COMPARISON OF TWO CROSSDOCKING LAYOUTS AT A JIT MANUFACTURER

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ABSTRACT

In this study, the actual layout of a crossdocking operation at a major automotive manufacturing plant is compared to a newly designed layout. The impact of the layout changes on the performance of the team members in the logistic area is analyzed using travel distance as the performance measure. The results show that the performance will be dramatically reduced if the suggested changes are implemented

Keywords: crossdocking, logistics, manufacturing, simulation, layout problem

INTRODUCTION

The pressure to produce a wide variety of models has made mixed-model assembly lines an integral part of the Just-in-Time (JIT) production system. On a mixed-model assembly line, several different models of a basic end product are produced at the same time; for example, Camrys with and without moon-roof, with right or left steering. This leads to the problem of balancing and sequencing the different models on the assembly line. One of the goals of sequencing is to keep the usage of every part in the assembly line constant to ensure a smooth production. Many algorithms have been developed to help with the sequencing of mixed-model assembly lines, but little attention has been paid to the challenges that frequent deliveries pose for the support people in the logistics area. One of the goals of JIT is to keep inventory low which leads to frequent deliveries and the need for innovative storage and transportation solutions. In an ideal situation, the suppliers would deliver the needed parts directly to the workstation at the assembly line in the exact quantity at the exact time and in the sequence needed. In this ideal case, the inventory level at and between all workstations would be zero. In reality, only a few parts are delivered directly in sequence to the assembly line; for example, car seats, thus different intermediate storage solutions have been developed: Flowracks or floor staging areas, internal sequencing areas and lane storage/crossdocking area. In the lane storage area the incoming parts are sorted by line and then are immediately delivered to the line. This sorting process is called crossdocking.

Statement of the Problem

This project has been conducted in cooperation with Toyota Motor Manufacturing Kentucky (TMMK). The team members on the assembly line suggested lowering the amount of material on their workstations to reduce unnecessary movement/walking and therefore their overall workload. Currently, material is stored in up to three rows of parts in a flowrack, with an overflow area to accept excess material in case all rows are full. The excess material will be stored in an intermediate storage area consisting of flowracks and designated floorspace for larger parts. This makes a redesign of the existing lane storage area necessary.

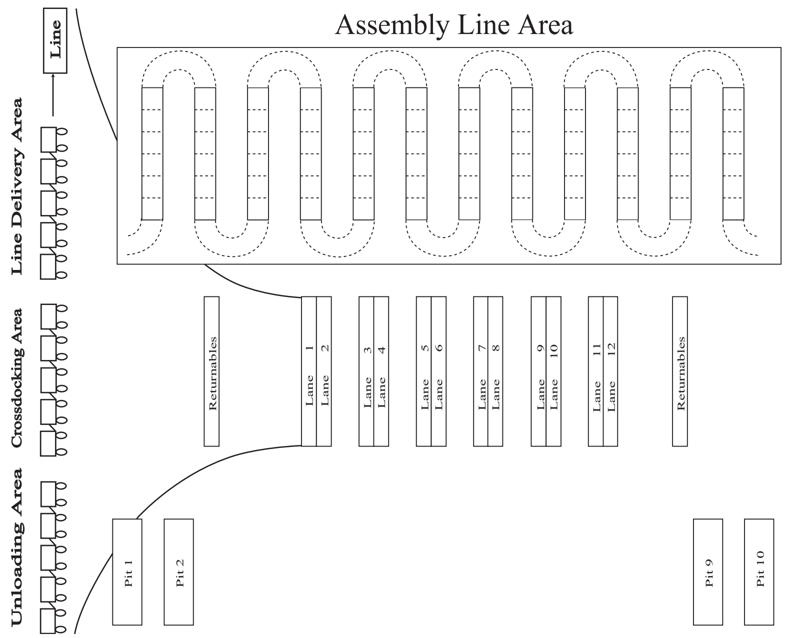

Figure 1: Layout of the Unloading/Lane Storage/Assembly Line Area at Toyota, Georgetown

