Proceedings of the 11th North American International Conference on Industrial Engineering and Operations Management, Milwaukee, Wisconsin, USA, June 9-11, 2026

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/NA11.20260279
Published: June 9, 2026

Analysis of Batch vs. One-Piece Flow Manufacturing of Spherical Bearing Assembly Process

Angel Rivera, Joel Romero and Max Gargano
Manufacturing Engineering Undergraduates
Department of Engineering and Desing
Western Washington University (WWU)
Bellingham, WA, USA

Moh'd Ragheb El-Sharo
Associate Professor
Industrial and Systems Engineering Program
Department of Engineering and Desing
Western Washington University (WWU)
Bellingham, WA, USA

Abstract

This paper compares batch processing to one-piece flow manufacturing on a housed bearing assembly line at a regional bearing manufacturer. The study used time study data from the company's internal assembly timestamp records alongside direct observation of the three-station line. Value stream mapping documented the current and future states of the process. Simulation results show that one-piece flow reduces cycle time by 38%, reduces lead time by 46%, reduces work-in-process inventory wait by 56%, and increases daily capacity by 62%, from 254 to 411 units per day. A workstation task redistribution is proposed that balances all three stations at 40 seconds per unit without adding staff.

Keywords
One-piece flow, batch processing, value stream mapping, time study, lean manufacturing.

1. Introduction
A regional bearing manufacturer produces self-aligning spherical bearings characterized by an outer ring with a spherical curved outer diameter, abbreviated as (OD). The spherical OD bearings are assembled into machined loading slot style housings. The assembly work is executed using a production and assembly line layout (cell) design with three machines/stations operated by one worker each on a push system. The production is in the form of make-to-order (MTO). Because of MTO style of production there is a longer lead time for customers to receive their orders.

The cell has used batch processing (push system) for years, moving groups of units through each station together before passing them to the next. Workers report that batch processing feels faster because they are always actively working and it improves their perceived worker utilization. Measured output does not support that perception. Station no. 2 carries a heavier task load than the other two stations and runs at twice the cycle time of Station no. 1, forcing the whole line to wait for it. Management defined a clear goal for success in this study which is to demonstrate that this cell can produce more than 300 units per day using the same three workers. This study was conducted to evaluate whether one-piece flow could meet that condition and to identify the structural changes needed to support it.

1.1 Objectives
The objectives of this study are to document the current state of the assembly line through observation and value stream mapping, to compare batch processing and one-piece flow across cycle time, lead time, WIP inventory wait, and daily capacity, and to propose a workstation task redistribution that balances the line without adding staff.

2. Literature Review
Manufacturers sometimes face situations where the production rate of the equipment is much greater than the demand rate for any single product type or category. This happens when manufacturers strategically offer a variety of products and customizations. This type of production allows for the utilization of the same equipment/station for a variety of products (Groover, 2015). Batch production or (Medium Quantity Production) is a manufacturing technique where products are created in batches instead of one product at a time. The manufacturing equipment/station can be reconfigured to produce a different product in the next batch. However, the drawback of such technique is the setup time (time lost between production runs) to changeover the station or equipment from a product type to the next. According to (Groover, 2015), cellular manufacturing is designed to produce a limited variety of products or a product family that has the same manufacturing processes. For this case study, the production was historically designed as a cell to produce a limited variety of products. However, the production frequency and style were in the form of batch production.

Value Stream Mapping (VSM) has been historically used in improving batch processing and particularly in bearing manufacturing to eliminate waste, reduce inventory and increase throughput. VSM as a tool helps with measuring the gap in performance through comparing the “current state” and the “future state” (Mayatra et al., 2016). In their study, they were able to improve lead time by 50%. Their ideas for improvement were in the following methodology 1) to suggested linking steps together so parts move immediately from one process to the next without sitting in a bin, 2) for areas where continuous flow wasn't possible, they implemented "supermarkets" (controlled inventory stores) and Kanban signals to ensure the upstream process only produced what the downstream process actually needed, 3) they redesigned the schedule to distribute work evenly, avoiding "spikes" in production that cause stress on the system.

