ADAPTING LEAN AND ADVANCE MANUFACTURING TECHNOLOGY AT INERTIAL ASSEMBLY LINE

Margie S. Tolentino
Giovanni L. Arante

ACTIVE PASSIVE SAFETY ELECTRONIC OSS INS
Continental Electronic Technologies Phils. Inc., 16 Ring Road LISP 2-SEZ, Brgy. La Mesa, Calamba City, Laguna Philippines
margie.tolentino@continental-corporation.com & giovanni.arante.2@continental-corporation.com

ABSTRACT

Lean technology plays a vital role in meeting challenging customer demands in manufacturing industries. This project is drawn on a tactical business strategy to address the volume gap of Inertial products in the next 5 years. The creation of an effective and efficient backend assembly line is the goal of the project with the use of Lean Six Sigma techniques and integration of Lean Project Management tools.

Before the implementation of this project, the backend capacity of Inertial assembly line is not sufficient to meet existing and future customer demand for 2024 due to low cycle time of the old assembly line. With the introduction of a new backend assembly line using lean concept design and advance manufacturing technology, the capacity of the backend assembly significantly improved.

The project resulted not only in increased capacity but in the elimination of other process wastes such as excess motion, transportation, and long changeover.

1. 0 INTRODUCTION

1.1 Background

Based on the 5-year plan released in 2017, Inertial products were expected to end production by 2023 due to declining forecast volume of 60%. However, in 2020 5-year planning, product volume increased to 45% by 2023 and 101% by 2026. Demand for production will be met until 2031. Due to the aged assembly line, one of the business risks highlighted was the delivery of existing and future Inertial products.

Due to old technology, new product introduction takes too long or sometimes not feasible. The assembly line has been running for more than 18 years and most parts are obsolete. Because there are not enough replacement parts on the market, downtime is prolonged. Maintenance cost is high because parts are not available in the regular market and consequently these were bought at a high price from trading suppliers. Due to parts deterioration and old technology, Overall Equipment Effectiveness is low at an average of 67% against the current target of 75%.

2. 0 REVIEW OF RELATED WORK

This project is not related to previous Inertial initiatives having the same productivity issue. Review of related work is not applicable.

3.0 METHODOLOGY

To achieve the define goal of this project, the team used Lean Project Management tools and techniques from planning to closing phase. Lean Six Sigma tool such as Plan-Do-Check-Act cycle was applied to reach the desired solution and drive improvements.

3.1 Plan Phase

In this phase, the team explored all information gathered, performed brainstorming, selected potential solutions, and developed an action plan to implement the selected solutions.

3.1.1. Identification of the Opportunity

Inertial assembly line has been in operation for more than 18 years. Maintaining an efficient and profitable production is a challenge. With the decreasing volume forecast observed on current Inertial models from 2017 to 2021, production operation for Inertial products was expected to end by 2023.

However, during strategic planning last 2020, increased demand for new models was observed. Using line loading simulation, the current assembly line will have capacity issue by 2024 as shown in Figure 1. The old assembly line is planned to be dismantled by end of 2025 due to deterioration and inefficiency. This scenario poses a significant risk for the business to sustain current and potential customer demands as well as maintain its leading share in the market demand for sensor cluster products.

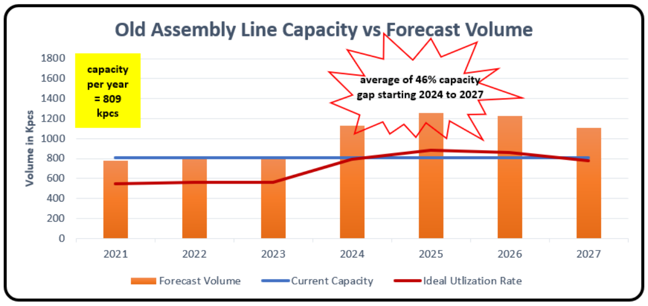

Figure 1. Line capacity simulation showed old assembly line had an average capacity gap of 46% starting 2024. Equipment Utilization already at peak starting 2021.

An opportunity to improve capacity by developing innovative and effective solution was developed. With Lean Six Sigma tools and techniques and Project Management Principles as the framework, this project was initiated to assure business continuity for Inertial until 2031.

The team identifies the problem using Value Stream Mapping. The assembly line was identified as the bottleneck in the current stream flow impacting line capacity as shown in Figure 2.

