ISEN 645 LEAN ENGINEERING

ROCHESTER SENSORS

FINAL REPORT

Team #25

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06th May 2023

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EXECUTIVE SUMMARY

Rochester Gauges is one of the leading manufacturers of level gauges, started in 1913 and grew to various product lines across the globe. In the later part of the 19's they acquired Rochester Manufacturing too. Currently, Rochester Sensors is located across the globe with its headquarters in Dallas, Texas, USA. Here in this ISEN-645 project, we are working mainly on their warehouse to transform it into a much-optimized Lean warehouse using Lean warehouse management system engineering. For implementing this we have received the past three years' outgoing Kanban-ID's and in-depth details regarding the dates, deadlines, quantity, BOMs, Product families, etc.,

Using the data and spreadsheet provided we have pulled a lot of sub-data and visualized them and found some amazing correlations in the graphs based on which we have made lots of findings and hypotheses. We have consolidated all the data into a single report. We have analyzed the AS-IS condition of the warehouse and suggest a series of successive corrective improvement measures in the TO-BE condition. For the brief explanation of the TO-BE, we have made 8 design steps for the Lean warehouse System and identified seven forms of waste that exist in the system, which is explained as Needs Analysis and Requirements Definition (NARD).

Based on the above-said analysis of the AS-IS, we have suggested necessary Engineering actions in the TOBE condition, for this engineering action we have prepared a detailed Implementation plan by use of a living document, a GANTT chart. In the Gantt chart, we have given a proper timeline of the steps involved including who is responsible for each task and the respective state in which they are in. Micro-Level design is developed and considerable suggestions for Task engineering are made to level the demand for kanban in the warehouse picking process, Approaches for micro-level design are discussed. For the suggested micro-level design, we have created a detailed Analysis of the Alternative (AOA) plan and chosen to proceed with the most optimal one with our current availability of cost and resources. For that selected alternate rationales are listed and explained in detail for every condition and design concepts are explained.

In the TO-BE condition of Lean warehouse management system engineering, we have considered certain conditions and constraints with which the day-to-day process and procedures must be done. A redesigned warehouse management system and the Standard work chart are also made. With all the above-mentioned points, we can achieve a Lean Warehouse Management System Engineering.

INTRODUCTION

Rochester Sensors was one of the leading manufacturers of Sensors and Gauges which is used for various indicators functions in the industrial solutions domain. Rochester Gauge was initially started as Rochester Manufacturing in 1913. It's the first company to develop and manufacture a liquid-level gauge for propane industries.

They became a foremost innovator in agricultural and processing equipment across the world. Rochester gauge is the type of device used in vehicles to measure the fuel in the gas tank of various earth movers and off-road vehicles. Rochester Sensors currently produces products that include liquid level gauges, liquid level sensors, liquid level senders, liquid level switches, aircraft fuel, engine instrumentation, diaphragm temperature sensors, pressure sensors, bimetal thermometers-electrical system safety disconnect switches, and flow sensors which are designed with greater reliability & accuracy which enables the original equipment manufacturers (OEM) to get the required components at an effective cost. Rochester Gauges totally has 200 employees, and the revenue generated per employee is in the ratio of 1:375000 (USD). Rochester Gauges' peak revenue was achieved in 2022 totaling up to $75 million US dollars.

The objective of this project is to implement LEAN WAREHOUSE MANAGEMENT ENGINEERING in Rochester Sensors and enhance it to utilize lean tools and principles. As per the data provided the warehouses in Rochester Sensors have a lot of waste involved in them and it is highly unorganized and needs Warehouse Management Engineering. So, for this, we have developed a Need Analysis and Requirements Definition (NARD) and Engineering action plans. With the action plans, we have suggested six lean optimization techniques that can be implemented in Rochester's warehouse to attain Lean in the system. Based on that, we have taken one of the Engineering actions and developed and iterated it into a Micro-Level design.

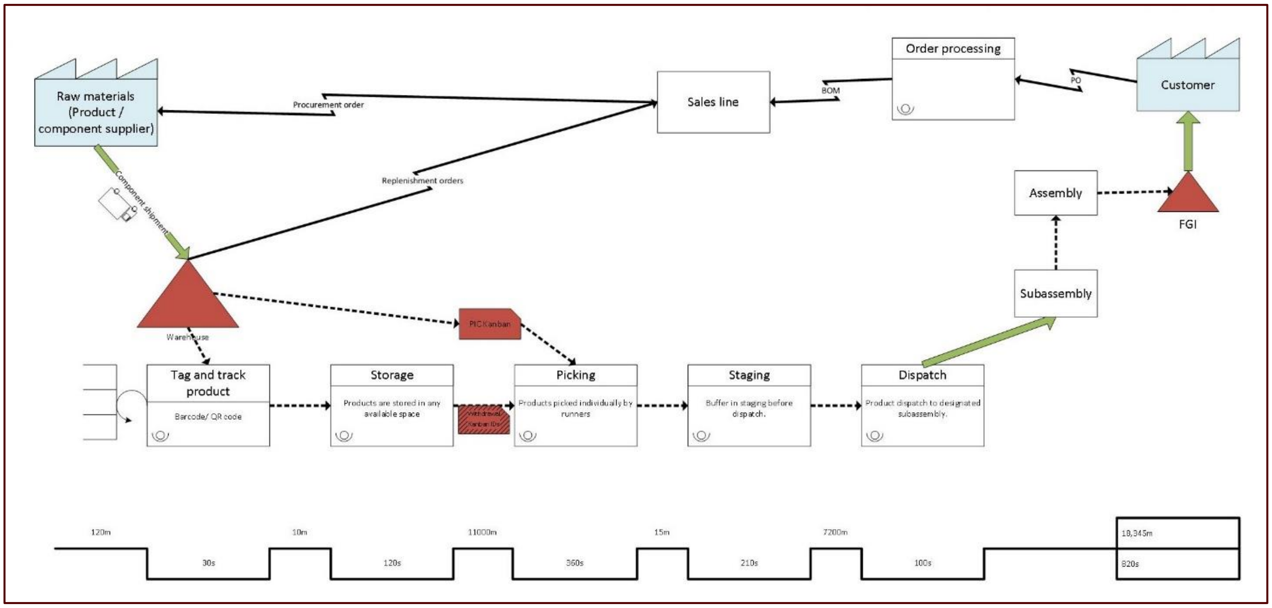
For the developed micro-level design, we then develop various alternatives with various levels of satisfaction and cost occurred. From this, we have selected the most optimal for this scenario and discussed the Analysis of Alternatives (AOA) with the required information. And a detailed Business case report is also generated.

With this, we can attain a Lean warehouse management system engineering for the Rochester Sensor and convert the current AS-IS to the TO-BE model.

ASIS OVERVIEW

IDEF0: A well-represented AS-IS IDEF0 model for Rochester warehouse operations is attached along with this report. In this ASIS model, the products are received and sent to be stored adhering to the standardized SOPs and safety measures taken into consideration, and detailed control and inventory records of the products as the output of receiving the products is being noted. After storing the products, the products are transferred to pick the orders by getting input as updated inventory record details. The warehouse uses a system for inventory management. Warehouse personnel are responsible for processing orders, tracking inventory levels, and managing shipments. The current system is time-consuming, which results in lower production and higher costs.

VSM: A well-represented AS-IS VSM model for Rochester warehouse operations is attached along with this report.



The current warehouse system has low efficiency, bottlenecks, and waste, which affect the value stream of the warehouse. The value stream is not optimized properly, which results in a longer lead time and less throughput. The current warehouse does not have a proper functional inventory management system that regularly updates the product tracking information throughout all the processes included in the ASIS value stream map. The information from the sales line is electronically transmitted to the component supplier, and reorder or replenishment orders are transmitted directly to the sales line. The components are tracked from the moment they enter the warehouse and are stored only in the available places of their product family. The picking process is done only for individual components, as visualized in the ASIS value stream map.

WASTE TYPE	NEEDS FROM THE ASIS	WAYS TO MITIGATE/ELIMINATE IN TO-BE (COUNTERMEASURES)
OVERPRODUCTION	• Unsatisfied customer demands, in the event of items not being supplied as per the due date, lead to a loss in business. The inventory stays in the warehouse for a prolonged period, reducing the cash flow and sometimes becoming dead. • Allocating excessive operators for the demand. This essentially means not leveling the load among the operators, where some operators are always working with an increased load than others. • Incorrect tracing of parts and packing into the final shipment area, which needs to be retraced and kept in the earlier position. This unwanted iteration due to incorrect tracking is a waste.	• Ensuring the on-time delivery of the components • Leveling the load throughout the day and among the operators • Implementing a state-of-the-art Visual control system that tracks real-time progress with key indices defined
INVENTORY	• Incorrect purchase and storage that do not correlate with the actual demands lead to an inventory build-up. • Unused consumables like polythene covers, pallets, carton boxes, straps, unusable forklifts, and other pieces of machinery. • Poor performance leads to the loss of customer orders and associated inventory storage in the warehouse. Poor information sharing system, unattended orders staying at the order desk due to lack of better tracking.	• Correctness of procurement Vs the actual demand patterns • Defining the inventory and re-order points for the consumables that account for 2% of the overall cost of running the warehouse. • Defining the performance-related metrics and tracking for continuous Improvements
MOTION	• Excessive movement of operators to pick up the tools/equipment/ fork lifters. • Excessive movement of incoming components from suppliers, staying at various locations before getting placed in pallets. • No defined movement of components toward the shipping area after being retrieved from the storage location.	• Define the layout of the warehouse with a dedicated location for each entity like machinery, Items, packaging area, visual controls, and discussion rooms. • Defining standard workflow for operators syncing with the overall warehouse management system.
WAITING	• Waiting for incoming components to be allocated for a storage location. • Waiting for Kanban's orders for a prolonged time against the due date. • Unattended orders waiting at the order desk.	• Implementing a warehouse management system for real-time tracking of empty bins, suggesting locations based on key attributes like consumption patterns, and optimized travel distance.

	• Hold at all stages including unloading, packing, shipping center documentation, inventory log, and non-value-added component retrieval activities.	• A visual control system that displays the number of orders logged and attended and the current progress across all areas in the warehouse. • Defining the no. of operators, shipping lines, and documentation systems to ensure continuous flow at all stages and to reduce the wait time.
OVER-PROCESSING	• Double handling of goods, retrieving the same item number by two different operators • Retracing the goods from the shipping location back to the original storage points due to the wrong item number pick up, the same item number picked by multiple operators, item number whose work order has already been completed.	• A visual Control system that will display information, so that no two operators do the same work at the same time. • Implementing Poke-yokes that will ensure the correct pick-up based on logically derived from the information system.
TRANSPORTATION	• Inefficient movement of operators on tracing an item ID. • Unwanted movements in transporting material from the pickup location to the shipping area. • Inefficient methods were followed in transporting the Item ID from the storage location to the shipment and in the pulling process. Operator movements in handling the packaging materials. • Manual checking of Item ID by the quality team in the shipping area before dispatch and non-standard work methods in documentation leads to movements in receiving approvals by various authorities leading to unwanted transportation	• Re-defining the complete warehouse layout and optimizing the travel distance can also optimize the overall operating cost of the warehouse. • Standard work procedures to transport the materials, including loading and unloading processes. • Self-certification of quality systems through barcoding & poke-yokes ensures no quality defects in the retrieval process.
DEFECTS	• Defects in wrong picking of an Item ID. • Defects in terms of wrong picking of material ID reaching the manufacturing location • Mislabeling the boxes and re-working the packed shipments. • Loading the components into the wrong truck damaged the packing.	• Automated verification checks, in terms of the demands Vs the actual shipment while creating shipping documents. • 5S, categorization, and quality checks in the labeling areas to ensure the correctness of packing systems. • Proper workflow and defining the packing/ freight standards from the supplier end for the ease of unloading and subsequent packing from the warehouse end

8-DESIGN STEPS FOR THE TOBE LEAN PRODUCTION SYSTEM

1) Define the TAKT: The kanban pull system in the warehouse has been pulled by the kanban orders and the takt time for the kanban pull system is determined. Based on the given date, the number of Kanban IDs released per day for the worst-case scenario is at the UCL limit.

