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A Bottleneck Analysis of Robotics and Automation in the Coca-Cola Production Line †

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Abstract: Automated material transfer between workstations is a key feature of flexible manufacturing systems. The aim of automation is to increase the output rate while reducing the manufacturing throughput. However, machine idle time contributes significantly to the overall throughput time and cannot be completely eliminated; it can only be minimized. Accurately locating the bottleneck and synchronizing it with other assembly line equipment can help reduce throughput. The process or activity with no idle or waiting time is known as the bottleneck in a production system. In this paper, we will analyze the bottleneck in Coca-Cola's production line at Lae and provide suggestions for reducing throughput.

Keywords: bottleneck; throughput; maximum production rate; idle time; servers

1. Introduction

An automated material movement, or handling, system refers to using a computer control system to regulate and transport materials to build products between workstations from start to finish in a flexible manufacturing system. The unit load, Mini-load, Person-on-board, Deep lane, and automated item retrieval systems are the five categories of ASs/RSs. A Deep lane AS/RS is utilized for massive warehouses with numerous layers of shelves and storage units, whereas a unit load AS/RS is used for lesser loads [1,2].

An automated material handling and storage system has the advantages of reduced throughput, enhanced product quality, and reduced labor costs.

The control system that operates these conveyors ensures that a proper conveyor speed is maintained between various workstations. A manually used forklift moves goods to storage; the storage system is not automated [2,3].

This brief paper seeks to determine a bottleneck by analyzing Coca-Cola production's automated material flow and storage system. This study also provides a process flow analysis of the Coca-Cola factory's manufacturing process to suggest ways to lower throughput as shown in Table 1.

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Table 1. Detailed overview of the 13 processes in the production line.

	Process	Description
1.	Bottle preforming	Preforms are loaded onto the rinser, and the process starts.
2.	Blow molding	The PET preforms are heated to 180 °C and blown using 40 bar air pressure. The bottle takes the shape of the mold casing.
3.	Bottle cap feed	All caps are checked for defects and ovality before being sent to the filler.
4.	Mixing	The mixer processes CO_2 + Syrup from the syrup room, chills it to 2 °C, and sends it to the filler for filling.
5.	Filling	Bottles from the blow mold oven are filled and capped by injecting beverage through a filling nozzle at high pressure.
6.	Fill level inspection	After the bottles are capped, their levels and capping quality are checked using an X-ray camera. Products with lower levels or faulty caps are rejected automatically.
7.	Date coding	The bottles are coded for manufacturing or expiry dates.
8.	Labeling	The bottles are labeled with the trademark label.
9.	Packing	The bottles are separated into 4-by-6 blocks and wrapped with the shrink film wrapper.
10.	Tunnel heating	The tunnel heats the film and shrinks it at 180 °C. The packs are ready to be palletized.
11.	Palletizing	The machine sorts the cases into layers and stack each layer on the pallets.
12.	Stretch wrapping	The pallet products are wrapped and sealed as finished goods.
13.	Transport to storage using forklift	Manually driven forklift is used for transportation to storage. End of the line.

2. Methodology

Our research group planned a field trip to the Coca-Cola plant in Lae to learn about its automated material transportation and storage system. The factory's process engineers kindly provided us with a tour of the entire manufacturing process. We conducted a manual process flow analysis using the data and information we gathered during the field trip.

3. Results and Discussion

Conveyors account for the majority of Coca-Cola's automated material transportation in Lae. A system of rollers and conveyor belts transports the Coca-Cola bottle from one cell to the next. The Coca-Cola storage system is not automated. Only a manually operated forklift is used to move it to the warehouse for storage [1,2].

The first step of process flow analysis is to locate any potential bottlenecks. Next, the remaining aspects of the process are based on the metrics for measuring its success. These consist of throughput and utilization (Figure 1).

