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Improve Quay Crane Reliability through Lean-Kaizen

Rajamahanti Surya Kiran[1] | Bathineni Vijaya Kumar[2]

[1]Assistant Professor, Department of Mechanical Engineering, S V P Engineering College, P M Palem, R K Nagar, Visakhapatnam-41.
[2]PG Scholar, Department of Mechanical Engineering, S V P Engineering College, P M Palem, R K Nagar, Visakhapatnam-41.

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ABSTRACT

Continuous waste reduction via improvements is what Lean-Kaizen entails.This work demonstrates the use of the LeanKaizen co ncept in the container terminal sector at Seaport.Ship to shore cranes/quay cranes are used in container terminals at seaports.Reli ability isvital since it has a direct impact on customer satisfaction and requires a substantial amount of time and money.The work' s goal is to focus on current maintenance procedures, evaluate pertinentdata usingMAXIMO 7.5 CMMS software, and decrease v ariability and downtime bypreventingbreakdowns during vessel operations.The present condition of quay crane maintenance at a specified container terminal was documented, and a map of the current state was created.In order to bridge the discovered gap, the "5-why" technique was used to uncover root reasons, and Kaizen events were recommended as remedies. In the Lean Kaizen event, Brainstorming,DMAIC methodology, value stream map technique was applied to reduce the breakdown on container cranes by enriching the preventive maintenance plans and scheduling process.This research would eventually seek to enhance the maintenance process and minimize quay crane downtime, as well as monitor the modified procedure for a few months to demonstrate the study's success.

KEYWORDS: Lean-Kaizen, Value stream map, Lean manufacturing, Kaizen event

I.INTRODUCTION

In the quayside area, a quay crane is utilized for loading and unloading activities with containers from/to container vessels. Container terminals are where containers are moved from one mode of transportation (container vessel, feeder vessel, etc.) to another (chassis, autonomous guided vehicle, Shuttle carriers) and vice versa. QC cranes, also called as ship-to-shore cranes, travel over rail lines. A move is the term used to describe the process of loading and unloading a container. To unload the container, the QC spreader is put on it, secured with twist locks, and then raised by a hoist. The container is moved to the quay by the crane's trolley, when the spreader is dropped and the container is either placed on the ground (wharf) or loaded into a transport vehicle. The spreader is hoisted again after freeing the twist-locks and releasing the container.

1.1 INTRODUCTION ABOUT LEAN KAIZEN

Container terminal operations are under consistent pressure from customers and competitors for producing quality service at the lower cost. In order to meet these expectations, the service providers are working on adopting lean tools/technologies/principles/methodologies by implementing continuous improvement programs that minimize service cost, reduce delivery time, and

improve quality of service. Lean-Kaizen is composed of two words that is Lean and Kaizen, lean means elimination of non-value added activities and Kaizen means continuous improvement. Lean-Kaizen means continuous elimination of wastes through small improvements. Kaizen is a popular technique that applies to eliminate wastes at all levels of any organization.

"KAIZEN Event Process" includes the Overview Full Process- Prepare Event- Conduct Event- Follow-up Event.

Visual control, value stream mapping (VSM), standardization of work, pull system, and Kanban, sometimes known as the lean building block, have all been used to eliminate waste in operations. Through this study, an attempt was made to adopt the Lean-Kaizen concept using value stream mapping in order to address all forms of inefficiencies and waste present in the selected seaport container terminal's quay crane maintenance process and procedures. The research shows how to identify and execute Kaizen events, as well as the advantages that come with them. This research aids managers and practitioners in identifying waste in procedures and practices

II.LITERATURE REVIEW

Lean is a program that focuses on increasing operational efficiency, reduce costs, and reconfigure processes. It offers shorter cycle time and lead time, lower work in process (WIP) and costs, higher quality and revenue, increased production and profit, and better customer services. Lean principles (waste elimination, pull production, zero defects, streamlining of processes, quality at the source, and continuous improvement) have been accepted and applied by many Industrial managers across many disciplines. The Lean implementation success mainly depends on employee participation, proper skills and training, and top management commitment. The fundamental aim of Kaizen is to improve operations. The various studies in many countries had proved that Kaizen had progressively been accepted worldwide and could combine various waste elimination tools and techniques easily and effectively.