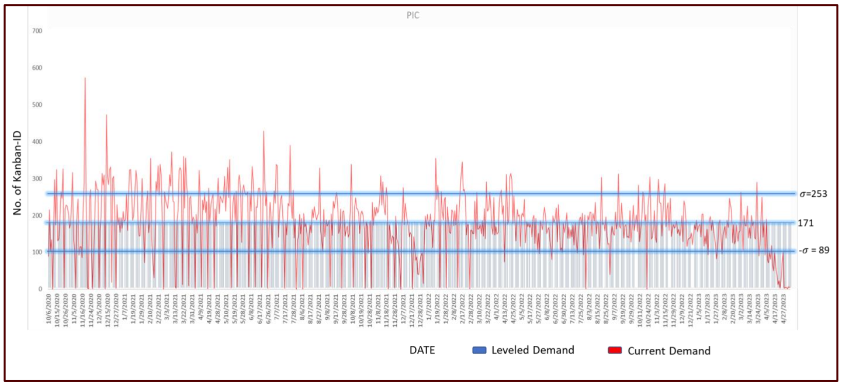
   Kanban ID's released = μ + σ = 171 + 82 = 253

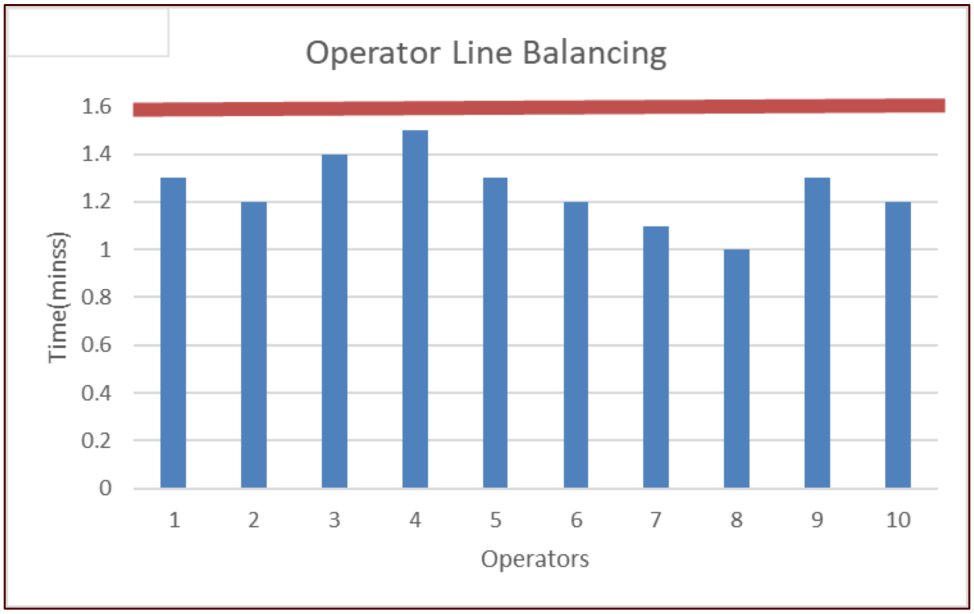
   Available production time = 450 minutes

   Takt time = Available production time / No of Kanban IDs to be closed

   Takt time = 450/ 253 = 1.77 minutes / Kanban ID

2) MTO or MTS: Product Variability
   125720 kanbans* 3028 parts = 380680160 variations
   The product variability is too high and takes huge space to stock the products. The warehouse system is triggered by Kanban orders and the system gets rid of variabilities. The buffer size is controlled by using the MTO approach. Hence the system is designed for the MTO approach.
3) Continuous flow processing: The continuous flow is introduced to the operator order processing which is the bottleneck process in the warehouse management system. The single-piece flow is introduced in the order processing by developing an algorithm with the part and operator availability this controls the operator motion and the to-flow motion of the operator from receiving to the pic station is restricted.
4) Single point in the production process (***PACEMAKER***): The pacemaker acts as a single point farthest upstream from the customer, that pulls the entire warehouse system. The sales line acts as the pacemaker that pulls the entire production system through the Kanban system, right from the warehouse supplier components to the assembly area and testing.
5) Leveling demand & workload: The pacemaker is controlled by leveling the Kanban orders from the production and leveling the operator workload. This is achieved by performing load leveling in the number of kanbans received per day. This unevenness in the demand will eventually result in uneven workflow and load distribution among the operators and resources in the warehouse. At times, operating at a maximum utilization in case of satisfying 573 kanban IDs per day, combined with the variability that is created from the resources, results in the WIP levels increasing in a non-linear fashion. To create an even workflow and load distribution among the operators and machinery it is important to level the demand over the day. This requires to be well synchronization between the production demands and supplier schedule, by creating necessary buffers in the production area to hold inventories to protect against uncontrolled demand fluctuations.





OPERATOR BALANCE CHART (OBC)

The operator's line balancing is performed to get complete utilization of the operators and to reduce the idle time in the system. This is achieved by leveling the operator task times to 90% of takt time and splitting the work evenly during the demand fluctuations.

6) Pacemaker Warehouse Mix:

Currently, once the Kanban IDs are released for a particular day of production, the tasks are assigned randomly to the operators without considering these factors and end up with uneven load distribution.

As demonstrated regarding the current system procedure, Kanban IDs are released for the D+2nd day's production. Once the IDs are released, the jobs are allocated in a random manner to the operators. Here, we need to understand that the operator's load can vary according to the type of component ID, its placement in the warehouse, level of placement, walk distance, the travel distance between the various component ID's tasked as a batch, type of retrieval equipment to be used for unloading etc.

7) Work Increment to be released consistently:

- Use of barcode scanners in the receiving station to process the kanban, reducing the cycle time and eliminating the WIP.
- The staging kanban can be reduced by developing algorithms with the operator's headcount and the kanban orders.

8) LPS realization plan:

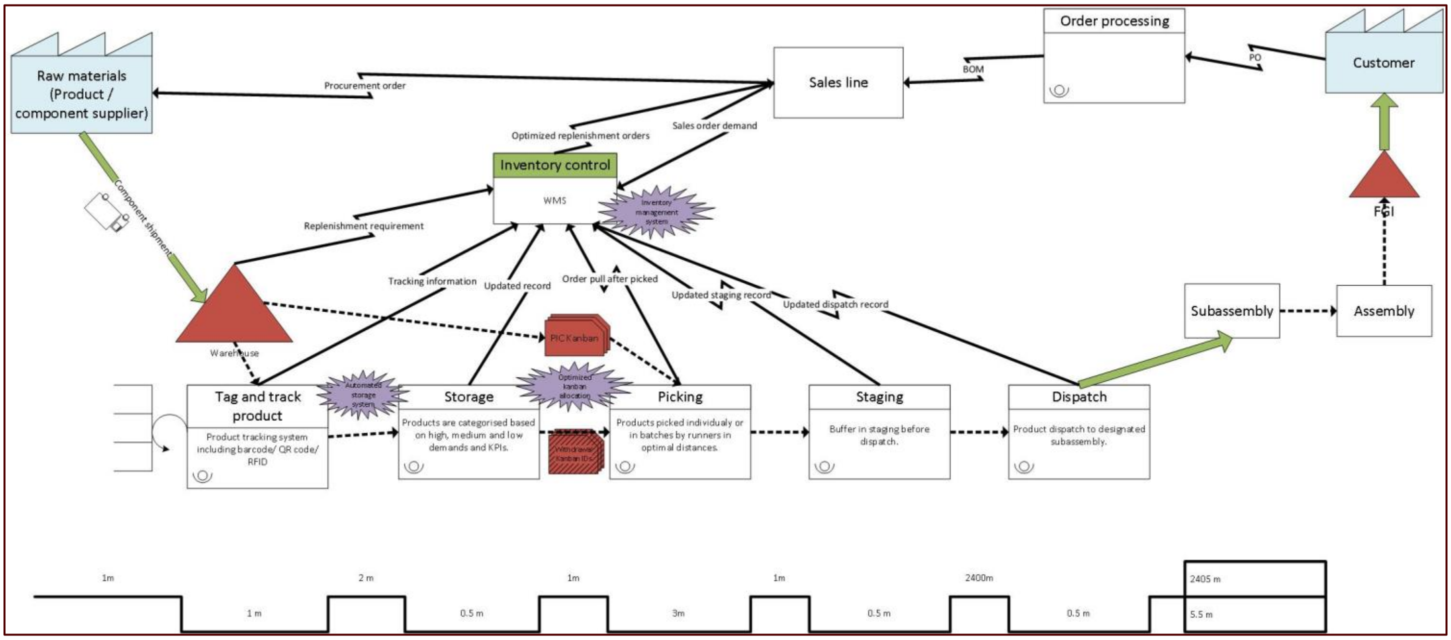
- Implementing visual controls to improve worker efficiency.
- Developed algorithms for kanban allocation to the operators and engineering the order processing, perform batch picking in the picking operation.
- Reorganized warehouse layout based on the kanban frequency, categorizing parts based on Fast, medium, and slow-moving in the warehouse.
- Task Engineering the layout by defining standard work, warehouse management system, visual controls, operating work allocation, well-identified location areas, and retrieval systems - A, B & C.
- Developed a mechanization matrix to identify the warehouse system that can be used for making a lean improvement in the existing warehouse system.

TOBE OVERVIEW

IDEF0: A well-represented TO-BE IDEF0 model for Rochester Lean Warehouse Management System Engineering is attached along with this report. Here in the warehouse, we should implement an automated inventory management system that integrates with other systems such as order processing and shipment tracking. By using QR codes, barcodes, or RFID technology, the improvised warehouse system will improve inventory accuracy and make product tracking more efficient. By making use of the TOBE system there is a huge reduction in labor costs and increased production, which will allow the warehouse to fulfill customer orders and needs more quickly and efficiently.

In ASIS, we released Kanban ids for individual components one at a time, each one picking the products. However, in TOBE, Kanban IDs are released in batches, and we have included an extra activity that comprises product picking in batches. We have included five main activities in TOBE, which include product receipt, storage, order picking, staging, and final dispatch of products to designated sub-assemblies. In each step, the product is tracked through the product tracking mechanism, and the information is gathered through the inventory management system. In each process, key performance indicators and quality checks are considered and included as important controls. Therefore, these are the main differences between ASIS and TOBE for IDEF0.

VSM: A well-represented TO-BE VSM model for Rochester warehouse operations is attached along with this report.

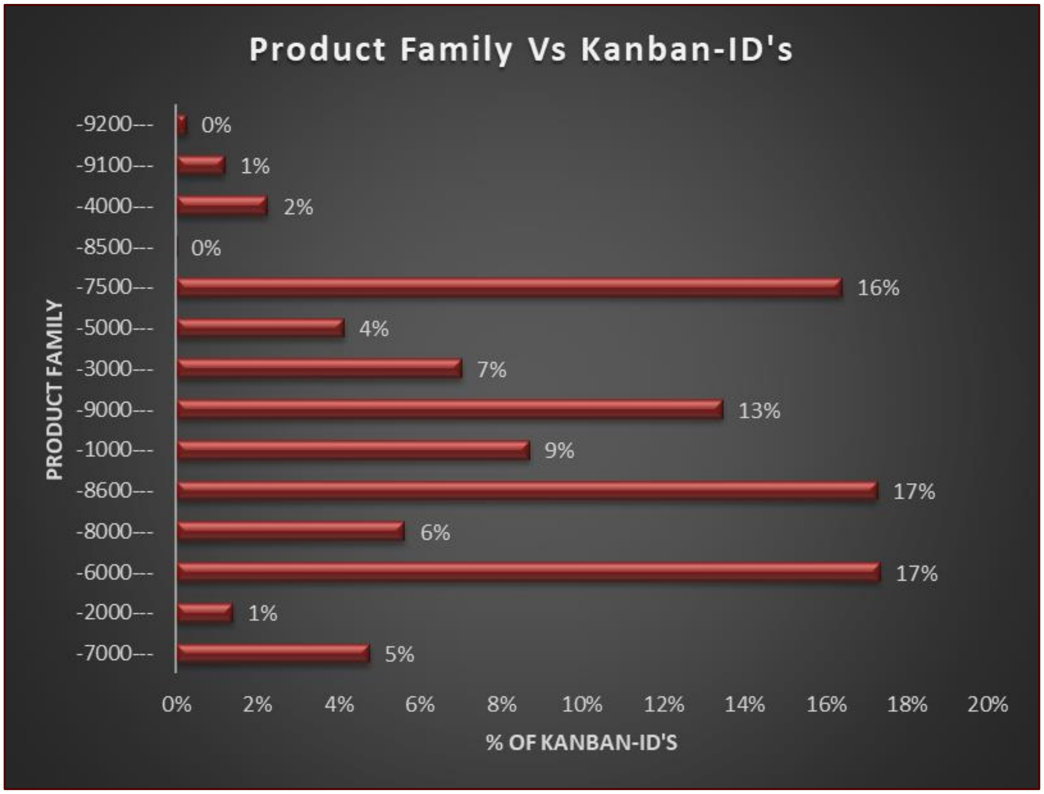


The TOBE warehouse system is designed with lean principles to eliminate waste and optimize the flow of goods and information. The proposed system has standardized processes to improve the consistency and quality of outputs. The information flow is different when compared to ASIS. The sales order information is transmitted to the functional inventory management system. The information from the five processes, including tag and truck products, storage, picking, staging, and dispatch of the products, is constantly fed to the inventory management system. The replenishment requirement information from the warehouse is electronically transmitted to the sales line through the inventory management system. Here, only an optimized replenishment order is transmitted to the sales line based on the current component demand. Batch Kanban is being introduced in the picking process, where kanban IDs are released in batches. Unlike individually in the ASIS value stream map, this is included as a kaizen burst between the storage and picking processes. Also, an automated storage system is included as a kaizen burst, which has a huge scope for continuous improvement. Therefore, these are the main differences between ASIS and TOBE for the value stream map.