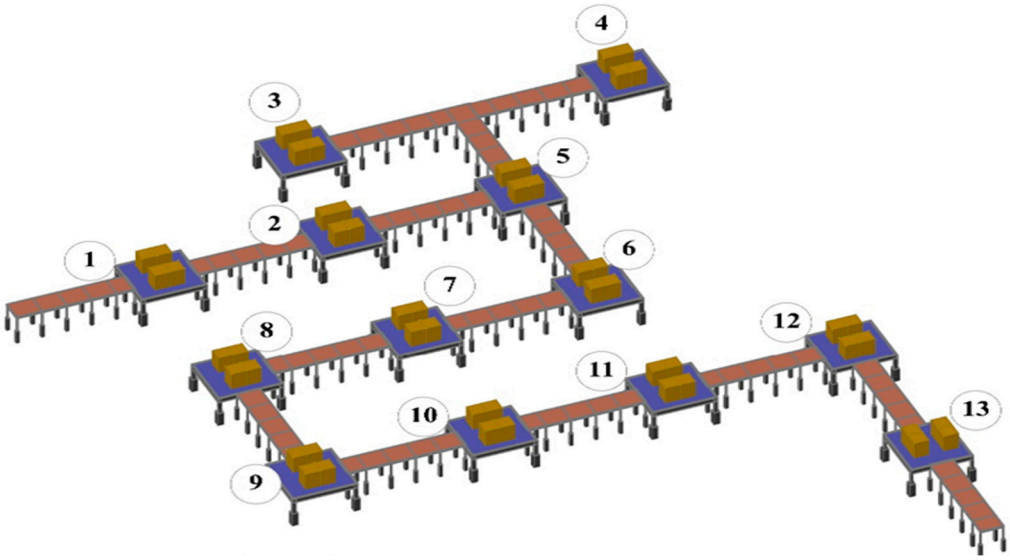


Figure 1. Overall process of Coca Cola PET production line.

Blowing a bottle takes around a minute, including when the premade bottles need to go through the blow mold oven. Once the blow molding station has produced the correct bottle shape, the bottles go to the fill station, where high-pressure beverage injection fills and caps them [3]. The filler is equipped with a circular arrangement of nozzles that is used to fill the bottles. Up to 50 bottles can be filled and sealed in a single pass or loop, since the bottles are filled while rotating on a loop conveyor. Therefore, supplying the number of bottles in a pass or revolution of the filler takes around a minute [3,4]. As filled and capped bottles leave the fill station, they pass through an inspection point, where an X-ray camera with sensors checks each bottle's fill level and faults [1]. The labeler is the next station on the PET production line, following the date coder. The bottles are labeled in the labeler using a reel-labeling wheel system with trade-marked labels. Here, the bottles are quickly labeled one at a time. Each bottle enters the labeler and is kept at a fixed distance by a mechanical fixture; it takes around 30 s to label each bottle. The bottles require approximately two minutes to travel from the packer's entrance to the heated channel's departure. The bottle pack is then transferred by a conveyor belt to the next station's palletizer [4–6]. The palletizer sorts the cartons into layers, which are each stacked on the pallet as shown in Table 2. A robotic arm sorts the pallets, and the process takes around five minutes [7–10]. The trip yielded a production rate of 2000 PET bottles per hour. The bottleneck station has a single server. The examination is carried out quickly and precisely using a single X-ray machine [4–6].

The utilization of the bottleneck station is 100% at maximum production rate $R_p{}^*$. The overall FMS utilization is calculated as

$$U_s{}^* = \sum_{i=1}^{n} S_i U_i / \sum_{i=1}^{n} S_i = \sum_{i=1}^{n} S_i (WL_i / S_i)(R_p{}^*) / \sum_{i=1}^{n} S_i$$

Only 36.4% of the assembly line is used during maximum output, indicating that specific machines must operate to their full potential due to bottlenecks. The bottleneck's production rate has to be raised to boost utilization. This is accomplished by either adding more servers or lightening the burden. The manufacturing lead time or the throughput can now be calculated. The waiting time T_w is zero.

$$MLT = \sum_{i=1}^{n} WL_i + WL_{n+1} + T_w$$

This means that it takes 25 min to produce a pallet and then move it to the end of the line.