Description of the Current Layout

A layout of the lane storage area and adjacent areas is illustrated in Figure 1. Trucks get unloaded in 4 pits, which are designed so that the forklifts have access on ground level, eliminating unnecessary up and down movement of the pallets and therefore increasing safety for the team members in that area. The truck schedule generally remains constant, although some trucks do not come in on a daily basis. Once a month the sequence schedule for the assembly line changes, and the truck schedule changes accordingly. These schedule changes also take into account the mileage per carrier and attempt to equalize it. In addition to the parts that are handled in the lane storage area, the trucks carry parts for other storage areas, such as sequencing parts and flowrack parts. Each incoming box is accompanied by a kanban card designating the lane and line to which the parts ultimately belong. Approximately 1300 different parts are handled in the lane storage area. A limited number of parts are used at more than one workstation. For these parts with multiple destinations, the kanban cards for each destination are printed with the different lineside/lane addresses. Therefore, in this study, parts with multiple uses and destinations can be considered as different parts. The number of team members is currently fixed at 8 working in the delivery area and 3 team members working in the sorting area. Every two hours, team members in the lane storage area rotate between crossdocking and delivery to line. Forklift drivers rotate jobs on a daily basis. The lane storage area consists of 12 lanes. The lanes and lines have corresponding labels, e.g., all dollies/parts from lane 4 go to a part of the assembly line that is also labeled 4. Each lane is separated into 3 sections.

Section 1 "unloading area": Parts are unloaded from the truck and brought into the unloading area of the designated lane via forklift.

Section 2 " crossdocking area": The crossdocking area is separated from the waiting area by a red line; only electric cars, called tuggers, operate behind the red line, no forklifts are allowed. A team member pulls all full dollies from the loading area into the crossdocking area, removes the packaging material and sorts out parts (crossdocking) that do not belong to that lane.

Section 3 "line delivery area": After crossdocking, the team member pulls the dollies into the ready area where they wait until a team member from the delivery team is able to bring them to the assembly line.

At the line, the parts are unloaded into a designated row in a flowrack. If the flowrack is full, the parts go into the overflow area for that workstation.

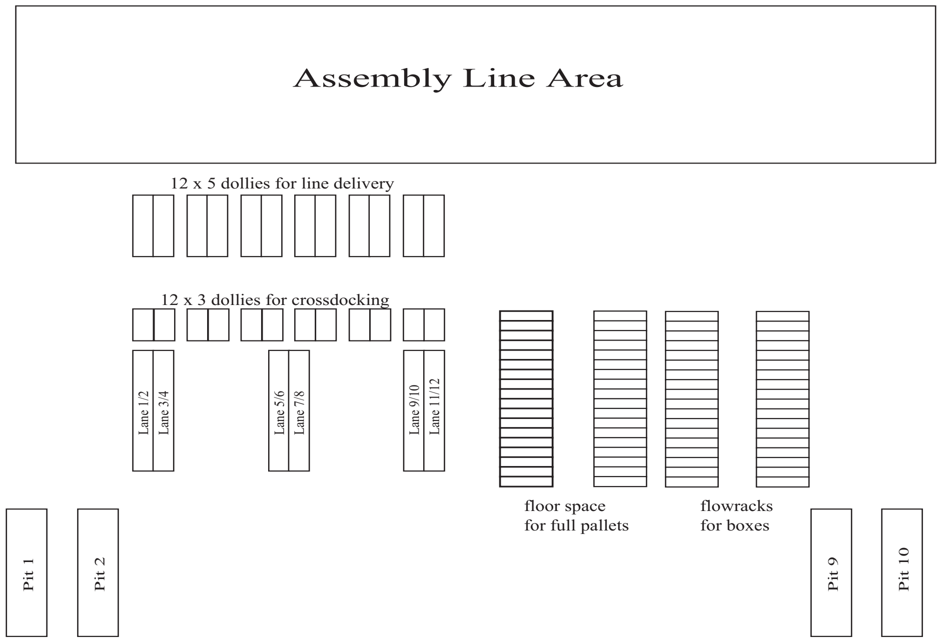

Figure 2: New Layout Proposed by Toyota

Proposed new layout

In a proposed new layout, illustrated in Figure 2, the material at the assembly line will be reduced to only one row of parts per flowrack and there will be no overflow area. Material with a low volume of containers per truckload and a high quantity of parts per container will be handled in the lane area; material with a high volume of containers per truckload and a low quantity per container will be stored intermittently in either flowracks or a designated floor space. Depending on container size, about 50% of the parts will be stored in flowracks/floor space. The parts will be picked from this area using dollies, which will then wait for the line delivery. The lane storage area will handle the remaining 50% and will be rearranged. Each lane will initially handle the material for two lines, and the final separation will take place during the crossdocking process. After crossdocking, the dollies will go to the same area as the dollies with the parts picked from the flowracks/floorspace, and they will be delivered to the lane together.