ENGINEERING ACTIONS:

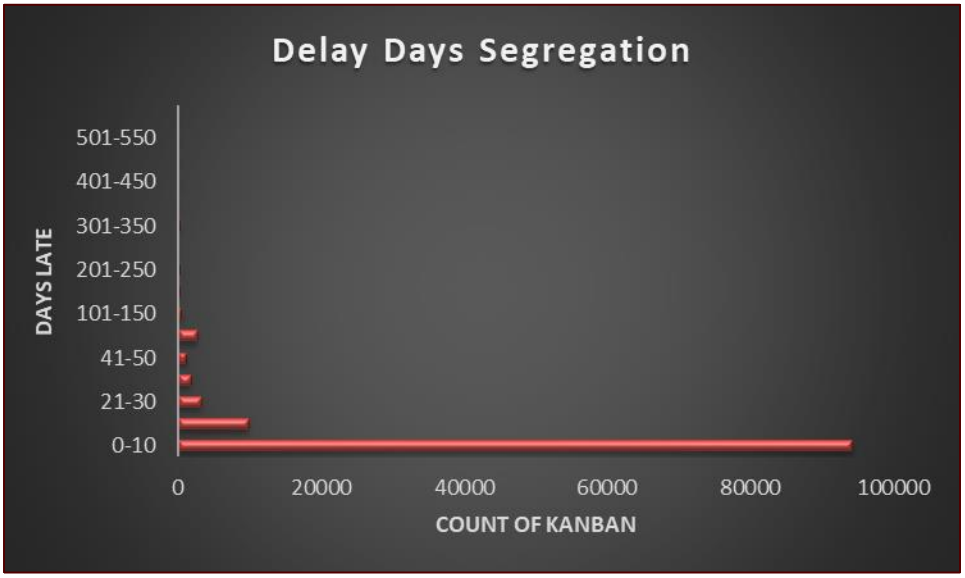
1. Leveling the demand and the workload inside the warehouse, thorough out the production time to reduce the variability in the system.
2. Line balancing in the shipping and receiving area comprised of activities like Item-ID quality checking, entry log, labeling, receiving end documentation, locating the empty bins, and waiting for the lifting equipment. Calculating the operator efficiency and calculation of the number of operators to be allocated at each location.
3. Implementing Visual Control systems throughout the warehouse, displaying key information on the Kanban ID's demand per day, numbers closed, live real-time status of each activity like documentation, SAP entry, the status of loading/unloading, no. of empty bins available.
4. Introducing a warehouse management system that suggests an optimal location for the Item-ID to be loaded into and unloaded from, considering the consumption patterns & cost of transport.
5. Based on the requirements from the production control, resizing the batch sizes of Items based on the consumption patterns, to reduce the number of packages thereby eliminating the efforts on labeling, multiple entries, multiple transportations, and dedicated data management for each item. This batch sizing will be implemented by defining at the supplier end itself.
6. Task Engineering the layout by defining standard work, warehouse management system, visual controls, operating work allocation, well-identified location areas, and retrieval systems - A, B & C.

CONSUMPTION PATTERN



These are important data cuts required for defining the future state. From the data provided, it is inferred that the product families 6000 & 8600 are the runners that have more Kanban IDs scheduled. Running a correlation between the count of item IDs & the product family, the predominant amount of item IDs are in the product families 6000 & 8600. This gives us logical justifications to design the layout of the warehouse based on the product families, which can eventually optimize the internal transportation cost by locating it near the shipping location. Also, based on the level of demand, the batch sizes can be re-designed specific to an Item ID, which can reduce multiple work order allocations, documentation, labeling, etc. All these will be captured in the micro-level analysis explained in the next section.

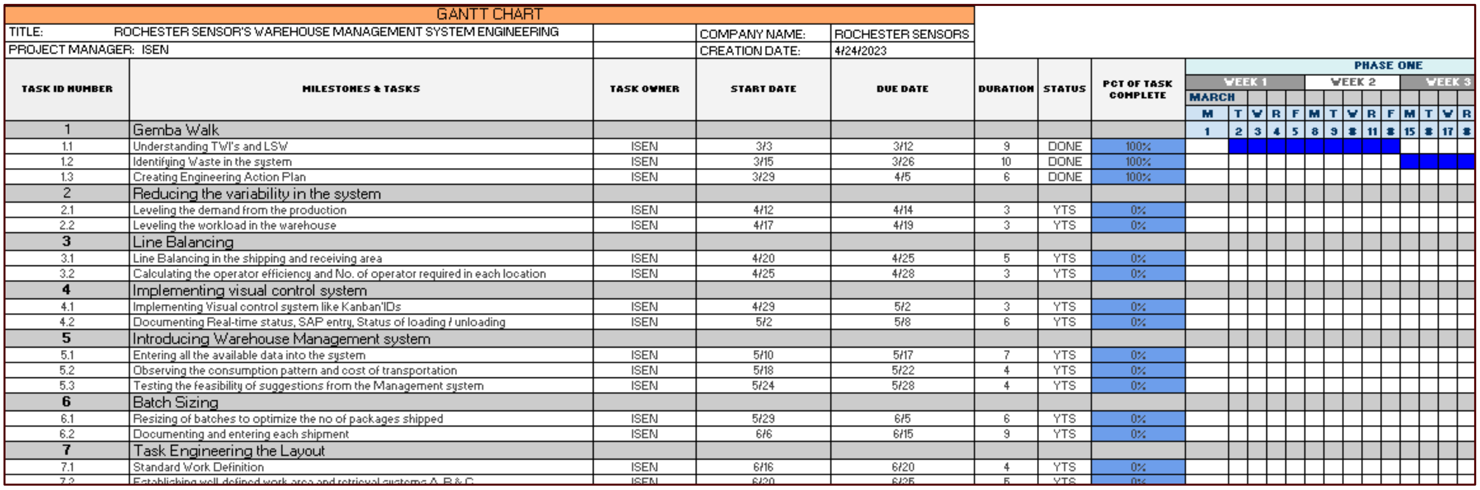
DELAY ANALYSIS



On analyzing the count of Kanban delays, against the days late, it is evident that the system is struggling due to a lack of standard work orders, workflow, uneven load distribution & poor visual controls. The system re-figures itself taking too much time against the defined takt time and completes most of the work orders delaying by 10 days. In the redesigned layout, all the activities have the standard work procedures and defined process time that is engineered to fall within the takt. This is measured in terms of performance metrics and continuous improvements are made based on standardizing the systems.

DETAILED IMPLEMENTATION PLAN OF THE PROPOSED DESIGN AND KAIZEN PROGRESS:

GANTT CHART:



GANTT CHART

TITLE: ROCHESTER SENSOR'S WAREHOUSE MANAGEMENT SYSTEM ENGINEERING

COMPANY NAME: ROCHESTER SENSORS

PROJECT MANAGER: ISEN

CREATION DATE: 4/24/2023

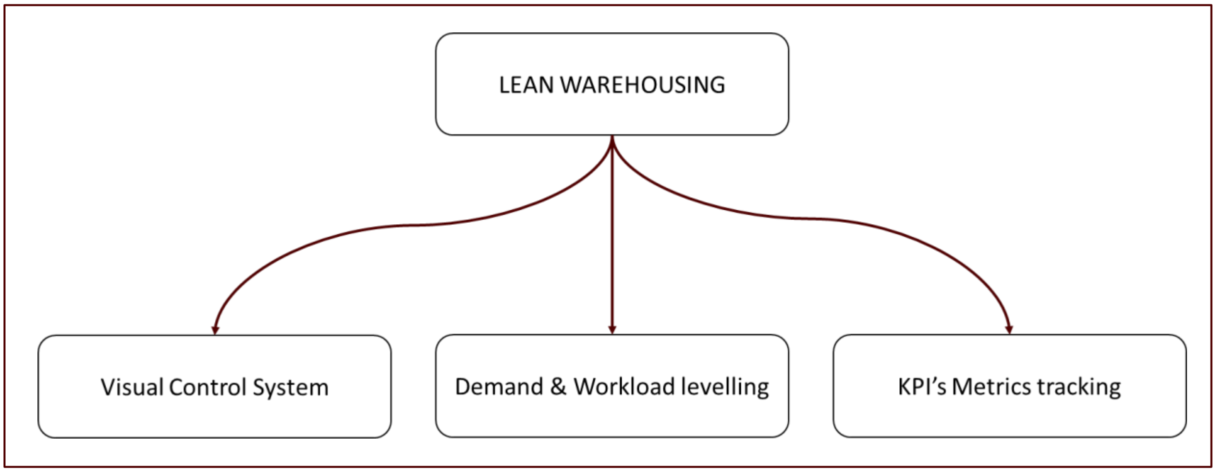
TASK ID NUMBER	MILESTONES & TASKS	TASK OWNER	START DATE	DUE DATE	DURATION	STATUS	PCT OF TASK COMPLETE	PHASE ONE													
								WEEK 1					WEEK 2					WEEK 3			
								MARCH													
								M	T	W	R	F	M	T	W	R	F	M	T	W	R
1	Gemba Walk							1	2	3	4	5	8	9	#	11	#	15	#	17	#
1.1	Understanding TWI's and LSW	ISEN	3/3	3/12	9	DONE	100%		■	■	■	■	■	■	■	■	■				
1.2	Identifying Waste in the system	ISEN	3/15	3/26	10	DONE	100%											■	■	■	■
1.3	Creating Engineering Action Plan	ISEN	3/29	4/5	6	DONE	100%														
2	Reducing the variability in the system																				
2.1	Leveling the demand from the production	ISEN	4/12	4/14	3	YTS	0%														
2.2	Leveling the workload in the warehouse	ISEN	4/17	4/19	3	YTS	0%														
3	Line Balancing																				
3.1	Line Balancing in the shipping and receiving area	ISEN	4/20	4/25	5	YTS	0%														
3.2	Calculating the operator efficiency and No. of operator required in each location	ISEN	4/25	4/28	3	YTS	0%														
4	Implementing visual control system																				
4.1	Implementing Visual control system like Kanban'IDs	ISEN	4/29	5/2	3	YTS	0%														
4.2	Documenting Real-time status, SAP entry, Status of loading / unloading	ISEN	5/2	5/8	6	YTS	0%														
5	Introducing Warehouse Management system																				
5.1	Entering all the available data into the system	ISEN	5/10	5/17	7	YTS	0%														
5.2	Observing the consumption pattern and cost of transportation	ISEN	5/18	5/22	4	YTS	0%														
5.3	Testing the feasibility of suggestions from the Management system	ISEN	5/24	5/28	4	YTS	0%														
6	Batch Sizing																				
6.1	Resizing of batches to optimize the no of packages shipped	ISEN	5/29	6/5	6	YTS	0%														
6.2	Documenting and entering each shipment	ISEN	6/6	6/15	9	YTS	0%														
7	Task Engineering the Layout																				
7.1	Standard Work Definition	ISEN	6/16	6/20	4	YTS	0%														
7.2	Establishing well defined work area and retrieval systems A, B & C	ISEN	6/20	6/25	5	YTS	0%														

A Detailed Gantt chart is attached along with this report, and it has been uploaded onto the portal.

- The bottleneck in the warehouse system is found to be the PIC Kanban processing in the order processing station. To reduce the lead time in the picking process we have introduced a Warehouse management system that runs an algorithm and finds the best optimal way to minimize the lead time. The algorithm provides the batch size of the kanbans to be picked and the material handling tool to be used to transport the part to the staging area.
- By developing IDEF3 in the Kanban order processing we developed the Standard work chart and the loops in the warehouse layout.
- We determined three alternative warehouse systems that can be implemented and identified the optimized warehouse system that can be applied for the Rochester Sensor Gauges by developing a scoring model from the cost, performance, and risk matrix.
- It is found that the Semi-automated system is the suitable one for the Rochester Sensor Gauges which is identified from the scoring model.
- We have also insisted on an optimized warehouse layout categorizing it based on the frequency of kanban. The parts are categorized into fast-moving, medium-moving, and slow-moving which controls the operator's movement.
- By performing the mechanization matrix, we have identified the suitable mechanization model for Rochester. The mechanization matrices show that medium mechanization is required to function in the warehouse. So, we have suggested a Semi-automated warehouse management system that is applicable in this condition.
- According to the standard work chart we determined that 10 operators are sufficient to carry the warehouse management system with minimized buffers and reduced lead time.
- Kaizen improvements insisted on using visual control charts and getting the complete utilization of the operators.

TOBE MICRO LEVEL DESIGN

Task Engineering, Metrics definition, Line balancing with operator efficiency (Point 6 of Engineering Actions)



The core lean principles followed while designing the TO BE state of Rochester's warehouse are the Visual control system, Heijunka on demands as well as workload/ day, and key performance indices tracking.

