2= the unloading time * the average conveyor speed
// Find the nearest empty machine with FOR LOOP
for (i=1; i<= the total of machines in the current intrabay, the order of nearest empty machine is unknown, i++)
{
if (the machine is empty)
The order of nearest empty machine is determined
else
All of machine in the current intrabay is busy
}
// checking lot is an unprocessed hot lot or not
if (the type of item is even number and equals the order of current intrabay times 2) This lot is an unprocessed hot lot
// Find order of the machine, which this hot lot is reserved before and this machine is not the nearest machine (machine X)
for (i=1; i<= the total of machines in the current intrabay and order of the machine X
is unknown, i++)
{
Order of this machine X is determined
The reservation of this hot lot in machine X is cancelled. The nearest empty machine is reserved this hot lot
}
// checking the total of unprocessed hot lot in a distance D1 in front of the nearest empty machine
if (the total of unprocessed hot lot is more than 1) The last hot lot is loaded to the empty machine
else
This hot lot is loaded to the empty machine
if (the type of item is even number and equals the order of current intrabay times 2 plus 1 and there are not any unprocessed hot lots in this
intrabay)
This lot is an unprocessed normal hot
// checking the total of processed hot lot in a distance D1 before the nearest empty machine
if (there is a processed hot lot within distance D1)
The unprocessed normal lot keeps going to next workstation
else
// checking the total of unprocessed normal lot in a distance D1 before the nearest empty machine and total of empty machine in this
intrabay.
if (the total of unprocessed normal lot is more than 1 and the total of empty machine in this intrabay also more than 1)
The second normal lot is loaded to the empty machine
else
This normal lot is loaded to the empty machine
// After processing, check the total of processed hot lot within a distance D2 in
front of the nearest empty machine
if (there are any processed hot lot within D2)
The processed normal lot in machine is stopped unloading
else
Unloading
//Unloading
The lot is loaded from the machine to conveyor to handle.
```

Fig. 13: The pseudo code of algorithm for normal conveyor

Furthermore, ISMI 450 mm Guidelines shows that 450 mm AMHS hardware designs must support the need for converting existing 300 mm fabs to 450 mm fabs. During the interim consortium work since the 2009 ITRS publication, consortium progress has resulted in 24 the completion of international standards for 450 mm carriers, load ports, and developmental test wafers and the evaluations for wafer size (ITRS, 2012).

This simulation models in this study are implemented with Flexsim simulation software (Gelenbe and Guennouni, 1991), a discrete-event simulation package from Canyon Park Technology Center (1577 North Technology Way, Building A, Suite 2300 Orem, Utah 84097 USA).

In a wafer factory, the AMHS is a quite complex system. It is too difficult to conduct 100% real situation. Thus, this study tries to simplify the system and makes several suppositions and imposes certain limits. The main research scope and the limiting conditions include the following steps as shown in Fig. 14:

1. The 450 mm wafer fab specifications of process equipment is similar with 300 mm wafer fabs (According to the data from the ISMI 450 mm Guidelines (ISMI, 2009).
2. The factory has a central aisle for 145 feet long among entire simulation fab model. There are total of 69 sets of process machines distributed into five intrabays (100 feet long for each intrabay). There are not any stockers for each intrabay or interbay.
3. All of the conveyors move with the same direction. The intrabay is connected to the interbay by conveyor-curved.
4. The conveyor speed is 1ft/s.
5. The rotacaster speed is 0.5 ft/s.
6. The machine process time is 24h each day, 7 days each week for two weeks, for a total of 14 days. The

first week is the warm-up time for this simulation. In Flexsim simulation, we choose time unit is second.

7. Each load port machine can only perform loading or unloading operation for one lot. If front has a lot conducting the loading or unloading operation, back of this lot must stop until these operations complete.

8. There are no failures and maintenance activities on the conveyor and equipment during the simulation.

9. Because this research focuses on the performance of conveyor-based material handling system, the from-to relationship between two processing units is adopted, instead of considering the overall process flow of a wafer product.