CROSSDOCKING LITERATURE REVIEW

The success story of Wal-Mart [stalk-1992] and its improvement in lead time has brought attention to crossdocking operations. Wal-Mart achieved its goal of providing customers access to quality goods when and where they want them by making the way the company replenished inventory the centerpiece of its competitive strategy. Due to crossdocking, goods cross from one loading dock to another within 48 hours or less. By running 85% of its goods through its warehouse system, Wal-Mart reduced costs of sales by 2% to 3% compared to the industry average.

Gue [gue-1999] defines terminal layout as the arrangement of receiving/strip doors and shipping/stack doors, and the assignment of destinations to stack doors. Since the material flow in a crossdocking terminal and the travel distance for workers transporting freight largely depends on the layout of the terminal, the crossdocking literature is mainly concerned with layout studies.

Bartholdi and Gue [bartholdi-2001] ran a series of computational experiments to determine which shapes of crossdocks have the lowest flow cost and the least traffic congestion. They found that for small to mid-sized crossdocks (up to 150 doors), a rectangle or I-shaped crossdock performed best. For larger docks (150 to 250 doors), the T-shape performed best; for crossdocks that exceed 250 doors, the H-shape performed best.

In an earlier paper, Bartholdi and Gue [bartholdi-2000] created several models that guided a local search routine in assigning destination trailers to terminal doors. The goal was to minimize total labor cost, which was defined as the cost of moving freight from incoming trailers to outgoing trailers weighted against the cost of delays due to different types of congestion; in other words, worker travel time and worker waiting time. They found that the improved layouts tend to concentrate activity in the center of the dock. The highest-flow regions on either side in the center are slightly offset so that congestion in the center of the dock is reduced. The improved layout was implemented at a Viking terminal in Stockton and led not only to an improvement in productivity by 11.7 % but also to a noticeable reduction in freight processing time and other unexpected benefits.

Gue [gue-1999] investigated the effects of trailer scheduling on the layout of freight terminals. He developed a model of the material flow when a look-ahead scheduling strategy is used. In a look-ahead strategy, to minimize worker travel, incoming trailers are assigned to the door closest the shipping door with the most outgoing freight. Gue first used linear programming to assign trailers to doors and then ran a set of simulations to determine the layout with the lowest expected cost. The look ahead scheduling strategy reduced traveling cost by 15 to 20% compared to a first-come, first-serve policy. The new layout provides further savings of 3 to 30% depending on the mix of freight on incoming trailers.

Tsui and Chang [tsui-1990, tsui-1992] developed a microcomputer based decision support tool for assigning dock doors in freight yards. They used a bilinear algorithm to recognize shipping patterns. Recognizing these patterns leads to an improved assignment of incoming trucks to the receiving doors, minimizing travel distance for the forklift drivers and avoiding congestion.

METHODOLOGY

To compare the two layouts and the different incoming volumes of material, a simulation model has been developed which is described in the following section together with the parameters involved in the study and the performance measures.

Simulation Model:

Experimentation with a real world system is expensive and, in most cases, not practical. For this study, it would mean changing the layout of the lane, observing its performance for a week or month, and risking a shut down of the assembly line should the crossdocking not be done effectively and parts unable to be delivered to the workstation on time. In simulations, on the other hand, testing different scenarios requires only an adjustment of the simulation model, and it is a lot faster since only the actual events are simulated. A discrete event simulation model was created using ARENA. ARENA uses a graphical user interface (GUI) for SIMAN, a general purpose simulation language providing subroutines for event timing, file handling, and statistical calculations. The GUI speeds up the development of the model and the animation makes it easy for end users, such as the logistics manager, to understand.

Research Questions:

The difference between the current layout (5 dollies) and the proposed new layout (3 dollies) is the number of dollies in each section. The lower number of dollies leads to shorter distances between lanes and therefore automatically to reduction in workload. The more interesting question is the effect of the change in volume of material that has to be crossdocked.

Research Question: *Does the difference in the volume of incoming parts have a significant effect on the workload of the team members?*

Incoming Material Data

Currently, 24,396 boxes come in every day from which 1,784 or 7.31% have to be crossdocked. The proposed changes in the material flow will result in only approximately half of the parts handled in the crossdocking area, the other half will be stored intermediately in flowracks. From the new volume of 10,482 boxes 1,577 or 15.04% have to be crossdocked.

Performance Measure

The workload for the crossdocking team members is defined as the distance they have to walk to transport the boxes from one lane to another.

RESULTS

This section provides the results of the simulation runs and an analysis of the data.