Other applications of VSM has proven to be effective in imroving systems that use batch operations. In one study by Goriwondo et al. (2011) used VSM to for bread batch manufacturing identify and reduce defects by 20%, reduce unnecessary inventory by 18%, reduced workers’ motion by 37%, and most importantly, they increased throughput by 16%. In this study, the priority was to improve throughput while reducing waste and work-in-progress. Other researchers used VSM as their main tool for improving production and assembly processes of link and roller assembly (Manupati et al. 2019). In their study, they discussed the use of VSM to analyze the existing process and identify sources of waste and process imbalance. They concluded their research with estimation of improvements measured as 48% improvement in daily production activities of the link and roller assembly, and an average of 30% improvement in the utilization of available machines.

Barnes (1991) emphasizes that the primary objective of time study is not just to record times of production process and people’s motion. The objective of time study is to standardize methods to achieve the intended goals, and ensure consistancy and effeciency across all operations. Imblane in cycle times between stations can a bottleneck that cause a ripple effect that reduces the efficiency of the entire system. When one workstation’s cycle time is significantly higher than the other stations in the cell, it dictates the throughput of the entire cell, leading to several specific operational issues such as accumulation of work-in-process (WIP), reduction in throughput, reduction in resource effeciency, increased lead time, and quality risk. While Barens (1991) focuses on standardizing task times to eliminate "unproductive elements" that cause imbalances. Monden (2012) Discusses Heijunka (leveling) and how imbalances violate the "One-Piece Flow" principle. In our study, we focused on utlizing the leveling approach to reduce implance.

The idea of moving tasks from one process step to another was derived from the work of Shingo Shejo published in his book Revolution in Manufacturing: the SMID System (Shingo, 1985). In his book, the goal is to reduce cycle time by reidentifying some (internal) tasks as (external) and ressign them to be completed out of the process step cycle. Adaptation from his work has been utilized in our study to more some tasks from one workstation (process step) to another with the condition that the taskes are transferrable beterrn workstations and maintain the sequential order of the manufacturing/assembly process.

3. Methodology

Two methods were used: VSM and leveling the workload. VSM was mapped for the current and proposed future states. Data was collected from the company management system and direct observation of station cycle times confirmed against the company's internal assembly time records. The timestamp data contained production orders with operator-recorded elapsed times by phase, from which per-unit assembly times were derived by dividing elapsed assembly phase time by order quantity.

Current-state and future-state value stream maps were drawn to capture batch sizes, cycle times, WIP accumulation, lead time, and information flow across the line. The future-state map modeled one-piece flow with the proposed task redistribution (leveling the workload).

4. Data Collection

The company's internal assembly timetable was the primary data source for this study. The full dataset contained 554 production orders across multiple production dates within a span of three months. The data was cleaned from missing information and validated appropriately. After filtering records with missing timestamps, midnight crossings, and operator-flagged anomalies, approximately 291 orders were usable. The usable orders covered a wide range of housed bearing part types including pillow block bearings, flange units, take-up units, and ball bearing inserts. Order quantities ranged from 5 to 400 units per order.

The data was originally entered in an excel spreadsheet making statistical analysis possible using excel functions (STDEV and AVERAGE). The average per-unit Assembly phase time was 1.53 minutes per piece, which is approximately 91 seconds. The standard deviation was 0.83 minutes, reflecting the variety of part types and order sizes in the dataset. The 91-second average was used as the baseline cycle time for the batch processing model.

Figure 1 illustrates the cell design in a simple flow diagram. Station no. 1 (**Building**) covers primary bearing assembly and installation into the housing, including torque verification and grease fitting installation. Station no. 2 (**Inspecting**) covers housing label application with part number cross-reference, collar and wire tie installation, final inspection, cleaning, and bagging. Station no. 3 (**Packaging**) covers part box preparation and labeling, individual boxing of the bagged unit, and placement into the shipping container. Observed cycle times were 30 seconds at Station no. 1, 60 seconds at Station no. 2, and 30 seconds at Station no. 3.