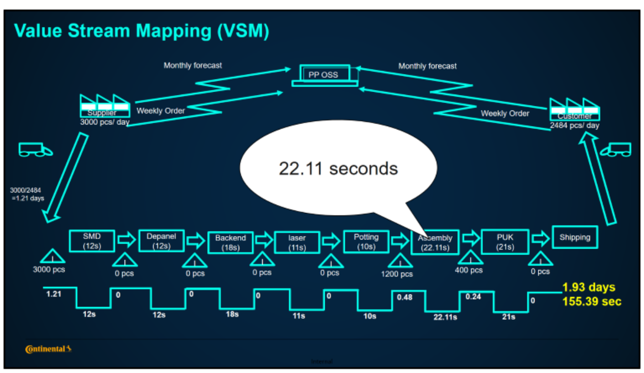

Figure 2. Value Stream Map of Inertial Products identifying bottlenecks.

To further identify opportunities for improvements at the assembly line, the team performed Gemba Walk and observed process wastes that can be eliminated such as unnecessary movements and transportation due to poor machine design, waiting time due to prolonged changeover and long walking time of operators from loading to unloading and vice versa.

Using Scaling technique as shown in Figure 3, shows that new products of Inertial are with enhanced software and hardware designs which are more adaptable to be produced in Industry 4.0 set up. The need to adapt to this changing industrial environment can provide the organization a competitive advantage. The old assembly line was assessed not adaptable to this modern technology.

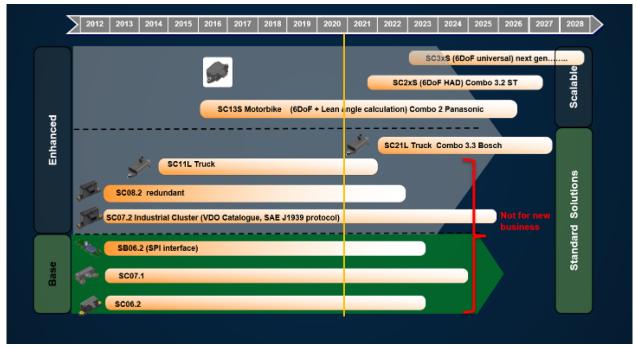

Figure 3. Horizontal scaling for new Inertial products SC1Xs, SC2XS, SC3XS models.

3.1.2. Opportunity Statement

During Value Stream Mapping, a customer demand of two thousand four hundred eighty-four pieces per day can be fulfilled within a lead time of 1.93 days and a value-added time of 155 seconds. Cycle time at assembly line was observed at 22.11 seconds. The assembly line stands out since it has the longest cycle time, making it the project's focus of improvement.

3.1.3. Initial Goal Statement

Increase capacity of Inertial assembly line by 45% through the reduction of machine cycle time from 22 seconds to 12 seconds by the start of 2023.

3.1.4. Alignment of Opportunity to Corporate Strategy

By utilizing lean design principles, process improvement tools and techniques, this project initiative is in line with Continental's manufacturing strategy which is, "Operational Excellence" as shown in Figure 4.

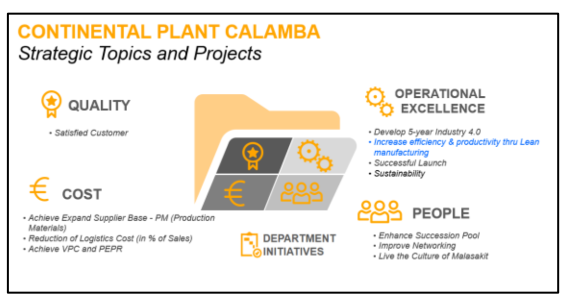

Figure 4. Continental Plant Calamba Strategic Topics and Projects

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3.2 Do Phase

3.2.1. Analysis of the Opportunity

The team performed Gemba walk to further investigate the underlying issue on low capacity at Inertial assembly line. Fishbone diagram was used to determine potential root cause with greater impact as shown in Figure 5.

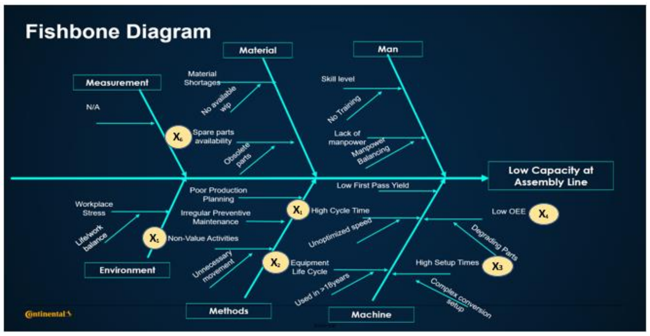


Figure 5. Fishbone Diagram was used to determine potential root causes of the Low Capacity at Inertial Assembly Line.

Table 1 to Table 6 are shown to illustrate the Potential Cause Validation Result.