Results Volume Changes

The first instinct would be to think that a reduction in volume will lead to an equal reduction of workload for the team members in the crossdocking area. Because two parameters are changing (the layout and the volume of incoming material) a direct comparison of the old system with the new system is statistically not possible. Therefore, two separate t-test were performed, one for the current layout and one for the future layout. The analysis of the data, provided in Table 1 shows that the change in volume actually leads to an increased work load. For the current layout the overall travel distance increased by 12.59% and for the future layout by 11.28% These surprising results led to further investigation.

Table 1: Comparison Current Data and Future Data for both Layouts

	Current Layout		*Future Layout*	
	Current Data	Future Data	Current Data	Future Data
Mean	306893	345543	262073	291641
Variance	1371536008	769019977	1037334960	577799668
Observations	1000	1000	1000	1000
df	1998		1998	
t Stat		2.33		2.33
P-Value		<0.0001		<0.0001
Difference		38650		29568.04
Diff. %		12.59		11.28

Table 2: Examples of Different Incoming Quantities and Crossdocking Percentages

Example 1	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	80	20	20	20	20	8	0	0.00
Reduction by 50 %	40	10	10	10	10	4	**0**	**0.00**

Example 2	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	80	20	20	20	20	8	0	0.00
Reduction by 50 %	40	15	15	5	5	4	**10**	**25.00**

Example 3	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	40	10	10	10	10	4	0	0.00
Reduction by 50 %	20	5	5	5	5	2	**10**	**50.00**

Example 4	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	40	15	15	5	5	4	10	25.00
Reduction by 50 %	20	10	10	0	0	2	**0**	**0.00**

Example 5	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	10	10	0	0	0	1	0	0.00
same quantity	10	3	3	2	2	1	**7**	**70.00**

Example 6	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	5	5	0	0	0	1	0	0.00
Increase by 100%	10	10	0	0	0	0	**0**	**0.00**

Example 7	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	5	5	0	0	0	1	0	0.00
Increase by 100%	10	5	2	2	1	1	**5**	**50.00**

Example 8	Quantity	Part A	Part B	Part C	Part D	Pallets	CD Parts	CD %
	10	5	2	2	1	1	5	50.00
Increase by 100%	20	10	10	0	0	2	**0**	**0.00**

Eight examples (see Table 2) were constructed to illustrate the possible relationship between the incoming quantities, part mix and crossdocking activity. The pallet size in all examples is 10 boxes per pallet. Parts labeled part A belong in lane A, parts labeled part B belong in lane B, etc. All parts come from the same supplier in the same truck.

In Example 1, the original quantity of 80 parts is reduced by 50%, but since each part still fits on exactly 1 pallet, no crossdocking activity is needed. In Example 2, the original quantity of 80 parts is again reduced by 50%, but in this case, 10 parts or 25% have to be crossdocked. In Example 3, the original quantity was 40 parts; here a reduction by 50% will lead to 10 parts, or

50% of crossdocking activity. In Example 4, 10, or 25%, of the original 40 parts had to be crossdocked. In this scenario, a reduction of 50% will eliminate the crossdocking activity since all parts for lane A fit on the first pallet and all parts for lane B fit on the second pallet. Example 5 shows that the same quantity could result in drastically different crossdocking levels; an incoming quantity of 10 parts could either result in no crossdocking activity at all, when all parts belong to the same lane, or, result in 7 parts or 70% that have to be crossdocked. Examples 6 to 8 illustrate that an increase in quantity has the same effects as a reduction in quantity; either no change in crossdocking activity (Example 6), an increase in crossdocking activity (Example 7) or a reduction in crossdocking activity (Example 8).

In all these examples, the parts came from one supplier on one truck. The complexity of the problem increases when more suppliers are involved and the incoming quantities are split up into time intervals/trucks, making prediction of the relationship between the incoming parts and the workload of the team members even more complicated. Due to the complexity of the problem, this study is limited to the identification of the factors involved; namely, pallet size, incoming quantity, part mix, number of suppliers, and delivery interval/number of trucks. The analysis of the relationships among these factors and their influence on the workload is left to future research.

CONCLUSION

The proposed change in layout seems to have an adverse effect on the workload of the team members in the crossdocking area. The reduced volume of material handled in the crossdocking area leads to smaller quantities for each part and therefore a higher percentage of pallets that have to be crossdocked. In addition, the other 50% that now go into flowracks/floor staging area has to be handled increasing the workload even more. On the other hand the material at the assembly line workstations will be reduced, saving time for the assembly line team members. Therefore, the whole system has to be considered when making a decision about the proposed changes in layout. The benefit of shorter walking times for the team members at the assembly line could lead to an overall shorter lead time outweighing the increased workload for the team members in the logistic area.

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