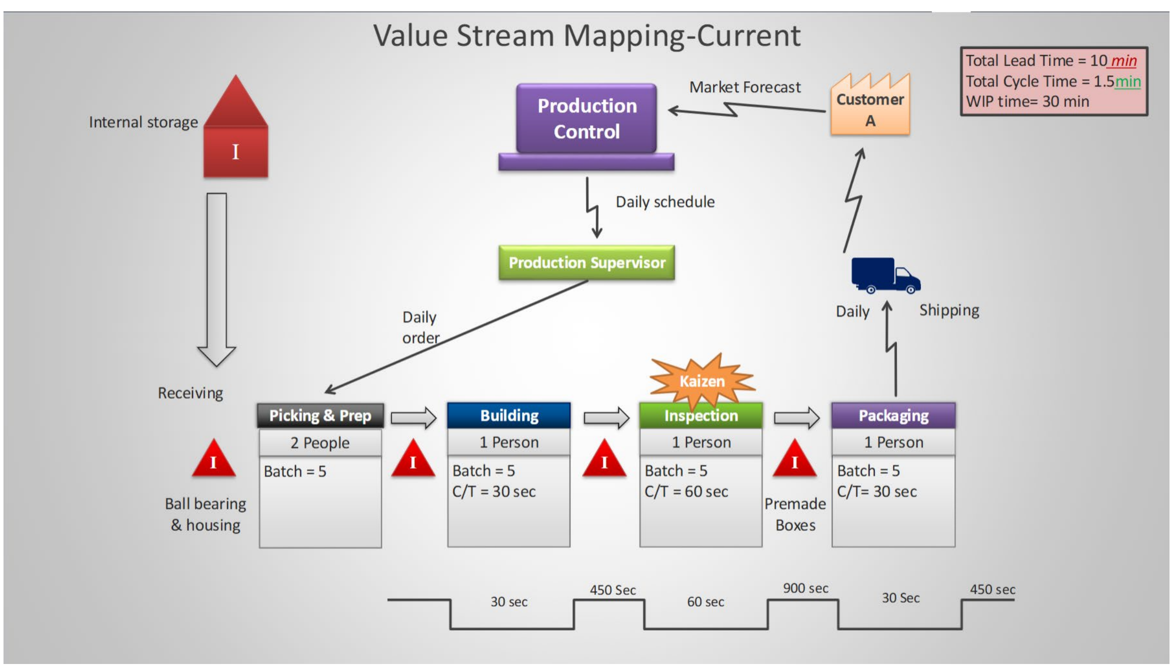
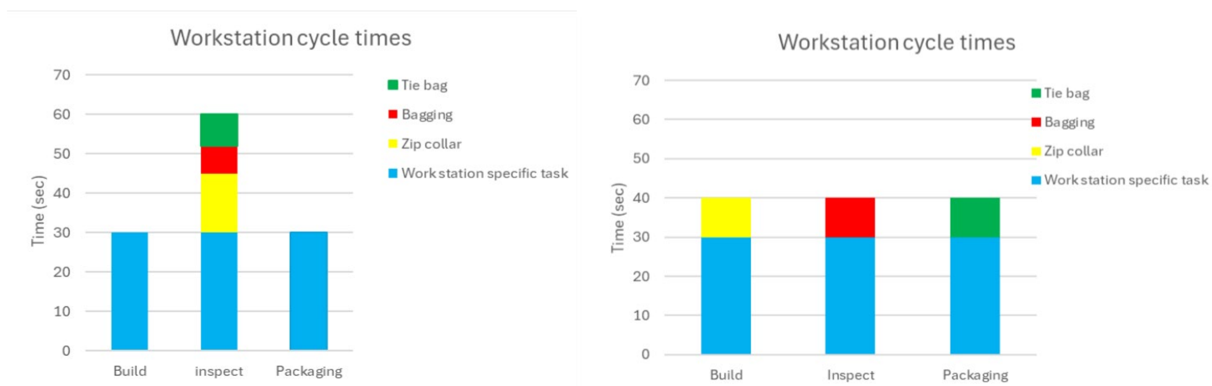


Figure 1. Current State VSM for the Manufacturing/Assembly Cell

Station no. 2 at 60 seconds is the bottleneck. Building and Packaging both run at 30 seconds, meaning both stations sit idle for 30 seconds after every unit while waiting for Inspection to clear. Current-state VSM parameters for the full line are a total lead time of 10 minutes, a total cycle time of 1.53 minutes, and a WIP time of 30 minutes. The Inspection and Packaging sub-process alone carries a total batch lead time of 5 minutes, a cycle time of 1 minute (60 seconds), and a WIP time of 15 minutes.

To balance the workload, focus was placed on the three mains process steps around the bottleneck, Building, Inspecting, and Packaging stations. The three stations' cycle times were broken by two categories: workstation specific tasks and non-workstation-specific tasks that were then illustrated in Figure 2 (a). The balanced workstation tasks were then reconstructed to balance the workload between stations based on total time and then these times were illustrated in Figure 2 (b).