10. There are two kinds of products in factory: hot lot and normal lot (each lot contains 12 pieces of 450 mm wafer).

11. The inter-arrival time of transport request is probabilistic and is assumed to be of exponential distribution. Statistical distributions like exponential distribution are used throughout simulation in order to model the variations that occur in real life systems.

12. The loading time = the unloading time = 5s. Therefore, D1=D2= 5s * 1ft/s = 5 feet.

```
   // Start
Define variables and constants is used in this program
Define tables which is used in this program
The type of hot lot is an even number from 2
The type of normal lot is an odd number from 1
D2= the unloading time * the average conveyor speed
// Find the nearest empty machine in intrabay
for (i=1; i<= n, the order of nearest empty machine in intrabay is unknown, i++)
{
if (the machine is empty)
The order of nearest empty machine intrabay is determined
else
All of machine in the current intrabay is busy
}
// Find the nearest empty machine in “quick” area
for (j=n-2r+1; j<= n-r, the order of nearest empty machine is unknown, j++)
{
if (the machine is empty)
The order of nearest empty machine in “quick” area is determined
else
All of machine in the “quick” area is busy
}
  // checking kind of lot
if (the type of item equals the order of current intrabay times 2)
    This lot is an unprocessed hot lot
    if (There are any empty machine in intrabay)
       if(There are any empty machine in “quick” area)
          // Find order of the machine X, which this hot lot is reserved before and this machine is not the nearest machine in “quick” area
for (i=1; i<= the total of machines in the current intrabay and order of the machine X
is unknown, i++)
{
Order of this machine X is determined
The reservation of this hot lot in machine X is cancelled The nearest empty machine in “quick” area is reserved this hot lot
}
            Close output of conveyor_k. This hot lot is moved to conveyor_k+1 (port 2)
            Then open output of conveyor_k
       else
            This hot lot keeps moving (port 1)
    else
          This hot lot keeps moving (port 1)
else
     if (The type of item equals the order of current intrabay times 2 plus 2)
          This is processed hot lot
          Close output of conveyor_k. This lot is moved to conveyor_k+1 (port 2)
          Then open output of conveyor_k
     else
          if (The type of item equals the order of current intrabay times 2 plus 1)
              This is processed normal lot
              Close output of conveyor_k. This lot is moved to conveyor_k+1 (port 2)
              Then open output of conveyor_k
          else
              This is unprocessed normal lot. This lot keeps moving (port 1)
```

Fig. 14: The pseudo code of algorithm for rotacaster (Supposed that lot comes to r^{th} rotacaster in intrabay. n is total of machines in intrabay and r is the order of current rotacaster, r < n/2)

3. Performance index

This study defines the lot delivery time as follows:

$$Lot\ delivery\ time\ =\ transport\ time\ +\ loading\ and\ unloading\ time\ +\ waiting\ time\ +\ blocked\ time. \tag{1}$$

The transport time is the time for one lot keeps delivering non-stop since the start of the interbay until going out of this interbay. It does not include the time one lot re-enters into one intrabay.

The loading time is the time for unprocessed lot is loaded to the empty machine.

The unloading time is the time for processed lot is unloaded to the conveyor for handling.

The waiting time is the time for one lot has to re-enter one intrabay because it did not complete processing operation in this intrabay.

The blocked time is the time for one lot is stuck because of loading or unloading procedure of other lots.