According to Karen Martin & Mike Osterling (2007) [24],Kaizen Events are an effective way to train organizations to break unproductive habits and adopt a continuous improvement philosophy while, at the same time, achieve breakthrough performance-level results. Through Kaizen Events, cross-functional teams learn how to make improvements in a methodological way. They learn how to quickly study a process.

Kumar S, Harms R (2004) [9] stated that continuous improvement can be achieved through process mapping to visualize wastes and ultimately trigger Kaizen activities.

Bateman NA (2005) [25] notified that Lean-Kaizen implementation is the way of improving the performance in internal and external quality of service processes.

Bhuiyan N, Baghel A (2005) [26] illustrated that continuous improvement program helps in identifying and eliminating wastes in the production line and improves the quality of product.

Brunet AP, New S (2003) [27] conducted empirical study on Kaizen and concluded that Kaizen evolves uniquely within each organization.

Van Scyoc K (2008) [28]evaluated various quality improvement tools and techniques such as Kaizen and poke-yoke to improve both the leadership in process safety and the performance of a fieldwork team. He explored how methods are applied for improving product quality to attain continual improvement with process safety.

Glover et al. (2011)[30] notified that sustaining results of a Kaizen event is difficult over time for many organizations. They identified the factors which prominently affect sustainability of work area employee attitudes and commitment organization.

Karim and Arif-Uz-Zaman (2013) [31] proposed a methodology which enables systematic identification of manufacturing wastes, select appropriate lean tools, identify relevant performance indicators, achieve significant performance improvement, and establish lean culture within the organization.

Dibia et al. (2014) [32] developed a social technical model named as lean "Leadership People Process Outcome" and measured benefits as waste elimination and process optimization that drive the industry towards continuous improvements.

Stadnicka D, Ratnayake RMC (2016) [33] explored the advantage of lean tool implementation in the plain old telephone service industry.

Chen et al. (2010) [34] implemented Value stream map practices (VSM) is a fabrication process and identified process improvement opportunities by drawing current and future state map of the existing processes. The study proposed Kaizen events to bridge the gap between current and future state of the fabrication process and after applying Taguchi experiment design and rabbit chasing techniques, the study witnessed the reduction in variation of plasma cutting process, reduction in inventory levels, and improvement in the system flexibility of the organization.

Singh et al. (2010) [29] conducted a case study in crankshaft gear manufacturing process and bridged the gap between current and future state of manufacturing organization and finally concluded that VSM is a dominant tool that helps an organization to improve the understanding towards lean. Applied VSM to identify wastes such as WIP, lead time, and manpower by bridging the gap between current state and future state of a production industry. Singh et al. concluded that VSM is valuable practice for identification and elimination of various wastes. VSM, a lean manufacturing technique, is dissimilar than orthodox techniques and enfolds both value added and nonvalue added activities.

Ramesh V, Kodali R (2012) [36] proposed a decision framework for accurate selection of VSM tools based on organization priorities. The study concluded that VSM can reduce all system wastes, minimize resources and optimize organizational performance level.

Vinodh et al. (2013) [37] eliminated wastes by applying VSM using 5S in the investigation conducted in a cam shaft manufacturing steering system of automobiles, and the study explored that VSM can eliminate wastes.highlighted that VSM is a significant lean manufacturing technique that emphasis on the micro-analysis of a manufacturing process.

Dorota(2014) [38] applied VSM with Kaizen for further reduction in product lead time and to improve the safety of the workplace in a smallscale bench vice manufacturing organization.

Prashar A (2014) [6] employed the Lean-Kaizen approach using VSM for process improvement through redesigning an assembly line in a manufacturing steering system of automobiles. VSM simplifies lean implementation track by detecting gap areas in the organization.