(a) Before (b) After

Figure 2. stack-up Chart for Tasks in the Manufacturing/Assembly Cell

5. Results and Discussion

5.1 Proposed Improvements

Inspection station (Station no. 2) is the bottleneck which is caused by an uneven distribution of tasks across the three stations. The proposed improvement was to redistribute work of Station no. 2 by combining the collar and zip-tie task with the Building station (Station no. 1) and moving the bagging step to Packaging station (Station no. 3). This brings all three stations to an equal cycle time of 40 seconds per unit. The future-state VSM reflects a total lead time of 2 minutes, a total cycle time of 40 seconds, and a WIP time of 10 minutes under one-piece flow with this rebalancing.

By fully utilizing all three stations simultaneously under one-piece flow, station downtime is eliminated, and throughput increases. No additional staff are required. All existing process steps are preserved.

5.2 Numerical Results

Table 1 shows the performance comparison between batch processing and one-piece flow across the four measured metrics. All values are derived from the flow model built using the observed station cycle times.

Table 1. Performance Comparison: Batch Processing vs. One-piece flow

Metric	Batch Processing	One-Piece Flow	Improvement
Cycle time (subsequent unit)	91 sec/piece	56 sec/piece	38% faster
Lead time (5 units)	600 sec	280 sec	46% faster
WIP inventory wait (5 units)	1,350 sec	600 sec	56% less
Daily capacity (8 hr, 80% efficiency)	254 units	411 units	62% more

One-piece flow outperforms batch processing on every metric. Cycle time drops from 91 to 56 seconds per unit. Lead time for five units falls from 600 to 280 seconds. WIP inventory waiting across five units is cut from 1,350 to 600 seconds. Daily capacity at 80% efficiency over an 8-hour shift rises from 254 to 411 units, exceeding the 250-unit management threshold by 64%.

5.3 Future State VSM

The suggestions to improve the process were illustrated in the future state VSM shown in Figure 3. With the balance between workstation (cycle times), it was feasible to apply one-piece flow in the cell. The main noticeable time saving was the WIP time as illustrated in the future state VSM.