To put it briefly, the bottleneck station and the upstream workstations are automatically managed to prevent lines and waiting times. For instance, if there is a chance of a queue in the manufacturing line, the workstation's speed will rise. Similarly, if there is a chance of an idle condition, the workstation's speed drops. Before the next work item arrives, this automated control system ensures that every workstation completes its tasks on schedule. As a result, there is no longer a need for workstation lines or wait times. Each workstation is used more efficiently, and there is a low total throughput.

Table 2. Estimated time for each workstation and material handling processes.

Operation	Description	Station	No. of Servers	Workload of Station, Sec/Bottle	Convey/Move Sec/Bottle
Loading	Loading preformed bottles onto conveyor	01	02	005	Start
Rinsing	Rinsing each preformed bottle	01	02	005	030
Blow molding	Blowing the preformed bottles into desired shapes in the mold	02	50	060	030
Filling	Filling and capping happen in the same station	03	50	060	030
Fill level inspection	Inspection of the fill level and capping quality	04	01	001	020
Date coding	Printing of manufacturing date and expiry date	05	01	002	015
Labeling	Labelling with trademarked labels	06	01	030	010
Packing	Packing of the bottles into packs/cartons	07	01	120	120
Palletizing	Sorting of the cartons/packs onto pallets	08	01	300	420
Stretch wrapping	Wrapping of the pallets	09	01	120	180

4. Conclusions

Three automated material handling systems are utilized in the Coca-Cola facility in Lae: robotic arms, conveyors, and loops. The robotic arm is utilized for palletizing, the filling machine uses a loop, and the conveyors at the downstream workstations employ a loop. A manually operated forklift moves cargo from the manufacturing line's end to the storage unit. Automation is not implemented. The facility could increase the number of servers at the bottleneck station to boost throughput or decrease the burden by speeding up or shortening the processing time for each item.

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References

1. Ajenblit, D.A. Applying Genetics Algorithms to the U-shaped Assembly Line Balancing Problem. In Proceeding of the IEEE Conference of Evolutionary Computation, Anchorage, AK, USA, 4–9 May 1998; pp. 96–101.
2. Yin, X.; Pan, L. Direct adaptive robust tracking control for 6 DOF industrial robot with enhanced accuracy. *ISA Trans.* **2018**, *72*, 178–184. [CrossRef] [PubMed]

3. Heizer, J.; Barry, R. *Production and Operation Management*; Allyn and Bacon Inc.: Boston, MA, USA, 1988.
4. Ribeiro, J.; Lima, R.; Eckhardt, T.; Paiva, S. Robotic Process Automation and Artificial Intelligence in Industry 4.0—A Literature review. *Procedia Comput. Sci.* **2021**, *181*, 51–58. [CrossRef]
5. International Labour Office. *Introduction to Work Study*, 3rd ed.; ILO Press: Geneva, Switzerland, 1979.
6. Goldratt, E.M. *The Goal*, 4th ed.; The North River Press Publishing Corporation: Great Barrington, MA, USA, 2014.
7. Rout, A.; BBVL, D.; Biswal, B.B.; Mahanta, G.B. Optimal trajectory planning of industrial robot for improving positional accuracy. *Ind. Robot. Int. J. Robot. Res. Appl.* **2021**, *48*, 71–83. [CrossRef]
8. Rout, A.; Mahanta, G.B.; Gunji, B.; Deepak BB, V.L.; Biswal, B.B. Kinematic and dynamic optimal trajectory planning of industrial robot using multi-objective ant lion optimizer. In *Advances in Mechanical Engineering: Select Proceedings of ICRIDME 2018*; Springer: Singapore, 2020; pp. 1475–1486.
9. Mohamed, A.; Ben, J.; Muduli, K. Implementation of Autonomous Maintenance and Its Effect on MTBF, MTTR, and Reliability of a Critical Machine in a Beer Processing Plant. In *Applications of Computational Methods in Manufacturing and Product Design*; Springer: Singapore, 2023; pp. 511–521.
10. Oyekola, P.; Oyewo, T.; Oyekola, A.; Mohamed, A. Arduino based smart home security system. *IJITEE* **2019**, *8*, 2880–2884. [CrossRef]

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