Ciarapica et al. (2016) [40] proposed VSM as proactive approach to choose the best technological approach at the commencement of the project.

III.METHODOLOGY

Lean-Kaizen process starts with reviewing of current state and identifying the variation/waste in the existing process. Ways of identifying waste/variation is mentioned hereunder:

Identifying 8 types of waste:

- Rework, adding or removing material or information/ not 1st time right or clear
- Doing more than needed for immediate use. Quantity problem – cannot be sold
- Any delay between the end of one process and the start of the next activity
- Underutilized creativity and capability
- Unnecessary movement of products, materials or information
- Any material, documents or information not yet used by next process
- Unnecessary movement of people
- Using more activity than is needed or adding more than agreed standard

IV.OBJECTIVES OF THE WORK

The Major function of quay crane in container terminals is to handle the containers to and from ship to shore and vice versa.The handling of each container through quay crane is consider as "move".Hence it is worth to add following as objectives

- Analyze current Mean move between failures (MMBF)
- Improve in mean move between failures (MMBF)
- Analyze the current mean time to repair (MTTR)
- Reduce in repair time (MTTR)

V.EXISTING METHODS

Current process detailed below from arising breakdown to work order completion. In current state, at the time of break down Quay crane operator is informing to Tally clerk through Intercom device. Tally clerk will convey the Breakdown information to Operations

supervisorthrough Radio or phone communication. Operations supervisor will inform to Operations planning through Radio or phone communication. Operations planner will create Service request in Maximo software and convey the message to Engineering control room officer through Radio & Phone. Engineering CRO will check in remote crane management system to reset the fault. If fault got reset remotely Maintenance request will be cancelled and crane readiness information will be given to operation planning. Operation planning will convey the message to operations supervisor from thereto QC operator to restart the operation. On the other hand, if the fault is not reset remotely then CRO will review the maintenance service request and he may seek further info /Approve the service request. Once SRApproved,workorder will be raised in system(MAXIMO) with the status of WACCPT.CRO will add anticipate require material and manpower resources in WO and route the work order status to APPR. Approved workorder will be appeared in EM supervisor (MAXIMO) inbox. EM supervisor will assign the EM technician for particular breakdown work and route the workorder to INPRG status. Operations team will be updated on work status through EM Supervisor. Once Job completed WO status will be changed to COMP status in MAXIMO.

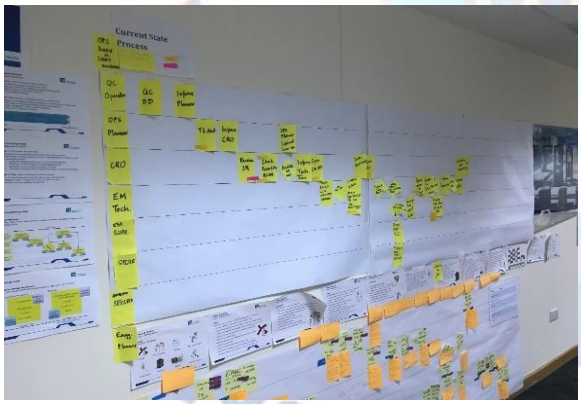


Fig-1 Current state process

In existing process all work related updates are being provided through Emergency Maintenance supervisor. EM supervisor is fully engaged in rectification work as well as communication with operations over break down. In existing process entire quay crane is maintained at same frequency whereas failure rate is different for subassembly to subassembly of crane. Spare spreaders are parked at workshop and will be shifted to quay area at the time of quay crane spreader break down only.EM crew and Supervisor has single utility vehicle. Heavy tool box is being used for attending break downs which is difficult to handle all the times

VI.PROPOSED METHODS

By analyzing the existing methods new methods have been proposed.It has been discussed over cross function personnel to identify the wastes in the existing process and to enrich the process flow. The below fig is a Pink post it = Waste/ Variation/ causes.