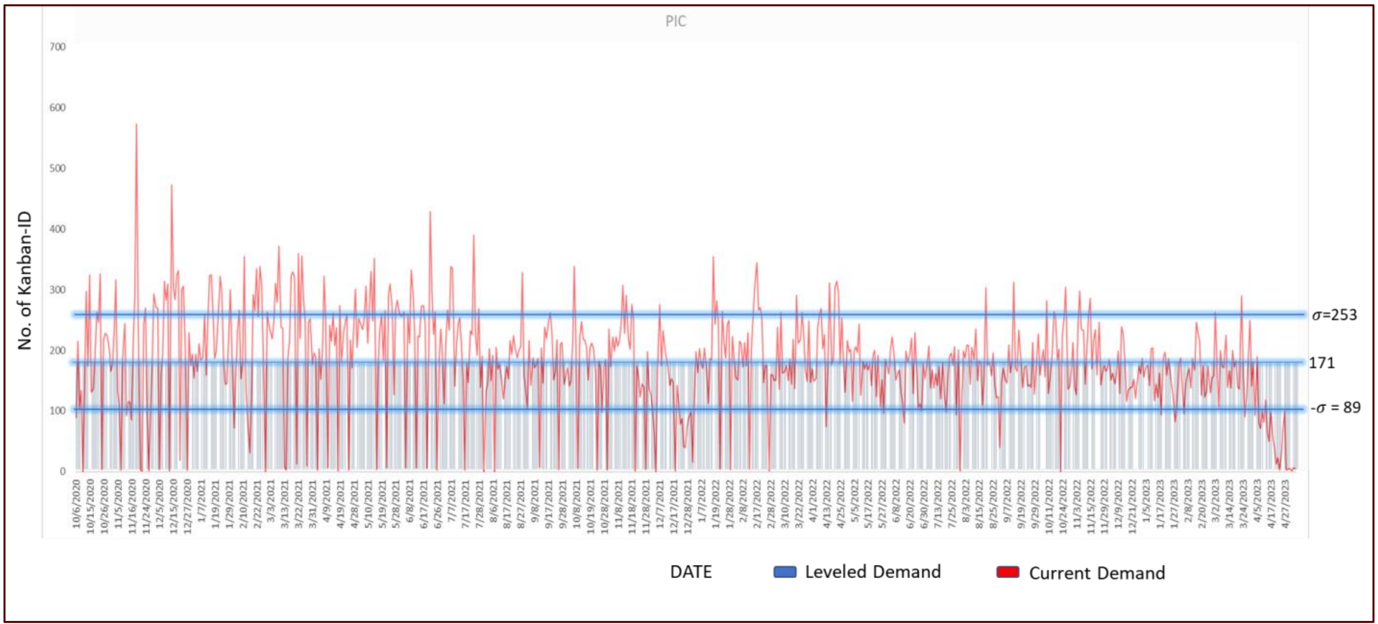
Visual Control system - In the current ASIS state, there happens to be a lack of information sharing between the resources in the workstation that leads to errors, wrong picking & placing, waiting time for the component to be in-warded as well as for shipment, unwanted transportation in search of empty bins, same work orders being attempted by multiple operators.

To avoid these wastes, there demands a state-of-the-art visual control system that would eventually be the cornerstone of Rochester's warehouse system. This includes housekeeping shadow boards that display the dedicated location for each of the machinery and tools, painting guiding lines on the floor with signs indicating directions, signal boards that show the routes for every BIN location, large digital display boards at multiple locations visible to all, containing real-time information on the Kanban ID's logged, attended work orders and work in progress, delayed orders and pace at which the work orders are being completed. This will potentially help to reduce problems by identifying the waste instantaneously and shortening the lead time.

KPI's Metrics tracking **-** After designing the realization state of the warehouse production system by incorporating visual controls, load leveling, kaizens, workload optimization, and re-designing the information system and the layout, it is necessary to track key performance metrics for constant evaluation and driving continuous improvements.

PERFORMANCE	On-time delivery	COST	Transport	RISK	Safety
	Information management		Manpower cost		Reliability
	Quality		Material Handling / Serviceability		Repeatability
	Overall Equipment Effectiveness		Overheads / Indirect labor		Maintenance
	Operator Efficiency		Cost of delay in shipments		Financial

Demand & workload leveling - As it can be inferred from the below graphic, the schedule of Kanban IDs over each day is erratic and ranges anywhere between 20 to 573 per day. This unevenness in the demand will eventually result in uneven workflow and load distribution among the operators and resources in the warehouse. At times, operating at a maximum utilization in case of satisfying 573 kanban IDs per day, combined with the variability that is created from the resources, results in the WIP levels increasing in a non-linear fashion. To create an even workflow and load distribution among the operators and machinery it is important to level the demand over the day. This requires to be well synchronization between the production demands and supplier schedule, by creating necessary buffers in the production area to hold inventories to protect against uncontrolled demand fluctuations.



APPROACHES FOR MICRO-LEVEL DESIGN

1. Takt time definition for emptying the Kanban cards, average demand over the month, and the number of IDs to be shipped each day over the available operation time. Based on the talk time and the calculated operational time define the flow, and modification of the layout based on the product family/work cell. Enable the stratification among the Item-IDs based on the consumption patterns in terms of push, pull continuous flow.
2. Incorporate technologies / state-of-the-art Visual control system/warehouse transportation based on the business case analysis - A, B &C (discussed in the next section), to arrive at a decision satisfying key metrics on Cost / Performance & Risk
3. Stabilize the demand, process time, and level of activity by employing demand leveling techniques, and workload estimation. Standardize the process through continuous improvements.

CONOPS:

CONOPS aka VSM deals with Lean engineering using Value Stream Map [VSM] as a way to characterize the critical facets of the operation. IDEF3 Model Development Process: Here we use IDEF3, each activity can be modeled in detail, and the relationships between different activities can be identified. The receiving order process involves many activities, such as verifying the order details, inspecting the received goods, and updating the inventory record. This can help in identifying potential areas for optimization, such as reducing the time taken to inspect goods or streamlining the inventory update process. By developing IDEF3 in the kanban order processing we developed a standard work chart and the loops in the warehouse layout. In the IDEF3 model, the process PIC kanban orders initially moved into getting computer generated pick list. Moreover, it goes to take parts from the storage in batches and goes to the staging area where the products are assembled before dispatching. Once the picked parts are reached in the staging area it moves to the next step which is to process PIC kanban orders.

In Object State Transition (OSTN), once the product requirement orders are received it goes to the Inventory management system and processes PIC orders as it performs an automated inventory management system. Then Inventory Management System (IMS) generates an optimized PIC list. It is then converted into batch kanban ID's which in turn move the material handling system PIC kanban order in batches. It is moved by a material handling tool. Moreover, the process is from storage in batches. It goes to the components picked from storage based on demand and then to the area where components are placed in the staging area for dispatching. Batch Kanban is being introduced in the picking process, where Kanban IDs are released in batches. We have included an extra activity that comprises product picking in batches. In each process, key performance indicators and quality checks are considered. Placing products close to the staging area speeds up the process and reduces unwanted Waste in the process. Warehouse in Rochester Sensors, we have a separate Staging area from where the order is dispatched to the Production shop floor. In the staging area, they always maintain a minimum of two days of WIP Kanban's staged and in ready-to-dispatch condition.

ANALYSIS OF ALTERNATIVES (AOA)

Based on the ASIS state and wastes identified, we have the Micro level designs focusing on the Visual controls, heijunka, task engineering, and operator’s head count. All these approaches are combined and stratified into three levels, that are based on the same grounds and vary on the technology and practices that are put in place. We named each system A, B & C which are described in detail in the upcoming sections.

The various key performance indices are measured across all these systems and an optimal one is selected based on the scoring models, weighted by keeping in view the various factors.

Inference: To perform the Alternative Analysis, we have three different warehouse management systems and analyzed the optimized system that reduces the buffer. The alternatives used for analysis are listed below:

1. Traditional Warehouse System: This system uses the kanban in which the information is transferred from one station to another manually. The system involves skilled workers who can perform multi-tasking for moving the materials and analyzing the requirement that is demanded from the production. The production kanban and withdrawal kanban are used for the material flow. The pull system is implemented to have a frequent supply of parts at the desired time of production. The material handling and the material flow are completed and performed manually which increases the labor cost and increased lead time associated with the system as well. This system is prone to high system variations and highly dependent on the operator’s efficiency. Though the initial cost of investment is low the scoring model shows that the ROI and the running cost for this type of system are high compared to that of the other warehouse models that are taken for analysis. The scoring model shows that the reliability and repeatability of the system are low and need improvement in safety and quality of service.

2. Semi-automatic warehouse system: This kanban information is transferred using the barcode scanners and AGVs to transport the parts from the cell to the loading station. This system is a kind of semi-automatic controlled by the SAP and motion controlled by certain automation technologies that reduce uncertainty. The use of barcode scanners reduces the cycle time and lead time. The kanban data can be retrieved very quickly and the desired part can be tracked from SAP. This system is highly recommended in places where frequent withdrawal of kanban takes place. On-time delivery and serviceability are achieved to a greater extent by using this model. Though it is prone to high material handling costs, it has a very high ROI compared to traditional warehouse systems. The safety and quality are comparatively higher than that of the traditional system. We highly recommend this system for medium-scale industries with moderate daily requirements.

3. Fully automatic warehouse system: The Kanban pull system is completely automated and the human-machine interface is minimized. The movements of materials are performed using pick-and-place robots and cell structure is followed for every product family. On-time delivery is achieved with reduced buffer stock. The motion is controlled with reduced lead time by implementing level-4 automation into the system. This system has been creating great value in the supply chain network of major companies like Walmart to increase customer goodwill. This system is highly recommended for large lot-sizing industries where their material handling cost can be reduced, and the system variations are low. The scoring model shows that it is highly reliable and safe to implement in industries. This model is recommended to have an immediate change in the lean kanban production system.

AOA			
	A	B	C
Alternative	Manual kanban system	Electronic Kanban System	Full Automatic Kanban System

Performance evaluation matrix:

SYSTEMS	COST per Month						PERFORMANCE					RISK			
	Transport	Manpower cost	Material Handling/ serviceability	Overheads/ Indirect labor	Cost of delay in shipments	Total	On-time delivery	Information management	Quality	Overall Equipment effectiveness	Operator Efficiency	Safety	Reliability	Repeatability	Maintenance
A	8000	10000	1800	500	12000	1	10%	40%	40%	28%	56%	30%	42%	30%	20%
B	6500	8000	2200	500	4000	3	92%	85%	80%	80%	87%	75%	80%	72%	66%
C	3000	3000	4000	400	1200	4	98%	95%	95%	92%	95%	96%	95%	92%	87%

- The alternatives described above (i.e.) A, B & C are evaluated on various performance metrics as described below. On the cost front, the major comparative features are the transportation cost, material handling cost & opportunity cost. These are measured quantitatively accounting for all the costs incurred for the three alternatives.
- The performance metrics are the most important ones as all the continuous improvements and the current system performance state are measured based on this. It is evident that we get an enhanced performance on the implementation of the automated system, but the business case decision is based on the return on investment and the economies of scale.

Weighted Scoring Model:

- The business case report is presented as follows summarizing the cost justifications, expected benefits, return on investment, expected cash flow, and the analysis of the Alternatives matrix.
- Since the evaluation metrics are both quantitative and qualitative, we have gone with a careful approach to the weighted scoring model based on ranking. This model briefly ranks the various attributes, and a proper rationale is arrived at in choosing the best alternatives. It is being inferred here that, based on the cost/ performance & risk and the business model of the organization, taking into consideration the expected growth rate and business strategy, it is optimal to go with system B, which has a semi-automatic retrieval system with enhanced visual control system and data Integration.

Cost Range		Rank
1	10000	5
10000	20000	4
20000	30000	3
30000	35000	2
35000	40000	1

Range of Performance/risk		Rank
0	10	1
10	20	2
20	30	3
30	40	4
40	50	5
50	60	6
60	70	7
70	80	8
80	90	9
90	100	10

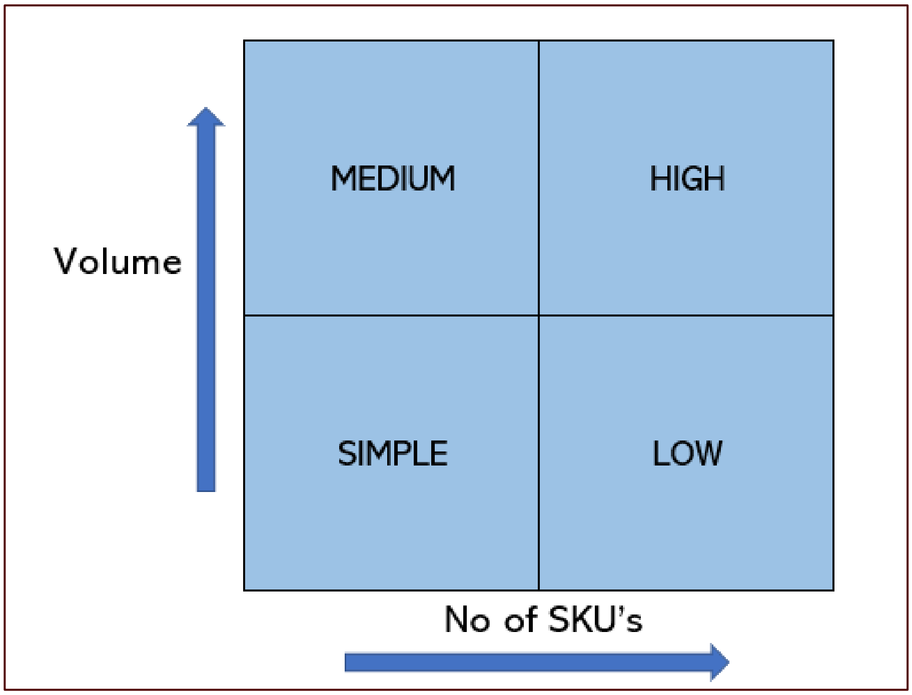
WEIGHTAGE	50%	30%					20%				RANK
	Cost / month	Performance					Risk				
SYSTEMS	Transportation + Manpower cost + Material Handling serviceability + Overheads Indirect labor + Cost of delay in shipments	On-time delivery	Information management	Quality	Overall Equipment effectiveness	Operator Efficiency	Safety	Reliability	Repeatability	Maintainence	
A	1	1	4	4	3	6	2	5	3	2	1.3
B	3	10	9	7	7	9	8	7	8	7	3.4
C	4	10	10	10	10	10	10	10	10	10	4.4