To get better performance, a factory always tries to reduce delivery time as much as possible. In theory, the loading and unloading time cannot be changed, it are fixed time. Otherwise, the transport time, waiting time and the blocked time are variable time. They can be reduced by a good dispatching method. This study uses lot delivery time as the performance index. The Eq. 1 is written in abstract terms:

$$Lot\ delivery\ time = fixed\ time\ (loading\ and\ unloading\ time) + variable\ time\ (transport\ time, waiting\ time\ and\ blocked\ time). \quad (2)$$

Based on the dynamics of a conveyor-based material handling system, this research uses two dominating control variables: the bay loading ration and the population of hot lots. Systems with heavy loadings are adopted to highlight the effect on the hot lot rules in limited-resource environment:

Bay loading is defined as the average number of hourly input lots divided by the maximum number of hourly output lots per bay. Firstly, we calculate the bay loading for each intrabay to find out the intrabay having the smallest bay loading number; it will be a bottleneck of all of five intrabay. Every calculation later will follow this smallest bay loading number. In this study, the simulation uses three loading ratios, or 92, 95, and 98% for the design specification. The Eq. 3 indicates the way to calculate the bay loading number in this simulation model. The bay loading of an intrabay is calculated for 1 hour and the time unit is second.

$$\text{Bay loading} = \sum_{i=1}^{i=m} \frac{3600s}{\text{setup time + processing time of machine i + loading/unloading time}} \quad (3)$$

m is total of machine in this intrabay.

The hot lot population is the average number of hot lots divided by the average number of lots in a bay. Because an increasing hot lot population imposes drastic time delays on normal lots, the test in this research use three hot lot ratios of 2, 6 and 10%.

The higher bay loading and higher hot lot population are reasons for the traffic jam in handling operation. The Eqs. 4 and 5 describe how to calculate the total of hot lots and normal lots got into the interbay per hour.

$$Total\ of\ hot\ lots\ arrived = hot\ lot\ ratio \times Bay\ loading. \quad (4)$$

$$Total\ of\ normal\ lots\ arrived = (100\% - hot\ lot\ ratio) \times Bay\ loading. \quad (5)$$

Based on these data, we can calculate the inter-arrival time for simulation model, as follow:

$$The\ inter-arrival\ time = 3600s/ Total\ of\ lots\ arrived \quad (6)$$

Each experiment is conducted three times. The total number of simulation experiments performed is 3 (hot lots ratio) x 3 (bay loading) x 3 (replication) = 27. The simulation horizon is set to 14 days long with 7 days pre- run for each experiment.

4. Simulation results and analysis

To emphasize the advantages of the dispatching method in this study (R-HPD), we choose differentiated preemptive dispatching policy (DPD) rule to compare the performance from two control variables: bay loading and hot lots population. The DPD rule utilizes the straightforward idea of first serve with the high priority. This policy is evaluated as a best rule for preemptive products in OHT applications. Otherwise, when applied to conveyor-based material handling system, DPD rule still keeps itself advantages.

Factories do not start each week without any work-in-progress (WIP) in fact, but the simulation is likely to start empty (no products at any of the machines). Thus, simulations of factories usually need a warm-up time (pre-run time). The simulation horizon is set to 14 days long with 7 days pre-run for each experiment. The research result is the average lot delivery time with the time unit of second and does not include the warm-up time.

$$The\ average\ lot\ delivery\ time = \sum_{i=1}^{i=l} lot\ delivery\ time \quad (7)$$

where: l is total of lots completed their processing operation and i is inter-arrival time.

As the results, the average lot delivery time with R-HPD is faster than the average lot delivery time with DPD in each scenario. This comment is right for both hot lots and normal lots. For example, the average delivery time of hot lots for 2% hot lot ratio ranges from 1306.44s to 1310.68s for DPD and from 610.12s to 702.36s for R-HPD, the average delivery time of normal lots ranges from 2092.99s to 5262.43s for DPD and from 1500.53s to 2699.53s for R-HPD. Therefore, at 2% hot lot ratio and 92% bay loading ration, the R-HPD rule reduce average delivery time of hot lots by 52.8% (from 1309.90s to 651.987s) (Table 1).