Fig-2 Identifying waste or variation

In existing method at the time of break down QC Operator is informing to tally clerk through intercom. tally clerk will convey the Breakdown information to Operation Supervisor through radio and operations supervisor to operations planning.In current process too many people involved and multiple communication and service requests for same break down. Sometimes break down duration is different in Engineering and Operation reports.EM supervisor productivity is less as most of time busy with phone and radio calls.

In this process multiple service request,multiple communication, information errors and multiple follow-up to EM supervisors considered as waste and new methods proposed in such a way that above mentioned wastes are limited to extent. Below orange post indicates the improvement idea proposals generated in brain storming session to overcome the wastes.

Orange post it = improvement idea

Fig-3 Generating Ideas for improvement

In new proposed process Operator will select BD from I-pad menu provided in Operator cabin. In addition, he can communicate directly to CRO on radio.Once Operator press the break down tab, service requestwill raise automatically in MAXIMO system and reach to CRO inbox.Here Tally clerk,Operation supervisor role detached in reporting breakdown and operation planner role limited to follow up of break down with CRO if breakdown resolution took long time.Once SR received to CRO inbox he/she will check in remote crane management system to reset the fault. If the fault is un resettable SR will be approved by CRO and workorder will be initiatedautomaticallyin system. CRO will route workorder to approve status and WO will reach to EM supervisor inbox. All follow up from operations department will be handled by engineering control room officer and EM supervisor can focus more on repair activities rather than communication part.

Proposed to analyze the breakdown count among each quay crane as well as sub-assemblies wise since failure rate of quay crane subassemblies would be different.Further Maintenance frequency can be amended for affected subassemblies. Proposed to amend the preventive maintenance plans task list with reference to break downs and cover the maintenance tasks in a planned way instead of unwanted break down.

All improvement ideas are arranged in impact vs effort pattern and highimpact, easy to implement tasks are chosen to initiate soon.

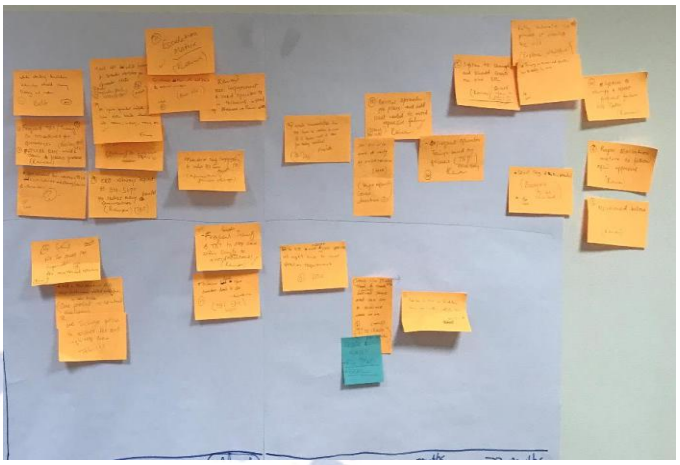
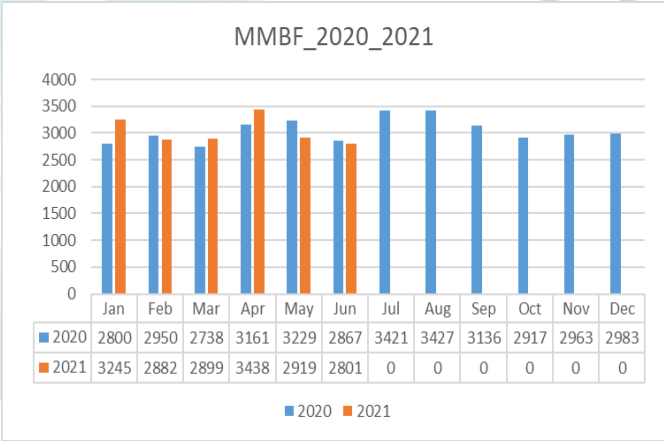