BUSINESS CASE REPORT – ROCHESTER SENSORS

Business Case Report - Rochester Sensor			
Project Name	Lean Warehousing - Rochester Gauges	**Date**	6th May 2023
Project sponsor	Head of Operations (ISEN)	**Project Manager**	ISEN
Contribution to Organization	Our focus here is satisfying the demands by incorporating state-of-the-art warehousing techniques by optimizing the operating cost of the warehouse. This also focuses on reducing inventory levels, improving responsiveness, and excellence in information management		
Options Explored	Based on the current state analysis and the requirements to be satisfied, three systems were identified. (Detailed information enclosed in annexure) A - Traditional warehouse system, employing an enhanced visual control system B - Semiautomated system with automatic retrievals from BINS, enhanced visual control system, with a predictive data management approach C - Complete Automation with robots incorporating symbiotic fulfillment centers		
Benefits	On-time delivery - Completion of the Kanban IDs before the due date specified. Customer Delight - Measured in terms of customer demands being satisfied. Opportunity cost - Cost incurred in terms of lost business will be kept minimum. Reduced Inventory - Inventory in terms of information, documentation, pallets, miscellaneous, items, lost orders Interconnected WMS - Data management system that shares information between various. distribution centers and production systems		
Time Scale	A - 3 months	B - 8 months	C - 11 months
Costs	A	B	C
	Infrastructure - $24,000	Infrastructure - $60,000	Infrastructure - $1,20,000
	Software Integration - $2200	Software Integration - $4000	Software Integration - $ 12,000
	Maintenance - $ 1200	Maintenance - $ 3000	Maintenance - $ 4,000
	Running cost (Direct + Indirect) - $ 7000	Running cost (Direct + Indirect) - $ 4000	Running cost (Direct + Indirect) - $ 4,000
Return	A	B	C
	Year 1 - $ 1600	Year 1 - $ 2000	Year 1 - $ 10000
	Year 2 - $ 1000	Year 2 - $ 40000	Year 2 - $ 60000
	Year 3 - $ 2000	Year 3 - $ 60000	Year 3 - $ 60000
Risks	Inconsistent performance	Skill dependent	Maintenance
	Manual dependency	Maintenance	Demand fluctuations

SELECTED ALTERNATIVE

LEVEL OF MECHANIZATION



Running through the Kanban data provided, we can infer that there are a whole lot of variants (i.e.) 3219 component ID and the volume being 1.25 lakhs over a three-year period. Also, only 20% of the product variants contribute to 80% of the kanban volumes being released.

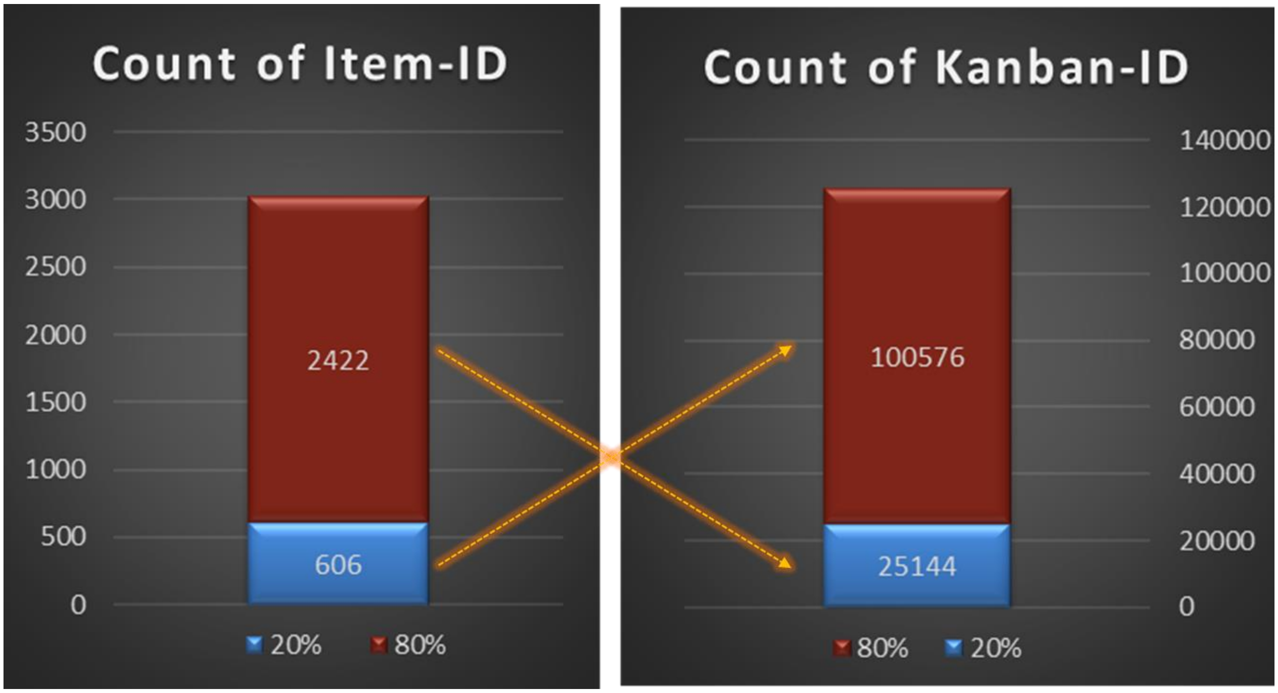
Thus, with the above inference combined with the ROI and the economies of scale, we are going ahead with the medium-level mechanization that has a QR code scanning system, operator workload allotment algorithm considering key factors, auto retrieval for top levels, SKU location & FIFO adherence algorithm, kanban closure counting, visual controls that are embedded into the warehouse management software.

RATIONALE

- Though the demands are dynamic based on the customer requirement, there seems to be a one-week lock-in period and a three-week tentative demand data. This provides us with spare time and plans our activities better and in an efficient way by putting in the right systems.
- By looking at the performance and demand, as provided in the data below, the mean number of Kanban IDs released is 182nos/ day, and the mean value of closed Kanban ID's 171nos/day. This explains that the system is performing as per demand but without proper systems resulting in delayed kanban delivery.

Kanban ID's (Mean)	
Released by system	closed by warehouse
182	171

- Pareto Analysis (80% – 20%) - Inference



This is an important piece of data cut that provides us insight into the 80-20 principle. The left-indicated bar graph provides us with the data on the total number of components released for the PIC items. The right-side graph provides us with the details of the number of Kanban's released. Here we can see that only 20% of the component IDs contribute to the 80% of the kanban IDs being released.

Hence, it is critical for us to focus on the 20% of the component IDs and leverage the improvements focusing on the same, to get results.

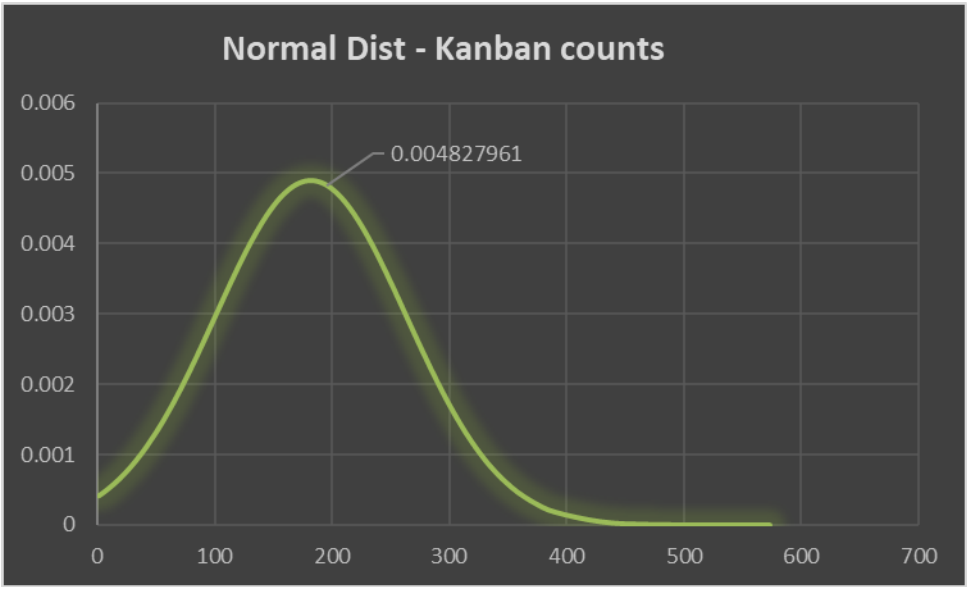
DESIGN CONCEPT FOR THE MICRO-LEVEL DESIGN:

HEADCOUNT ESTIMATION

From the Kanban data provided and with reference to the discussions with the M/s Rochester sensors, below are the calculations for the takt time calculation.

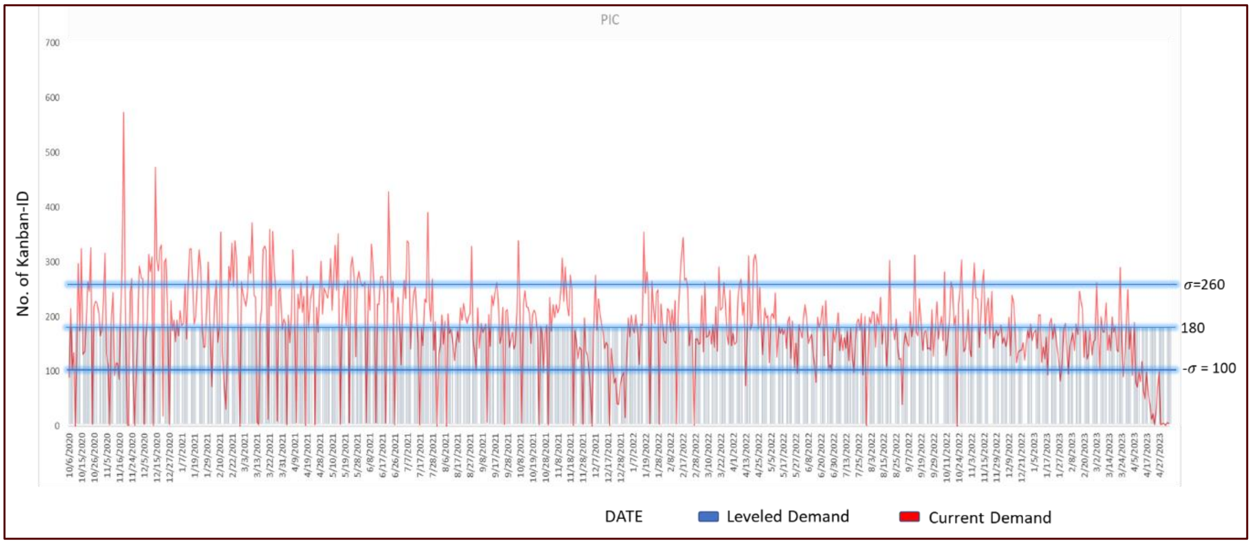
In the data set provided, there exist periods of time from 2019 to 2022. On examining the data, there seems to be an even distribution except for some of the days. Here for example, on considering the whole data set on the kanban date, the mean count of kanban IDs closed per day equals 171 kanban cards and the median comes to 172 cards. As the mean and the median value are close to each other considering the size of the dataset, we can conclude that the distribution is evenly spread centered around the mean. Below are the various values of the mean and median over various data ranges.

KANBAN ID'S RELEASE OVER TIME RANGE			
Period	Mean	Median	Std deviation
All years (2020 -2023)	**171**	**171**	82
The year 2020	**139**	**122**	65
The year 2021	**194**	**194**	93
The year 2022	**166**	**165**	79
The year 2023	**135**	**140**	62



Above, we can see the distribution of the Kanban counts over daily releases. We can here see that the distribution is normal and means over the value of 180 and a standard deviation of 80. This distribution is for the periods ranging from 2019 to 2022.

For the analysis purpose and with the factor of safety we will take into consideration the kanban ID's release over the whole dataset (i.e.) from 2020 to 2023. This will take a mean value of 171 and a standard deviation of 82. Due to the lack of sufficient data and the factors to be considered, we are proceeding with the whole data range, however, a dynamic working model is attached in this report, to calculate the takt time & the following headcount estimation. We are proceeding with the estimation, with the calculated mean value and the +/1 σ level, as provided below.



CURRENT SYSTEM PERFORMANCE & TAKT TIME CALCULATION

Available time calculation

Shift time – 8 hours.

Break time – 0.5 hours.