Table 1. Potential Cause Validation Result for High Cycle Time

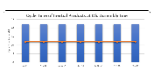
POTENTIAL CAUSE	VALIDATION METHOD	VALIDATION RESULT	ILLUSTRATION
HIGH CYCLE TIME	Time Study	Actual average Cycle Time was observed at 22 seconds at the current assembly line on all Inertial Products.	
SOURCE OF VARIATION: MACHINE			
In Charge: J. Pasion	Conclusion	**VALID**	Classification:
Date Performed: CW35 2021	Decision	**TRUE CAUSE**	**HIGH**

Table 2. Potential Validation Result for Equipment Life Cycle

POTENTIAL CAUSE	VALIDATION METHOD	VALIDATION RESULT	ILLUSTRATION
EQUIPMENT LIFE CYCLE	Verification of asset acquisition date and Gemba Walk	Current assembly line was in operation for more than 18 years. Most of the parts are obsolete. Equipment technology used is not adaptable to new product requirements.	
SOURCE OF VARIATION: MACHINE			
In Charge: M. Tolentino	Conclusion	**VALID**	Classification:
Date Performed: CW37 2021	Decision	**TRUE CAUSE**	**HIGH**

Table 3. Potential Validation Result for High Set Up Time

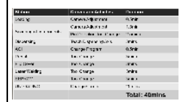
POTENTIAL CAUSE	VALIDATION METHOD	VALIDATION RESULT	ILLUSTRATION
HIGH SET UP TIME	Time Study	Conversion and machine set up activities from Loading to Unloading station took an average of 40 minutes.	
SOURCE OF VARIATION: MACHINE			
In Charge: G.Arante	Conclusion	**VALID**	Classification:
Date Performed: CW37 2021	Decision	**TRUE CAUSE**	**HIGH**

Table 4. Potential Validation Result for Low OEE

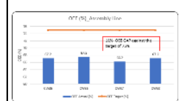
POTENTIAL CAUSE	VALIDATION METHOD	VALIDATION RESULT	ILLUSTRATION
LOW OEE	Gemba Walk	Average OEE was observed at 67% against the target of 75%. The team noted through production logs that machine maintenance was very long. Most sub assembly stations required frequent maintenance in a week. Obsolete parts took a long time to arrive extending machine downtime.	
SOURCE OF VARIATION: MACHINE			
In Charge: G.Arante	Conclusion	**VALID**	Classification:
Date Performed: CW35-CW38 2021	Decision	**TRUE CAUSE**	**HIGH**

Table 5. Potential Validation Result for Spare Parts Availability

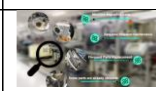
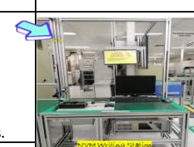
POTENTIAL CAUSE	VALIDATION METHOD	VALIDATION RESULT	ILLUSTRATION
Spare Parts Availability	Verification of machine spare parts master list. Verification of production downtime logs.	9% of frequently replaced parts are not readily available or with long lead time.	
SOURCE OF VARIATION: MATERIALS			
In Charge: G.Arante	Conclusion	**VALID**	Classification:
Date Performed: CW37 2021	Decision	**TRUE CAUSE**	**HIGH**

Table 6. Potential Validation Result for Non-Value Activities

POTENTIAL CAUSE	VALIDATION METHOD	VALIDATION RESULT	ILLUSTRATION
Non-Value Activities	Gemba Walk	Transportation from loading to unloading was 60 steps. Transportation from Unloading to NVM offline for SC1Xs product was 40 steps.	
SOURCE OF VARIATION: METHODS			
In Charge: G.Arante	Conclusion	**VALID**	Classification:
Date Performed: CW35 2021	Decision	**TRUE CAUSE**	**HIGH**

The team categorizes the Potential Root Causes. Six Potential Root Causes requires further validation to determine if these are valid factors. Table 7 detailed the result of the summary.

Table 7. Summary of Validated Potential Causes

Item No.	Category	Validated Potential Cause	Action Category	Decision
1	Machine	High Cycle Time	X-Item	True Cause
2	Machine	Equipment Life Cycle	X-Item	True Cause
3	Machine	High Set Up Time	X-Item	True Cause
4	Machine	Low OEE	X-Item	True Cause
5	Materials	Spare Parts Availability	X-Item	True Cause
6	Methods	Non-Value Activities	X-Item	True Cause

All the Validated Potential Causes are Within Team's Control. Upon consideration on the improvements to be implemented, the team can impact 46% improvement in the capacity (see Table 8).