Fig-4 Improvement actions

VII.DATA-COLLECTION & INTERPRETATION

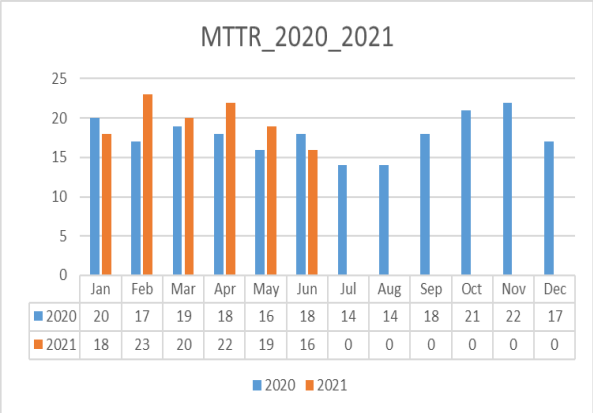
Mean move between failures(MMBF) is the ratio of containers being handled to number of stoppages. Measuring MMBF will give clear picture of quay crane performance as it indicates the performance value in container moves per each break down count. MMBF of quay cranes are shown & tabulated below in Graph-1.In this Graph monthly MMBF values for year 2020 and 2021 has been shown. MMBF in the range of 2,801 to 3,438 with an Average value of 3000 container moves.Higher the MMBF value will indicates the high performance of quay crane



Graph-1 QC Mean move between failures

MEAN TIME TO REPAIR:-

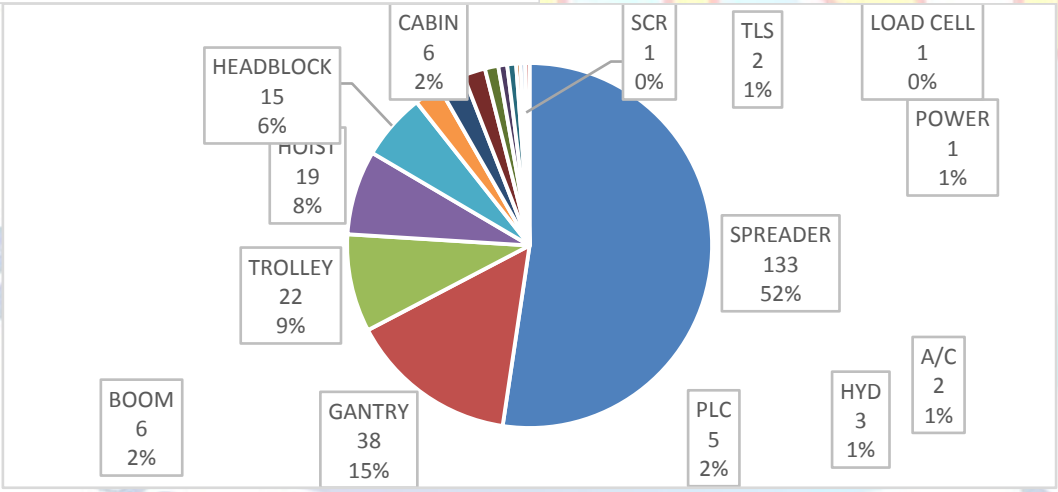
Mean time to repair (MTTR) indicates the average repair time of breakdown. In general, it is measured by ratio of total down time to number of stoppages. It gives clear picture on how quickly responded to break down, fix the equipment and put back to operation. Mean time to repair of quay crane break downs are shown &tabulated below in Graph-2. Monthly MTTR values for year 2020 and year 2021 has been shown. Here Mean time to repair in the range of 16 to 23 minutes with an Average value of 20 min.Lower values of MTTR will indicates high performance.