Total working time – 7.5 hours

Total working time (in minutes) = 450 minutes

No of Kanban ID' closed = μ - σ (Taking the lower control limit for worst case scenario)

μ = Mean = 171 (from table described in pg. No)

σ = Standard deviation = 171- 89 = 89 kanban ID's

Throughput rate = No of Kanban's to be closed/ total working time = 89/450 = 0.197 parts/ minute (Current system performance)

TAKT TIME CALCULATION

Based on the given date, the number of kanban IDs released per day for the worst-case scenario at the UCL limit.

Kanban ID's released = μ + σ = 171 + 82 = 253

Available production time = 450 minutes

Takt time = Available production time / No of Kanban IDs to be closed

= 450/ 253

= 1.77 minutes/ Kanban ID

TIME STUDY

Below is the various task breakdown of a picker along with the associated time. The central warehouse control assigns the task for the warehouse line, based on the Kanban ID's release from the central production system. In the current system, the Kanban IDs are released for the (D+2nd) production ['D' representing the current day]. This also means that all the materials are picked, run, and staged for the production scheduled for the day after.

PICKER TIME STUDY

S.no	**Activities**	**Time (minutes)**
1	Operator order assignment	0.25
2	Operators' walk time to the equipment area	1
3	Trolley/ Pallet location time	0.25
4	Trolley movement from equipment storage	0.25
5	Locate the SKU location	0.35
6	Move towards the SKU location with the trolley	1.5
7	Locate the component ID near the SKU location	1
8	Locate the 4-level tray	0.5
9	Move towards indexing equipment	1.5
10	Pull the equipment near the SKU location	0.8
11	Get the indexing equipment - for the levels	0.5
12	Index to the particular level	0.25
13	Locate the component ID	0.5
14	Remove for any package like polythene cover/ cotton wrap	0.5
15	Grab the component ID / IDs	1.5
16	Index to the ground level	0.25
17	locate the next component ID location	1.5
18	Walk along the warehouse to drop location	1
19	Drop the collected component IDs in the drop BIN	0.5
20	count for quantities	0.5
21	Paste the quantity details	0.5
	TOTAL	14.9 minutes

TIME STUDY OF PICKERS & RUNNERS

There are two major classifications of workers inside the warehouse who help in executing the transportation of Kanban’ D quantities to the staging area.

a) Pickers
b) Runners

Pickers: Pickers are the operators charged with picking and grouping the components of various Kanban. Once the picker picks up the component batch, he then transports them to the drop location, where there is a grouping of component IDs based on certain logic that would aid the assembly process. Once this is done, the task goes to the runners and the pickers are charged with another bunch of Kanban IDs to execute.
Runners: Once the pickers complete their job of dropping the kanban quantities into the drop BIN location, the runners are tasked to deliver the components to the staging area.

Calculation of headcount for the (current) ASIS system

Summation of Task Time = 14.9 minutes
Planned cycle time = 90% of Takt time = 0.9 x 0.1.77 = 1.6 minutes

$$No.of\ worker = \frac{\sum Task\ Time}{Planned\ cycle\ time}$$

$$No.of\ workers = \frac{14.9}{1.6}$$

$$No.of\ workers = 9.31$$

$$No.of\ workers = \ 10\ (Approx.)$$

This calculation is based on the current system performance.

IDENTIFYING THE WASTE, CLASSIFYING AND IDENTIFICATION OF THE RE-ENGINEERED ACTIVITIES

Summary	Present		Proposed		Difference	
	No.	Time	No.	Time	No.	Time
○ Operations						
⬡ Handlings						
⇨ Transportations						
□ Inspections						
D Delays						
▽ Storages						
Distance Traveled						

Plant: Current

Charted by: ISEN PROJECT TEAM 25

Date 02/05/2023 Sheet: 1 of 1

MAN ☐ ------------- MATERIAL ☐

Chart begins: Activity 1

Chart ends: Activity 21

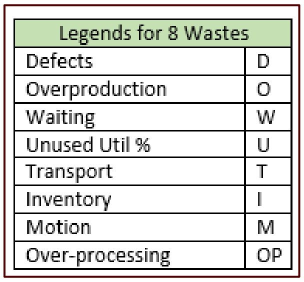
Details of Method

PRESENT ☐ ------------- PROPOSED ☐

Details of Method	Operation	Handling	Transport	Inspection	Delay	Storage	Distance in	Quantity	Time	Analysis Why? What?	Where?	When?	Who?	How?	Notes	Action Eliminate	Combine	Change Sequence	Place	Person	Improve
1. Operator order assignment	●	⬡	⇨	□	D	▽			0.25												
2. Operator walk time to equipment area	○	⬡	➡	□	D	▽			1												X
3. Trolley/ Pallet location time	○	⬢	⇨	□	D	▽			0.25							X					
4. Trolley movement from equipment storage	○	⬡	➡	□	D	▽			0.25								X				
5. Locate the SKU location	●	⬡	⇨	□	D	▽			0.35												X
6. Move towards the SKU location with the trolley	○	⬡	➡	□	D	▽			0.35												X
7. Locate the component ID near the SKU location	○	⬢	⇨	□	D	▽			1							X					
8. Locate the 4 level tray	●	⬡	⇨	□	D	▽			0.5							X					
9. Move towards indexing equiment	○	⬡	➡	□	D	▽			1.5								X				
10. Pull the equipment near to the SKU location	○	⬢	⇨	□	D	▽			0.8								X				
11. Get the indexing equipment - for the levels	○	⬡	➡	□	D	▽			0.5							X					
12. Index to the particular level	●	⬡	⇨	□	D	▽			0.25												X
13. Locate the component ID	●	⬡	⇨	□	D	▽			0.5							X					
14. Remove for any package like polythene cover/ cotton wrap	○	⬡	⇨	□	◗	▽			0.5												X
15. Grab the component ID / ID's	○	⬡	⇨	□	◗	▽			1.5												X
16. Index to the ground level	●	⬡	⇨	□	D	▽			0.25												X
17. locate the next component ID location	○	⬢	⇨	□	D	▽			1.5												X
18. Walk along warehouse to drop location	○	⬡	➡	□	D	▽			1												X
19. Drop the collected component ID's in the drop BIN	○	⬡	⇨	□	D	▼			0.5										X		
20. count for quantities	○	⬡	⇨	□	◗	▽			0.5							X					
21. Paste the quantity details	○	⬢	⇨	□	D	▽			0.5											X	

Therbligs: A study of motion economy in the workplace. There are 12 kinds of elemental motions used in this study.

POTENTIAL WASTE IDENTIFIED IN THIS SYSTEM: Refer to Legends for 8 wastes.



Legends for 8 Wastes	
Defects	D
Overproduction	O
Waiting	W
Unused Util %	U
Transport	T
Inventory	I
Motion	M
Over-processing	OP

Activity	Description	Therbligs	Wastes in System	Time (mins)	Task Time
A	Operator order assignment	P	W	2	0.25
B	Operators' walk time to the equipment area	NP	M	3	1
C	Trolley/ Pallet location time	NP	M	2	0.25
D	Trolley movement from equipment storage	NP	M, T	1	0.25
E	Locate the SKU location	P	W, U	2	0.35
F	Move towards the SKU location with the trolley	NP	M, T	2	1.5
G	Locate the component ID near the SKU location	NP	U, W	5	1
H	Locate the 4-level tray	P	U, W	2	0.5
I	Move towards indexing equipment	NP	M, T	3	1.5
J	Pull the equipment near the SKU location	NP	OP	3	0.8
K	Get the indexing equipment - for the levels	NP	OP	2	0.5
L	Index to the particular level	P	OP	6	0.25
M	Locate the component ID	P	W	2	0.5
N	Remove for any package like polythene cover/ cotton wrap	NP	M	2	0.5
O	Grab the component ID / IDs	NP	W	2	1.5
P	Index to the ground level	NP	M, T	3	0.25
Q	locate the next component ID location	P	OP	2	1.5
R	Walk along the warehouse to drop location	NP	M, T	2	1
S	Drop the collected component IDs in the drop BIN	P	M,T	2	0.5
T	count for quantities	P	OP,D,U	3	0.5
U	Paste the quantity details	P	OP	2	0.5
				Total	14.9

In this Production system, we have classified each and every activity based on the therbligs.

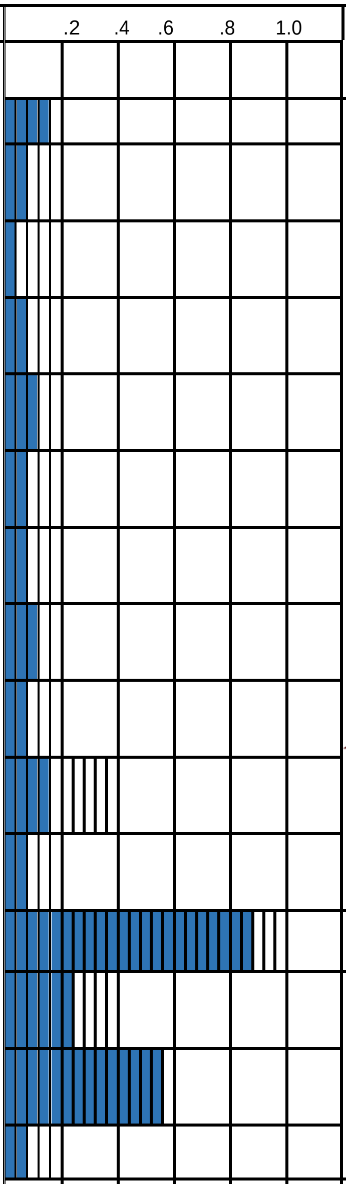
Productive time (P): Inspect, Process, Assemble,

Non-Productive time (NP): Walk, Fetch, Transport, Motion, Move, Carry, Pick

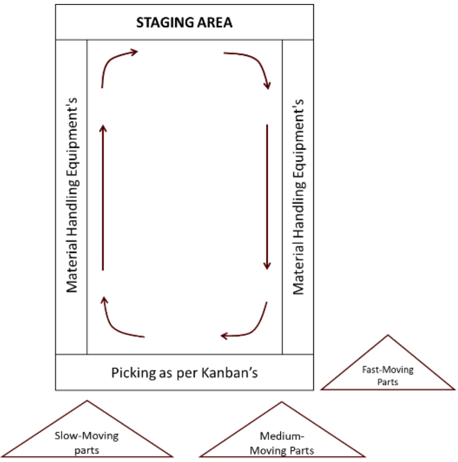
STANDARDIZED WORK

Manual Work	———————
Machine Time	…………………………
Walking	WWWWWWWWWW

Ref. Symbol	Cyclical Work Element	Element Time (Sec.) Manual	Machine	Walking
1.	*Operator order assignment*	0.1		
2.	*Operator walk time to equipment area*			0.75
3.	*Trolley movement from equipment storage*			0.1
4.	*Locate the SKU location*			0.25
5.	*Move towards the SKU location with the trolley*			0.25
6.	*Pull the equipment near to the SKU location*		0.8	
7.	*Index to the particular level*		0.25	
8.	*Remove for any package like polythene cover/ cotton wrap*	0.35		
9.	*Grab the component ID / ID's*	1		
10.	*Index to the ground level*		0.35	
11.	*locate the next component ID location*	1.5		
12.	*Walk along warehouse to drop location*			1.25
13.	*Drop the collected component ID's in the drop BIN*	0.5		
14.	*count for quantities*	0.5		
15.	*Paste the quantity details*	0.15		
	Sub-Total	8.1 minutes		
	Total Operator Cycle Time			



LAYOUT SKETCH & WALK PATH



No.	Non-Cyclical Work Element	Time		Freq.	Total
	Total Operator Time				

Notes

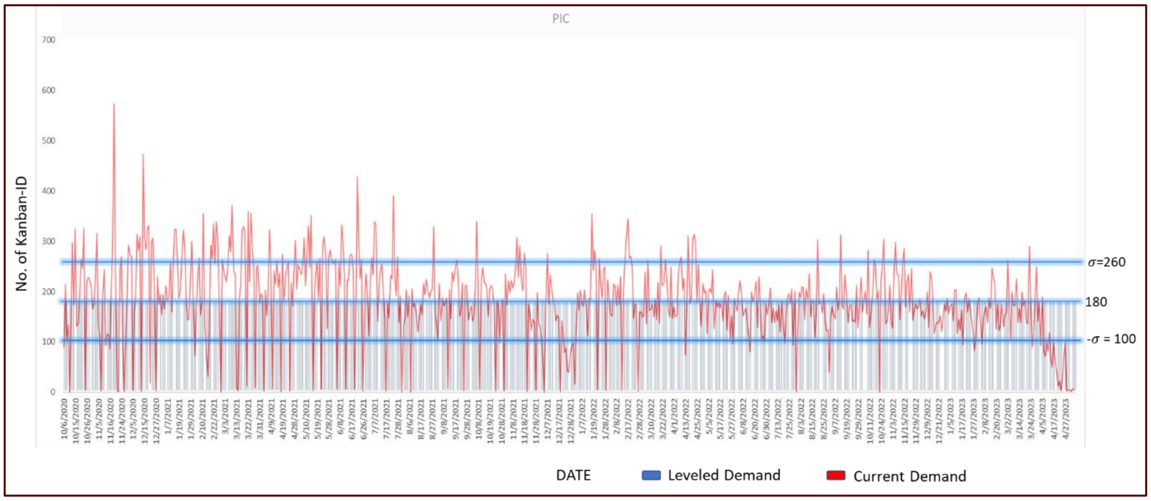
KEY PERFORMANCE INDICES FOR MEASURING SYSTEM PERFORMANCE:

Here is a detailed discussion of how the proposed design and the indicated kaizens would enhance the system's performance. The below-mentioned KPIs are critical to measuring the system's performance. To get an advantage when compared with the current AS-IS warehouse system. While implementing our trajectory we should have the following KPI's in mind.