Table 1: The experimental results

System configuration		Average lot delivery time (second)			
		Hot lots		Normal lots	
Hot lot ratio (%)	Bay loading ratio (%)	DPD	R-HPD	DPD	R-HPD
2	92	1306.44	610.31	2092.99	1500.53
	96	1311.52	640.21	3482.1	1876.66
	98	1310.68	701.25	5262.43	2447.21
6	92	1311.31	610.12	2410.92	1836.21
	96	1315.91	645.13	4317.06	1936.69
	98	1332.41	686.92	9074.11	2577.36
10	92	1311.67	621.36	2476.26	1694.88
	96	1316.06	660.02	4840.09	2145.46
	98	1351.4	702.36	13353.31	2699.23
Average		1309.90	651.987	4045.85	2079.359

If any lot cannot complete processing operation because there were no empty machines within the intrabay, it has to move around inside the intrabay to wait for loading. This is the reason for the rapid increase of the lot waiting time. The serious traffic jam occurs in the intrabay 2 which has the smallest bay loading number (bottleneck). However, the problem above is solved very well with R-HPD rule. The average delivery time of normal lot is not affected so much when bay loading and hot lot ratio increase. The reason is lot uses “shortcut” to decrease the length of movement. Thus, number of lot in intrabay is always low and congestion does not happen often. Obviously, the R-HPD rule solves the serious traffic jam at high bay loading much better than DPD rule.

5. Research conclusions

In the next years, the semiconductor industry will undertake one of its most significant developments: the transition from processing 300 mm silicon wafers to processing 450 mm wafers. As with the last transition — from 200 mm to 300 mm wafers — this next transition, expected to be fully underway across the industry in 2015, will entail significant technical challenges for automated production systems. This increased wafer size potentially brings advantages in cost and throughput, but the upfront investment in systems engineering is high.

This study proposes coupling two lines of intrabay and using Rotacaster to move lot directly from line 1 to line 2 if necessary. In this way, the amount of lot is cut down quickly in the intrabay, eliminating traffic jams. The delivery time of lot in intrabay is severely reduced because of reducing the length of the road and blocked time.

The effective dispatching rule developed in this research calls “Using Rotacaster in the heuristic preemptive dispatching rule (R-HPD) for conveyor-based material handling system of 450 mm wafer Fabrication”. The objective of R-HPD rule is to minimize transport blocking and waiting time for hot lots while creating a minimal impact on the variable time for normal lots. This study gives different system configurations for the loading ratio, hot lot ratio. The simulation results, performed by using Gelenbe and Guennouni (1991) simulation software, show that the R-HPD rule reduces the average of hot lot average delivery time by 49.4%. It also reduces the average of normal lot average delivery time by 50.5%. Moreover, the average delivery time of normal lot is not affected so much when bay loading and hot lot ratio increase. Therefore, the R-HPD rule is good for the design of next generation semiconductor factory.

This study is not only dealing with traffic jams very well but also opening up a new direction in fabs configuration research. The increased wafer size potentially brings advantages in cost and throughput, but the upfront investment in systems engineering is very high. Billions of dollars will be invested to build new tools and ramp new processes, part of the decades-long effort to maximize the productivity and profitability of semiconductor manufacturing. With new considerations — changes in wafer size, weight, fragility, risk of damage or creation of damaging particles — existing wafer handling robots and the drives, motors, linear components and controls that automate these wafer handling tools will need a new generation of components to satisfy the requirements of 450 mm wafer handling. The Rotacaster’s creative construction has brought a new level of performance to conveyor transfer and multi-directional motion applications. By combining rotacaster with conveyor-based AMHS, this research helps system become more flexible and reduces the breadth of each intrabay as well as size of factory. Thus, this solution can save cost for buy factory premise and gain high profit from maximizing the productivity.

Further research can use more rotacaster in the factory configuration to expedite the movement of both hot los and normal lots. This will help system be more flexible and effective, for example, handling hot lot from line 2 to line 1 if necessary. In addition, future research will also consider expanding the simulation model in this study to full-scale AMHS applications.

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