Table 8. Team's Controllability

No	Category	Validated Potential Cause	Est. % Cont[a]	Controllability
1	Machine	High Cycle Time	20%	Within Team's Control
2	Machine	Equipment Life Cycle	10%	Beyond Team's Control
3	Machine	High Set Up Time	5%	Within Team's Control
4	Machine	Low OEE	5%	Within Team's Control
5	Materials	Spare Parts Availability	2%	Within Team's Control
6	Methods	Non-Value Activities	4%	Within Team's Control
			46%	

[a]Estimated Percentage Improvement Contribution of Validated KPIVs.

3.2.2. Final Goal Statement

Therefore, the Final Goal Statement of the project is, "to improve capacity at Inertial assembly line by 46% through reduction of machine cycle time by 32%, increase OEE by 9 % , reduce machine set up time to 50% and reduce non-value adding activities to 50% by end of 2022.

3.2.3. Solution Planning

The team performed brainstorming, together with Continental technical experts from Romania and Germany to generate ideas and concepts to meet the requirements of the identified solution. A mind map shown in Figure 6 resulted from the interdisciplinary inputs.

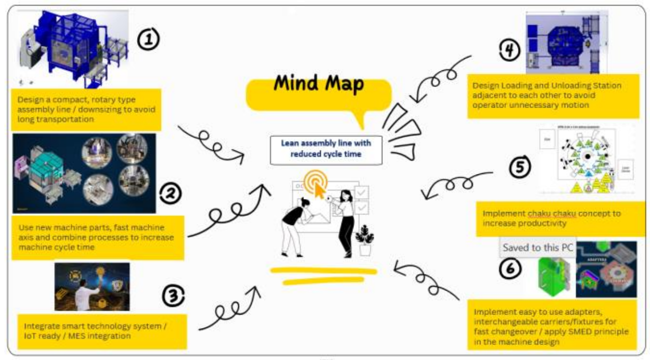


Figure 6. Mind Mapping. Summary of brainstorming ideas that forms the basis of the new assembly line specifications.

From this brainstorming, the team was able to define the alternative solutions to be adapted as part of the solution of increasing assembly line capacity.

3.2.4. Selection of Best Solution

To help the team identify the best solution, an alternative solution matrix was defined based on the allocated weight of each Validated Potential Causes as shown on Table 9.

Table 9. Alternative Solution Matrix

No	Validated Potential Causes	Alternative Solutions
1	High Cycle Time	Use new machine parts, fast machine axis and combine processes to increase machine cycle time.
2	Equipment Life Cycle	Upgrade some modules of the old assembly line to ensure production of Inertial products.
		Implement hardware / software modification of the old assembly line.
		Acquire new machine with latest manufacturing systems.
3	High Set Up Time	Implement multi product concept with easy-to-use adaptors and carriers.

4	Low OEE	Implement chaku chaku concept to increase productivity.
		Integrate smart technology system / IoT ready / MES integration.
5	Spare Parts Availability	Use of latest machine parts available in the market.
6	Non-Value Activities	Design a compact, rotary type assembly line / downsizing of machine to avoid long transportation
		Place Loading and Unloading Station adjacent to each other to avoid operator unnecessary motion.

The team was guided by the Pay-Off Matrix in Table 10 to determine the prioritization of each Alternative Solutions.

Table 10. Pay-Off Matrix

Validated Potential Causese	Alternative Solution	Safety	Quality	Cycle Time	Cost	Effort	Total Score	Team's Decision
High Cycle Time	Use new machine parts, fast machine axis and combine processes to increase machine cycle time.	5	5	5	3	5	23	GO
Equipment Life Cycle	Upgrade some modules of the old assembly line to ensure production of Inertial products.	5	5	2	1	1	14	NO GO
	Implement hardware / software modification of the old assembly line.	5	5	2	1	1	14	NO GO
	Acquire new machine with latest manufacturing systems.	5	5	5	1	4	20	GO
High Set Up Time	Implement multi product concept with easy to use adaptors and carriers.	5	5	5	2	4	21	GO
Low OEE	Implement chaku chaku concept to increase productivity.	5	3	5	2	4	19	GO
	Integrate smart technology system / IoT ready / MES integration.	5	5	3	3	5	21	GO
Spare Parts Availability	Use of latest machine parts available in the market.	5	5	5	3	5	23	GO
Non-Value Activities	Design a compact, rotary type assembly line / downsizing to avoid long transportation	5	5	5	5	5	25	GO
	Place Loading and Unloading Station adjacent to each other to avoid operator unnecessary motion.	5	5	5	5	3	23	GO

The team defined a decision matrix base on scoring against Safety (S), Quality (Q), Cycle Time (CT), Cost (C), and Effort (E). The total score is the cumulative scoring of each Pay-Off components. The team's decision shall be based on the Total Score; see Table 11.