1. Pick-Path distance: The main distraction in the warehouse setup is not having a well-designated path for reaching a particular place in the entire warehouse. All the parts and Sub-assemblies should be well placed and organized in the Warehouse using the following protocols.
    a) Floor plan: To have a clear and well-defined floor plan with a designated staging area to stock at least 2 days of in-process picks this ensures that even if there are any bottlenecks WIP wouldn't be disrupted.
    b) Tracking and Tagging: All the incoming parts are pasted with a QR code or Bar code that enables us to track the entire data and location of the parts in a single interface. This would help us to intimate the production if there is any future information regarding the defective batch from the supplier.
    c) Inventory Management System: A proper inventory management system that has track of all the parts in the warehouse and has all the log details which have been generated using the QR code from the parts.
    d) Categorization: All the parts and Sub-assemblies should be grouped based on similar product families and run rates in the warehouse,
    e) Requirements: Considering Shelf-life and storage atmospheric requirements they are placed as needed.

    After Ensuring all the parts and assemblies are placed as per the above-said steps, A proper Path must be made out for all the designated store areas and racks, Where the resource must use the same path to reach that rack every time. This is known as Pick-Path. It generally refers to the distance traveled by the worker to pick up the order that is in WIP now. Making use of the Pick-path distance concept would highly minimize the pick-and-place distance. And in warehouse management, it would help by increasing efficiency, reducing labor costs, and optimizing space.

2. Products per Order: Based on the Excel sheet provided to us we have extracted the data and plotted it to get the number of orders in a single day.



Here each pickup has its own unique Kanban ID, in general, based on the graph shown below we have a constant leveled demand of about 180 Kanban per day. The pickup process in the warehouse ranges from picking up one to one part of heavy components to picking up in batched based on the order quantity needs and requirements.

It is important to consider factors like the size, weight, and quantity of the products required which determine the no. of products per pickup.
The usage of Forklift, carts, and Semi-automated and automated machinery can speed up the picking process and enables us to fulfill the kanban requirements in an optimized way possible. So, to correctly generate the data required we need a Warehouse management software interface that would give all the required details for every pickup trip that we make inside the warehouse.

So, to conclude based on the above said information, Order pick-up per order depends majorly on various factors and requirements. And we would implement a Warehouse management interface to optimize the process as much as possible.

3. Build a Model: We can increase the overall efficiency and optimize the layout of the warehouse by building a model. For building a model we must make sure all the necessary steps are followed and achieved.
    a) To have a clear Goal: Just like making linear programming, we must identify the objective that has to be achieved because the model that we build should not have any scope creep with it. So, here as per the inputs and talk with Tim, our ultimate aim is to reduce the amount of time spent picking up the parts and reducing the human effort involved in it.
    b) Layout and Floor Plan: To design the warehouse and have a clear well-designated space for all the activities. in this way, we can avoid all the involuntary problems that may evolve in the future.
    c) Automated Storage system: As discussed in the Analysis of Alternative we have to select the most optimal system that would greatly reduce the time and human effort with respective the current incoming Kanban.
    d) Lean Warehouse Management System: As discussed in class, Lean warehouse management systems engineering is essential to make the current AS-IS highly disorganized warehouse into a well-organized supermarket.
    e) Benchmark: Once the model and constraints are developed, we have to determine the reliability of the model for the various conditions of demand and availability. And from the observed result we need to develop a checklist with higher and lower limits, and the level of accuracy that the model can reproduce.

    Once a model is built, we need to follow the same model which has been iterated for batch sizing of Kanban Quantity, tour to choose for picking and fulfilling the Kanbans.

4. Product Placement plan: It is the art of strategic planning and executing the placing of the incoming parts and components from the supplier using the inputs from the Lean Warehouse management system engineering model.

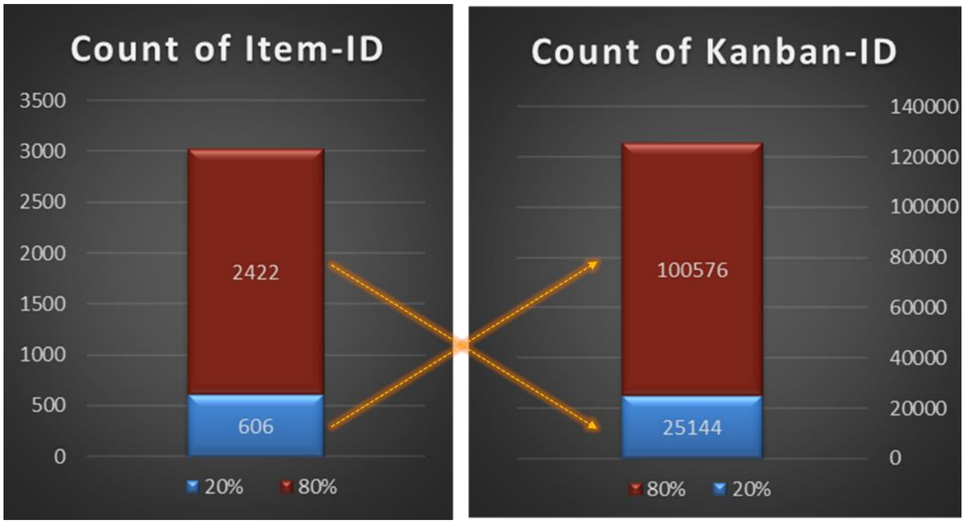
Based on the data we pulled from the input data about the Kanbans we have come up with the following criteria that have to be met and followed.

a) Product family categorizing: To study and categorize the incoming and available product families based on their physical characteristics and functional requirements.

b) Lay-line prints: To prepare a lay-line print from placing the parts throughout the warehouse, while drawing it necessary planning and correlation between the product families should be taken care of.

c) Periodic Review: Cyclic introspection of all the available stocks and to plan placement place for future requirements.

Based on the data we pulled from the Kanban-IDs provided we have found that there is a massive correlation between the KKanban-IDs and the IItem-ID i.e., Part Number



Here we have come up with a Hypothesis that, Under the current conditions of demand and requirements for the existing 11 to 14 product families, 80 percent of the Kanban's deal with the 20 percent of the Part numbers. This in-depth means that those 20 percents are the High runners in the entire warehouse. And much planning and importance must be given to placing those 20 percent in the warehouse.

5. Close to the dispatch area: Placing products close to the staging area speeds up the process and reduces unwanted Waste in the process. In the AS-IS condition of the Warehouse in Rochester Sensors, we have a separate Staging area from where the order is dispatched to the Production shop floor. In the staging area, they always maintain a minimum of two days of WIP Kanban's staged and in ready-to-dispatch condition.

So here in the TO-BE warehouse, we are giving additional importance to the Staging region, Staging place should be located in the most optimal place in the entire warehouse making it easy to reach from all the corners of the place.

a) Quick turn-around: Placing the high-runners near the staging/dispatch area speeds up the process of picking the parts from the rack and designated regions in the warehouse. This ultimately reduces the

b) Reduction of Man-hours: Placing parts near the dispatch area ultimately reduces the man-hours involved in picking the parts in the warehouse, this would considerably result in the reduction of cost in manpower and improved productivity by making the worked be more involved.

c) Optimize the available space: Once we came to know about the High-runners and low-runners, we can place the High-runners individually near the dispatch region and the low-runners paired up with the other low-runners in a much remote place in the warehouse itself. This would considerably increase the efficient use of space available in the warehouse.

Following the above-said points regarding placing the product near the dispatch area can help us increase the productivity of the worker, Reduce the headcount in the warehouse, and increase the quick turn-around.

6. Product-to-Activities ratio: The activity ratio is the measure of operating efficiency, here Product to activity ratio is the measure of how effectively we are handling the product against the activity/time. It is calculated by the number of products to be dispatched divided by the no. of activities required to dispatch the products.

   The thumb rule of the activity ratio is the higher the turnaround ratio, the higher the efficiency of the system. If the number of activities required to get a single product is high then the working or operating efficiency would be higher. (i.e., Well planned, and efficient break-down of the activity, this can be achieved by proper strategic planning and execution of the resources)

$$Product - to - activity\ ratio = \frac{Total\ no. of\ products\ handled}{Total\ no. of\ activites\ involved}$$

   This activity ratio is a continuous monitoring metric used to ensure the optimized operational activity in the warehouse. If the Product-to-Activity ratio drops we need to execute containment activities on the shop floor to find the root cause and come up with necessary retrospection to overcome it.

7. Slow Moving: Slow-moving parts in the inventory are the ones that are less frequently pulled from supermarkets. These parts may sit in the inventory for an extended period of time and have a high risk of expiring due to a low shelf-life period. So, we have to make sure the place occupied by the parts is very well optimized. These slow-moving parts should always be brought with the agreement of a mutual return-back guarantee.

   a) Regular monitoring of the metrics: Every month the currently available inventory is monitored and analyzed to identify the slow movers and take respective action and conduct retrospection.

   b) Change Inventory: Based on the result from the retrospection necessary changes must be made to the level of inventory and adjust to the latest condition of demand and requirements.

   c) Buy-back agreement: Slow-moving parts have a high risk of sitting in the inventory even over the shelf life, this type of parts has to be returned back to the original manufactured or supplier where they should be bought back, by doing so we can reduce the cost which would have a drastic impact on the entire value chain.

8. Medium Moving:

- The system with high volume and low part variabilities requires medium-level mechanization in the warehouse system to reduce the buffers in the Kanban's pull system. A semi-automated system with limited control over the operator's work efficiency. Certain automation can be implemented in material handling and delivery. Use of Electronic Kanban to minimize the lead time.

9. Fast Moving: Fast-moving parts should be placed near the staging area, which would help the workers to get the parts to the dispatch/staging area in a much less turnaround time. These kinds of fast runners contributed much of the cost and effort involved in the warehouse. The placement of the staging area should be in the middle of the warehouse enabling larger surface space to the rack around them, which could accommodate larger fast runners near it.

    a) Adequate Quantity: Being a fast runner there is a high risk of the quantities becoming extinct, so these high runner parts should always be made sure that they are in adequate numbers in the inventory.

    b) Predict future demands: Based on the current level of demand and the past historical data should be analyzed to forecast future demand, because in the worst-case scenario if they become extinct the consequence will be worse.

    c) Optimized Pickups: Picking up process should be optimized to reduce the number of times a worker has to go to and fro to pick up a single part so that we can do an optimized batching order by consolidating the similar Kanbans.

10. Keeping throughput low: The system has been developed to minimize the throughput time by increasing the service rate in the Kanban pull system used in the warehouse. This is achieved by increasing the utilization to an optimized level and reducing the variabilities in the system. The kaizen improvements in the material flow have been introduced in the warehouse by implementing a medium-level mechanization system into the existing warehouse model. The parts are positioned based on the kanban frequency by which the control of motion in the warehouse is achieved. This minimizes the operator's led time to move the parts to production. Use of electronic QR code scanners in the receiving end which reduces the operator processing time.

$$Throughput\ ratio = \frac{Production\ numbers}{Time}$$

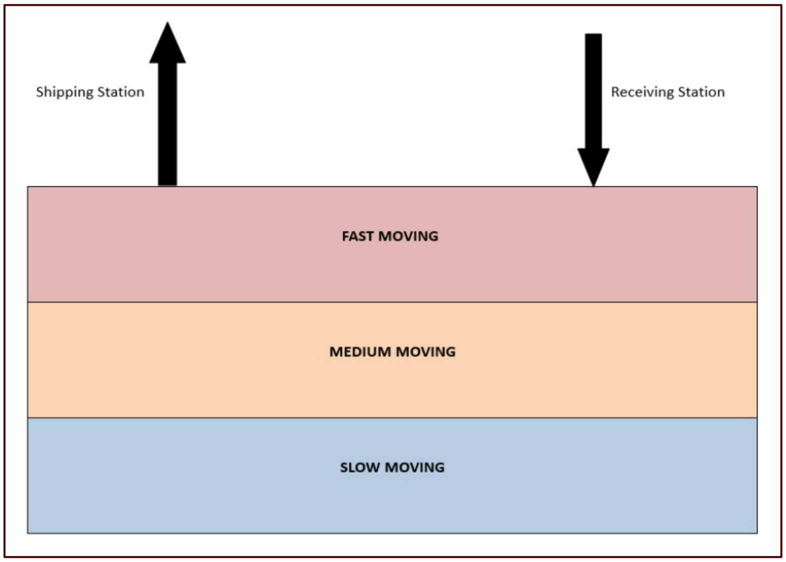
RE-DESIGNED WAREHOUSE OPERATION STRUCTURE

- Leveled workload - As demonstrated regarding the current system procedure, Kanban IDs are released for the D+2nd day's production. Once the IDs are released, the jobs are allocated in a random manner to the operators. Here, we need to understand that the operator's load can vary according to the type of component ID, its placement in the warehouse, level of placement, walk distance, the travel distance between the various component IDs tasked as a batch, type of retrieval equipment to be used for unloading, etc.