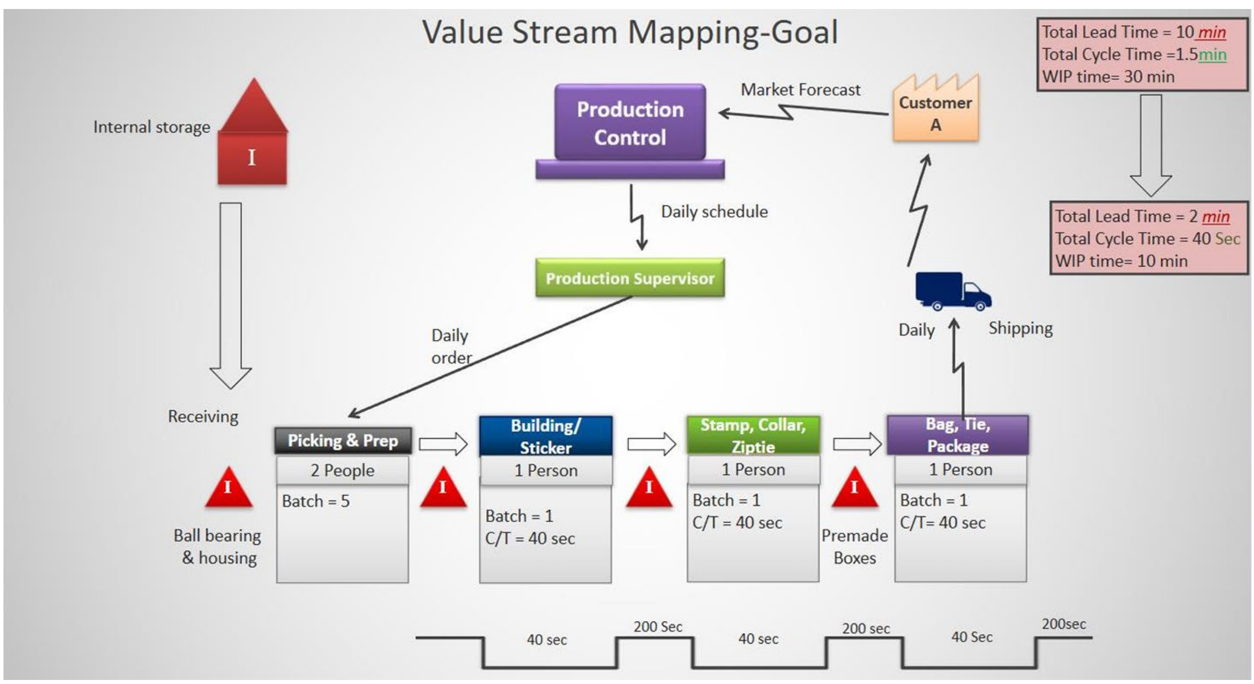


Figure 3. Future State VSM for the Manufacturing/Assembly Cell

5.4 Validation

The current state VSM parameters and observed cycle times are internally consistent. Building at 30 seconds and Packaging at 30 seconds against Inspection at 60 seconds produces the WIP accumulation and lead time captured in the current-state map. The 254-unit daily output at 80% efficiency over an 8-hour shift is consistent with the 91-second batch cycle time derived from the timestamp records.

The future state VSM parameters are simulated. A theoretical simulation comprised of 5 order batch quantities throughout an 8-hour shift at 80% capacity was used to quantify improvements in cycle time, waiting time, WIP time and other relevant measures. Furthermore, a pilot run of the one-piece flow configuration with the proposed task redistribution was recommended to validate the projected results against actual production output.

6. Conclusion

The findings of this study extend beyond housed bearing assembly. Any multi-station manufacturing/assembly cell with uneven task loading will exhibit the same bottleneck behavior, running at the pace of its slowest station regardless of how fast the others operate, which results in low resource utilization of the non-bottleneck process step(s). One-piece flow exposes that imbalance compared to batch processing. Batch processing, on the other hand, tends to conceal that imbalance. Our conclusion is that the prerequisite for the cell design is to have a balanced workload between all workstations to achieve a higher utilization with one-piece-flow.

VSM, Stack-up chart, and balancing the workload have proven to be very effective in breaking down the bigger problem into a more understandable and focused smaller problem. The tools helped us identify the system constraints, limitations, and bottleneck.

References

Barnes, R. M., *Motion and Time Study: Design and Measurement of Work*, 7th ed., Wiley, Hoboken, NJ, USA, 1991.

Goriwondo, M. W., "Use of the Value Stream Mapping Tool for Waste Reduction in Manufacturing: Case Study for Bread Manufacturing in Zimbabwe," *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management*, Kuala Lumpur, Malaysia, January 22–24, pp. 236-241, 2011.

Groover, M. P., *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*, 6th ed., Wiley, 2015.

Manupati, V. K., "Application of Value Stream Mapping for Cycle Time Reduction in Production of Link and Roller Assembly," *International Journal of Services and Operations Management*, pp. 135-158, 2019.

Mayatra, M. C., "Implementation of Value Stream Mapping Methodology in Bearing Industry," *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 2, no. 3, 2016.

Monden, Y., *Toyota Production System: An Integrated Approach to Just-In-Time*, 4th ed., CRC Press, 2012.

Shingo, S., *Revolution in Manufacturing: The SMED System*, CRC Press, Boca Raton, FL, 1985.

Biographies

Angel Rivera is a senior year undergraduate student in the Manufacturing Engineering Program at Western Washington University, Bellingham, WA.

Joel Romero is a senior year undergraduate student in the Manufacturing Engineering Program at Western Washington University, Bellingham, WA.

Max Gargano is a senior year undergraduate student in the Manufacturing Engineering Program at Western Washington University, Bellingham, WA.

Dr. Moh'd Ragheb El-Sharo is an associate professor in the Department of Engineering and Design at Western Washington University (WWU). He is the Faculty Lead for the Industrial and Engineering Program on the Peninsulas at WWU. Also, he is an Executive Consultant for Diamond Dental and Sapphire Clinics. He is an educator and a healthcare operations consultant and leader, a systems engineer, and a systems engineer with more than 15 years of experience improving performance, safety, and access across complex manufacturing and healthcare organizations. He currently serves as Director of Operations at Diamond Dental and Sapphire Clinics in Bellingham, WA, where he supports multi-site clinical operations, aligns operational strategy with organizational goals, and leads initiatives focused on growth, efficiency, and long-term sustainability. He holds an MS. and Ph.D. in Industrial and Systems Engineering and maintains a strong record of publications, conference presentations, and professional certifications in Lean and quality improvement.