Table 11. Pay-Off Matrix Scoring

Criteria	Score		
	5	3	1
Safety (S)	No impact on Safety	Minor impact on safety	Major impact on Safety
Quality (Q)	No impact on Quality	Minor impact on Quality	Major impact on Quality
Cycle Time (CT)	High impact on Cycle Time reduction	Low impact on Cycle Time reduction	No impact on Cycle Time reduction
Cost (C)	Zero investment	Low investment	High investment
Effort (E)	Easy to implement	Medium effort	High effort

Decision based on total score: 18-25 is **GO** , 17`0 is a **NO GO**.
Formula: Total Score = S+Q+CT+C+E

3.2.5. Designing of the Solution

With the support of the Continental Manufacturing Technology experts from Continental Romania and Frankfurt, the team drafted the equipment specifications which will guide contracted equipment integrators to fulfill identified solutions.

Equipment design using lean principles was developed thru Lean Check activity. In this activity, a series of workshops were performed in a cross functional team by simulating production environment of the new line including the new or integrated processes, workplaces and materials needed to build the finished product. This activity is scheduled to develop the Lean Design thinking of the cross functional team.

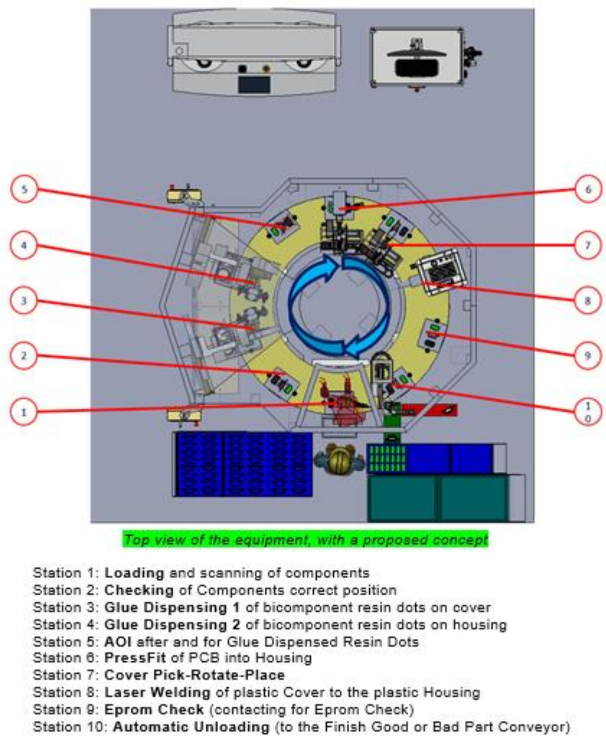


Figure 7. The top view shows the new assembly line have a compact feature design to assemble a product in 10 steps. Transport of the product between stations will be done by a rotary table.

The new assembly line was downsized to a compact size of 8 square meter from old assembly line area of 180 square meter. Chaku-Chaku concept was utilized making a smooth material flow from loading to unloading as shown in Figure 8.

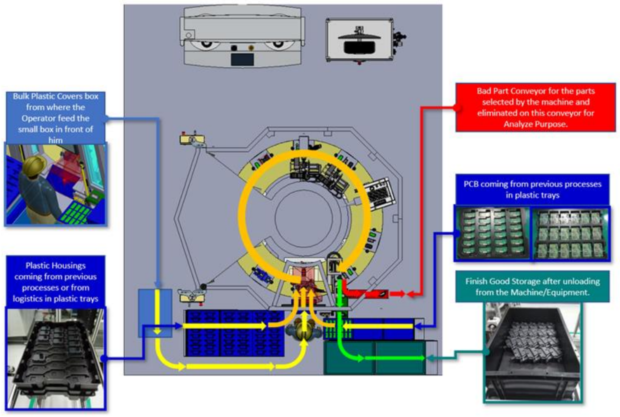


Figure 8. Raw materials, Finished Goods, Bad Parts flow in and out of the equipment smoothly.

Fixtures are designed to adapt to all Inertial products thereby allowing full flexibility of the line to operate in a multi-product concept. The design of machine fixtures, adaptors are all easy to use and with quick interchangeable features for fast maintenance and changeover as shown in Figure 9.