  Currently, once the Kanban IDs are released for a particular day of production, the tasks are assigned randomly to the operators without considering these factors and end up with uneven load distribution. It is important here to redesign the task allocation to work operators through an algorithm that optimizes the load. Also, since the daily Kanban release quantities may vary, it is important to leverage the information of the tentative Kanban release for the next two days to work proactively in case of a low load on that day. Following this, we can level the operating load of the warehouse as well as the operators. This can be done by calculating the load using the below matrix and grouping the component ID.

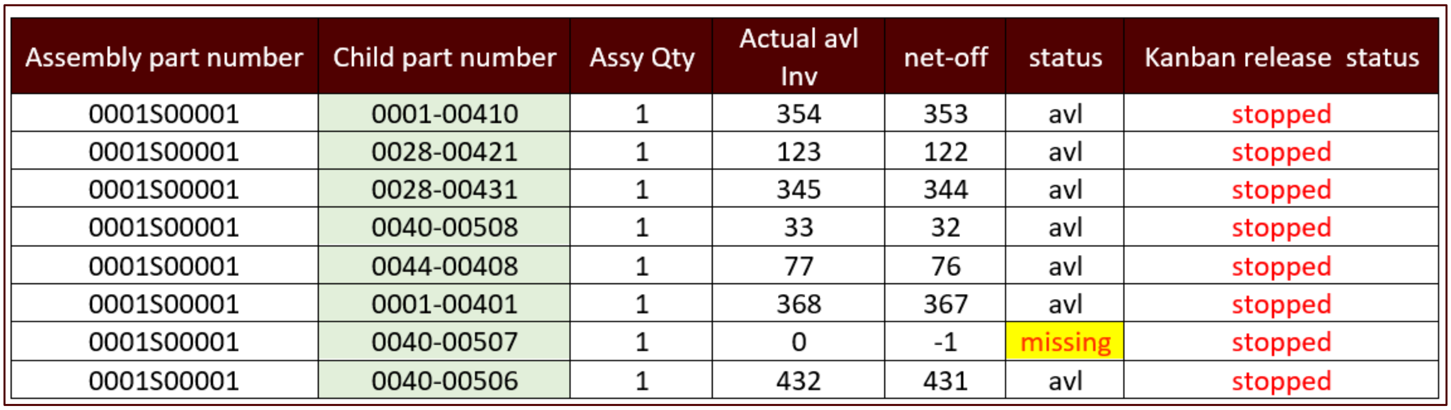
Component ID	**1**	**2**	**3**	**4**	**5**	..	..	**180**
Walk distance								
Type of component								
Level of placement								
Batch quantities								
Total time								
Retrieval system								
Component load								

- Product slotting - On a macro level correct product slotting will enable us to free up space, reduce travel time, increase visibility, and velocity to rem bottle neck sacks and wait time.



On a micro level, 20 % of the fast-moving parts when placed close to the receiving and shipping area sub-grouped by the family will allow us to reduce travel time, walk distance, and rapid response to the kanban requests. A schema of the concept is given above.

- Enhanced data management - In the redesigned layout, all the activities are optimized with the help of warehouse management software. It is of great deed to leverage the existing system using data entry from various locations. The real-time data tracking provides us with the inventory levels, BIN location, FIFO adherence, and material data input- part number, quantity, date of receipt, supplier details, etc. This is then used for many of the dynamic predictions that govern the efficient operation of the warehouse.
- WMS – planning interface - There is a special feature in the data management system, where once the kanban ID data consisting of the component IDs are linked with the assembly sequence and the assembly part number. Before the actual release of Kanban cards to the warehouse system, the interface checks if all the component IDs required for the performing production are available. If this is not the case, then the set of Kanban IDs for the assembly part number will not be released, thus protecting the warehouse from overloading/ performing activities that are potential NVAs.



Assembly part number	Child part number	Assy Qty	Actual avl Inv	net-off	status	Kanban release status
0001S00001	0001-00410	1	354	353	avl	stopped
0001S00001	0028-00421	1	123	122	avl	stopped
0001S00001	0028-00431	1	345	344	avl	stopped
0001S00001	0040-00508	1	33	32	avl	stopped
0001S00001	0044-00408	1	77	76	avl	stopped
0001S00001	0001-00401	1	368	367	avl	stopped
0001S00001	0040-00507	1	0	-1	missing	stopped
0001S00001	0040-00506	1	432	431	avl	stopped

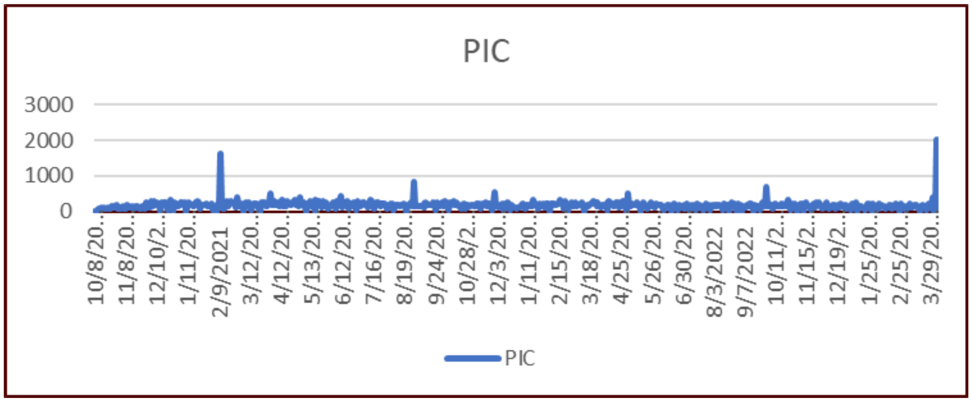
- Upstream optimization - To improve the efficiency of the warehouse, it is important to optimize the processes upstream, where the physical goods flow from the supplier end. Improvements like correct batch sizing of the quantities, type of packing for easy retrieval, modifications in the incoming material holding systems like trolleys, carton boxes, pallets for easy pickup and transportation within the warehouse, barcode/QR code entry for the incoming material & batch size consisting of information like component ID’s, batch size, date of shipment, etc. that can be used by the warehouse for their tracking. In a way, these improvements from the upstream reduce the actual operation to be performed by warehouse personnel and save time and enhance productivity.

REPLENISHMENT CYCLE/PICS PER DAY - DISTRIBUTION & LEVELING

Demand analysis: Based on the discussion with the M/s Rochester group, it is understood that demand is dynamic based on customer requirements. There are a whole lot of variants in the sensors, that are produced over a 47-work cell, with a diversified flow pattern as mentioned in the VSM diagram.

However, on a practical note, it is said that the production for over a week is fixed that does not change and there is a tentative three-week demand that is subjected to minor changes at the last time based on customer priority. This seems to be an important piece of information that we can actually use to perform demand/workload leveling in the warehouse.

Existing demand Distribution:



From the graph depicted above, demands/Kanban cards at the warehouse range from 1 to 1613, averaging to around 171. Though variations can be an outcome of unprecedented situations and accounting errors, below are the major causes that are important for us to understand to design a future state with systems that will ensure to keep this variation as low as possible.

1. With the PIC for a particular component ID completed, since some other components required for completing the sensor assembly is not in the warehouse, the production schedule is released for some other assembly ID, corresponding to a bunch of different component ID'. This results in additional kanban IDs being released on the same day, which causes variation in the load.
2. Because of line quality rejections of any component ID, there can be a complete change in schedule, and this makes additional Kanban IDs to be released.
3. Maintenance Issues preventing the production of a particular ID.
4. Variation in the supplies, not conforming to the on-time delivery resulting in a change of complete schedules.
5. Variations in the customer-communicated target date and incoming shipments, demand adjustments, and priority change.
6. This data is spread over the periods from 2020 to 2022, which was full of uncertainty with the COVID followed by the supply chain shock. Also, it is important to note, based on the communication with the director of the Rochester senor, he said there was a sudden 40% increase in sales immediately after COVID.

RECOMMENDATION FOR IMPLEMENTATION PLAN

Suggestions for Improvements in the TO-BE STATE

1) The operator order assignment is decided by the warehouse management system based on a pre-set algorithm. The algorithm considers the workload of each operator and the kanban data released by the production control. Now, the operator assignment is no longer manual, whilst it is fully automated based on a prediction system.
2) There is a total of 10 racks & 5 walk-in ways. Instead of a particular area dedicated to the equipment, we can include the equipment storage area near the rack system. This will decrease the cycle time of movement to grab the equipment and reduce searching for the equipment. Two racks share uses 1 equipment stored.
3) The WMS on allocating the workload for the operators, will clearly go through the component ID & can identify the location details on a FIFO basis. The operators dedicated to a particular walk-in way can get a printout of their assignments over time and the print consists of a list of details of component ID, its location, batch size, and delivery time.
4) An automated rack and pinion-based small automation can be done for the top level 4 trays. On the selection of a BIN number, the BIN gets located and indexes automatically to a dedicated location in the lower level. By this, we can avoid the use of large lifters and their associated time to power them & operate.
5) Improvements in the upstream process. Since all these packages and component IDs are located and received from the supplier, improvements in terms of modification of existing pallets that are used for transportation from the supplier, QR codes containing a part number, quantity, date of shipment, supplier name details, batch size, easy removal of a package, vehicle specification as per the loading docks, all these improvements can be done for better material handling, downtime reduction, data transfer to the WMS.
6) Bifurcation of stages in the warehouse namely, the fast movers, medium and slow movers on a macro level and subgrouping them on their product family and slotting at the appropriate levels for easy retrievals can greatly reduce the walk distance, distance relative to frequently picked component ID's, operator turn arounds, equipment turn arounds, etc.
7) Auto-label generation, once the components are picked, one of the many tasks of the operator is to label the component at the staging area. This manual operation can be eliminated by employing the dedicated operator assignment board to auto-generate labels along with the list of picks to be done by the operator.
8) Based on the forecasted business and the economies of scale, space utilization can be improved by utilizing the height of the warehouse and employing an auto retrieval system. This will enhance the warehouse capacity utilization and space for catering to growing production demands from the customer.

ADDITIONAL DESIGN AND ARTIFACTS

A warehouse is built to make the most of the space that is available, allowing for more storage/ picking and better accessibility. The need for additional storage space, which can be expensive, maybe lessened as a result. The flow of materials through the warehouse is shown to improve with an effective layout, requiring less time and labor to move items from one place to another. Throughput can be increased, and processing times shortened as a result. By creating clear and safe pathways for workers and reducing the need for them to cross paths with forklifts or other machinery, it can help lower the risk of accidents and injuries.

As the order is received, it goes to the tag and track place to get the products scanned using a QR code/barcode scanner. Then it moves to warehouse control supervision when then goes to the staging area for assembling the products. As the staging area is kept in the middle of the warehouse, it is very easy to access all the points inside the warehouse. The material handling points are kept next to the staging area and picking point. The production dept is located next to the staging area. There are three different types of picking kept, this is because in the warehouse the products are segregated based on fast-moving, medium moving and slow-moving. So, the picking area is built accordingly. However, once the product is moved from the picking/storage area, it goes to the dispatch area for shipment of the products. The warehouse layout is attached, and legends are shown next to the layout. There are four doors kept on the sides which consists of double doors as well as single doors. In this layout, it has three double doors and one single door.

The warehouse here implements an inventory management system that integrates with other systems such as order processing and shipment tracking. Moreover, it helps to reduce labor costs and to increase production, which allows the warehouse to fulfill customer orders and needs quickly and more efficiently. The warehouse is designed in such a way that it follows lean principles to eliminate waste and optimize the flow of goods and information.

CONCLUSION

The project dealt with the implementation of lean techniques in Rochester Sensor to reduce cycle time by reducing waste in the production system. Process mapping techniques such as value stream mapping, IDEF0 and IDEF3, waste analysis, 8-step lean production system design, and batch sizing. Significant improvements have been generated by developing an optimized information flow throughout the process.

Key performance indicators are leveraged in the order-picking process in the warehouse. New controls like automated storage systems and inventory management systems are proposed into the existing system to reduce manpower and picking cycle time.

A new facility layout is proposed in order to minimize the pick path distance and maximize the floor space utilization. The newly proposed layout attains this by placing the staging area in a location that minimizes the total pick travel distance and by segregating and storing the component parts of the master product based on high, medium, and low moving part categorization. This will be achieved by a unique racking system design.

An algorithm was developed to optimize the picking travel distance by taking various factors into consideration including component demand/kanban IDs released per day over a year, dispatch area distance, number of operators, throughput and product-to-activities ratio, and product segregation based on demand.

In conclusion, the implementation of lean techniques, process mapping techniques, and the introduction of new controls have significantly improved the production system at Rochester Sensor. The proposed facility layout, leveraging of key performance indicators, and development of an algorithm to optimize picking travel distance have contributed to the reduction of cycle time and waste. These improvements have ultimately led to the optimization of information flow, reduction of manpower, and maximization of floor space utilization, which are all critical factors in a successful warehouse management system.

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