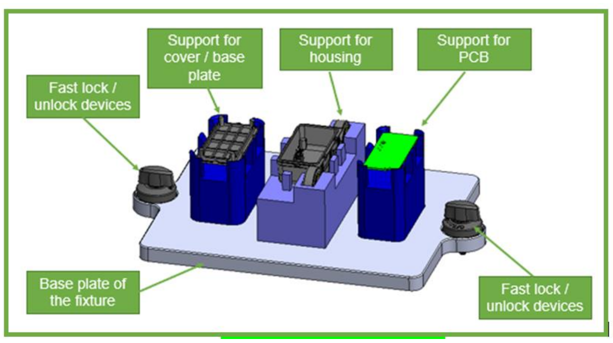


Figure 9. Isometric view of new assembly line fixture with adaptable and easy to use interchangeable mechanism.

Processes were optimized by integrating advanced manufacturing technology from Loading to Unloading

Table 12 shown below is the summary of Solution Implemented in the new assembly line.

Table 12. Summary of Solution Implementation

Validated Potential Cause	Alternative Solution	Date Completed	In Charge
High Cycle Time	Use new machine parts, fast machine axis and combine processes to increase machine cycle time.	CW45 2022	G. Arante / C. Tanasoiu / M. Tolentino / P. Wacker
Equipment Life Cycle	Acquire new machine with latest manufacturing systems.	CW43 2021	M. Tolentino
High Set Up Time	Implement multi product concept with easy-to-use adaptors and carriers.	CW45 2022	G. Arante / C. Tanasiou
Low OEE	Implement Chaku-Chaku concept to increase productivity.	CW46 2021	C. Tanasiou / G. Arante
	Integrate smart technology system / IoT ready / MES integration.	CW45 2022	G. Arante / B. Curatchia / M. Tolentino
Spare Parts Availability	Use of latest machine parts available in the market.	CW23 2022	C. Tanasiou / G. Arante / P. Wacker
Non-Value Activities	Place Loading and Unloading Station adjacent to each other to avoid operator unnecessary motion.	CW33 2022	C. Tanasiou / G. Arante / M. Tolentino

3.2.6. Potential Problem Analysis

The team performed potential problem analysis to ensure effective implementation of the defined solutions. Preventive

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measures were implemented for each of the identified possible issues and tabulated in Table 13.

Table 13. Potential Problem Analysis in Implementing a Lean Assembly Line

Potential Issues in Implementing the Defined Solutions	Preventive Action	Responsible	Due Date
Defined equipment parts are not available.	Provide approve alternative machine parts that can meet the technical specifications.	Catalin Tanasiou / Yann Dinard / Giovanni Arante	CW46 2021
Delayed equipment parts coming from Europe due to Covid 19 impact.	Pull in parts available locally within the region.	Margie Tolentino	CW49 2021-CW16 2022
Incorrect integration on Lean Design by the equipment integrator.	Hold regular desing review meeting with supplier to monitor accuracy of project accordig to design specifications.	Margie Tolentino	CW45 2021-CW24 2022
Pre acceptance of equipment was not possible to be done at the actual supplier site due to travel restrictions.	Conduct virtual inspection.	Margie Tolentno / Giovanni Arante	CW45 2021-CW24 2022
	Get support from other Continental Central IE within the region.	Shenglin Han	CW30-CW31 2022
Delay in the production release of equipment against project base timeline.	Prepare high risk spare parts planning for the old assembly line to extend equipment operation.	Giovanni Arante	CW50 2021

3.3 Check Phase

In this phase, the team validated the effectiveness of the proposed solutions using the defined validation plan and equipment specifications.

The released design from the equipment integrator was reviewed against the specifications. Cycle time was validated even at supplier side. Prior machine release from the supplier, the team performed process capability analysis on the new assembly to ensure that the equipment meets the lean objective of the project. Before equipment release, machine capability and process capability analysis were validated together with the verification of the defined machine cycle time.

3.4 Act Phase

After the design validation was approved and released, procurement planning was initiated. During this stage, close monitoring of equipment construction was observed by conducting regular project status meeting with technical experts, supplier, and process engineering team to ensure that equipment specifications and commercial aspects were considered prior and during the build.

Figure 10 below depicted the project timing for the new Assembly Line Industrialization.

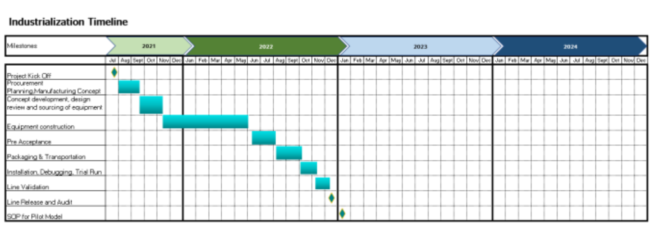

Figure 10. Industrialization Timeline for the New Inertial Assembly Line.

The team ensured that project scope, budget and timeline were within the target to ensure project success. The new assembly line was released last November 2, 2022, following VDA 6.3 Line Release Guidelines.

3.4.1. Standardization

The new assembly line was released through compliance and check framework of Continental Automotive standard on Development and Launching of Manufacturing Technologies and Equipment. Release of Equipment for pilot model SC21L was updated, reviewed, and approved last November 24, 2022.

4.0 RESULTS AND DISCUSSION

The innovative solution to improve the capacity of Inertial assembly line was piloted on one of the high-volume runners of Inertial (SC21L).

With low cycle time of the new assembly line, the capacity of the current assembly line increased from eight hundred nine thousand per year to one million six hundred nine thousand per year as shown in Figure 11.

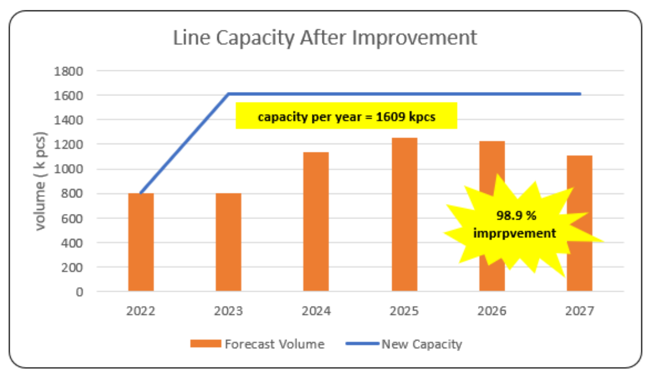

Figure 11. Graphical Capacity after improvement shows 98.9% improvement in assembly line capacity.

Industrialization data showed reduction of cycle time from 22 seconds to 12 seconds was achieved with the adoption of lean and advanced manufacturing technologies in the new assembly line. See Figure 12.

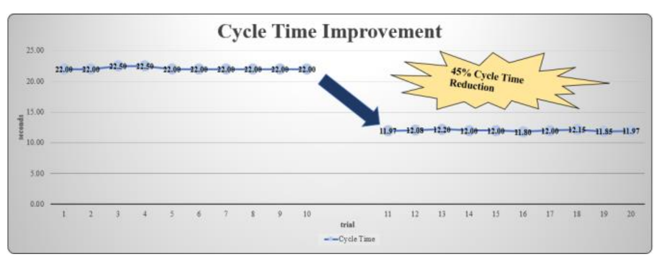

Figure 12. Cycle Time of the new assembly line for pilot model SC21L Wabco shows Trial 1-10 are cycle time data from USK line (old assembly

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line) while trial 11-20 are cycle time data from Xenon line (new assembly line). Cycle time improvement is 45%.

Changeover time significantly improved from an average of 20 minutes per conversion to an average of 10 minutes per conversion. This was possible due to the improved design of the machine using SMED principle allowing easy interchangeability and ease of use of each fixture and adaptors. Set Up Time improvement is depicted on Figure 13.

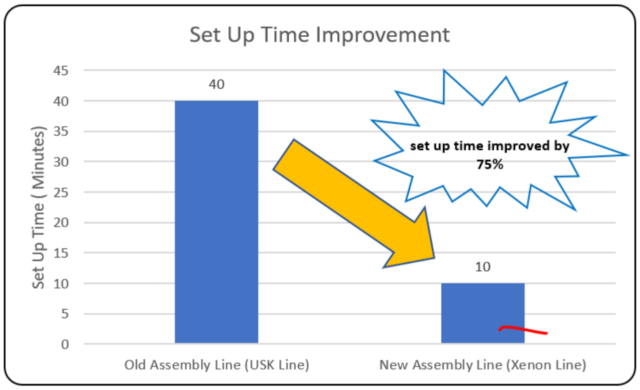

Figure 13. Set Up Time improvement from 40 minutes to 10 minutes.

Machine OEE during the trial phase significantly improved from an average of 75% to 82% (Figure 14).

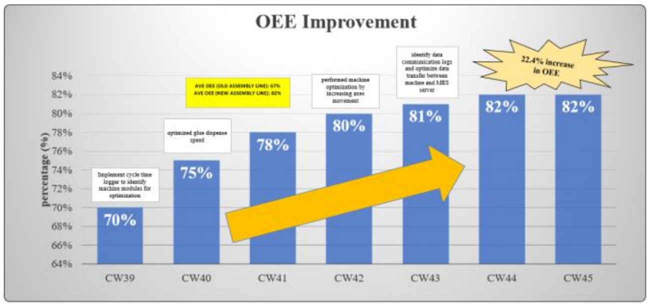

Figure 14. OEE Improvement trend done during equipment industrialization from CW39 to CW41.

During initial production for pilot model SC21L, OEE improved by 22.4% as of Q1 2023.

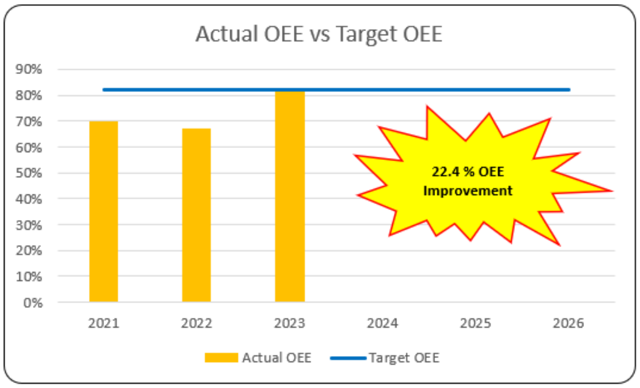

Figure 15. OEE improvement as of Q1 2023.

This project also reduced one headcount through the integration of NVM process into the new assembly line EEPROM station. Before, processing of SC1Xs and SC2Xs models required one additional operator to perform NVM process. With the inclusion of EEPROM Write function, offline process was eliminated. Figure 16 significantly shows the improvement in Non-Value Activities.

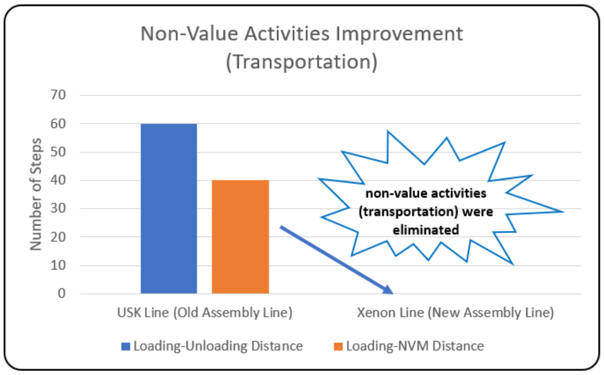

Figure 16. Elimination of Non-Value Activities on the new Assembly Line.

Considering all defined alternative solutions impacted the improvement in assembly capacity, Figure 17 shows in percentage the detailed improvement of each action taken by the team.

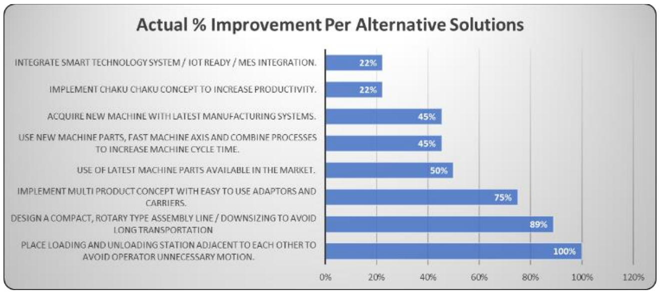

Figure 17. Summary of Actual % Improvement per Alternative Solution

The profitability of Inertial increased through the favorable Return of Sales (ROS) ratio provided by Plant Controlling. Figure 18 shows the trend of ROS until 2028.

	2023	2024	2025	2026	2027	2028	YTD
EBIT	486	4,344	4,867	5,951	6,016	6,053	27,717
Net Sales **	1,705	16,420	16,999	23,669	24,166	23,666	106,626
RoS (in % of Net Sales)	*28.5%*	*26.5%*	*28.6%*	*25.1%*	*24.9%*	*25.6%*	*26.0%*

*** sales price is based on external prices*

Figure 18. ROS rate for Inertial YTD is at 26%.

The stable ROS ratio shows how efficient the business production has become after the implementation of the solutions.

5.0 CONCLUSION

The current capacity of the Inertial assembly line is now at one million six hundred nine thousand per year which provides business security and continuity not only for the current Inertial products but also for upcoming products. Through effective Lean Project Management and adaption of Lean Six Sigma approach in resolving productivity challenges, market share is increased while customer demand can be manage effectively thus increasing business profits.

6.0 RECOMMENDATIONS

With the successful implementation of capacity improvement in Inertial assembly line, releases for all models are planned until Q1 2024.

To further improve line balance for backend processes, the team will focus on integration of leak test and upgrade of OP40 in 2024.

7.0 ACKNOWLEDGMENT

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9.0 ABOUT THE AUTHORS

Margie Tolentino is currently the Series Life Management of A PSE. She is responsible for project management of series products including change management, new process, new line introduction and product change introduction.

Giovanni Arante is the process and maintenance engineer for A PSE OSS Inertial responsible for process improvements and control as well as the functional engineer in charge for backend processes.

Internal