Graph-2 QC Mean move between failures

VIII.DATA-ANALYSIS & VALIDATION

Quay crane is a combination of various subassemblies and mechanisms. Before analyzing the breakdowns, it is worth to categorize the breakdowns type. In this analysis total breakdowns are grouped with respect to subassemblies. These break down are further categorized with respect to break down duration. This analysis reveals the subassembly and mechanism that is causing for more stoppages thus efforts can be applied in right direction to obtain better results. Technical breakdowns with respect to subassemblies or mechanisms are mentioned hereunder in Graph-3. Below graph summarizes the subassemblies with various color codes andit's percent of breakdowncounts

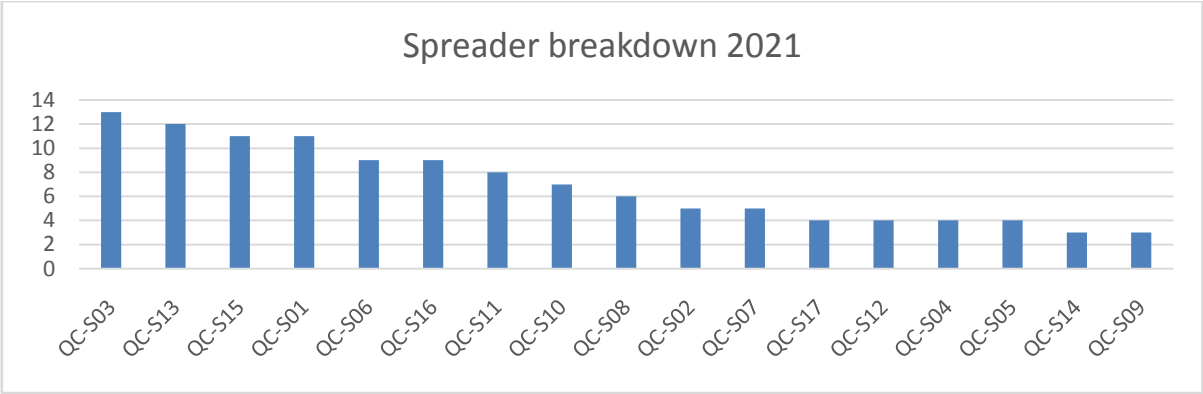


Graph-3 QC Subassemblies Break down count

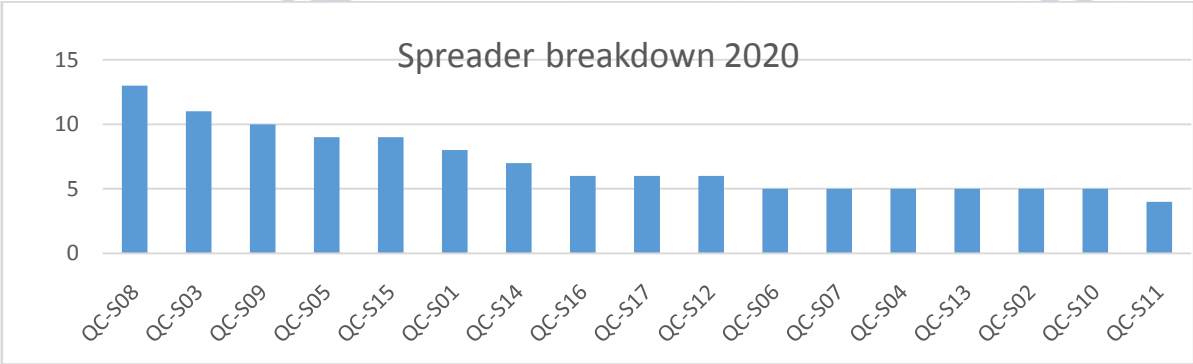
From the above analysis its proven that the most influencing subassembly for Quay crane stoppage is spreader which is shown in blue color.Hence its worth to analyze spreader in detail further.

QC Spreader Breakdown Analysis

Spreader is the attachment which is involved mainly in handling of container from vessel. it is hooked with Quaycrane to lock and unlock containers. Below Graphs shows spreader break down counts for entire year with individual spreader wise. The most break downs causing spreaders are identified and actions taken to improve the MMBF.



Graph-4 QC Spreaders Break down count year 2021



Graph-5 Breakdown analysis Spreader wise year 2020

Considering the above spreader counts, problem –solution matrix have been listed below for improvement in MMBF.

Table-1 Problem –Solution matrix for MMBF

Problem	Solution
QC-S03 always breakdown. Some spreaders repeated breakdown. In middle cranes.	Planning process for spreader in middle cranes to be rotated on external cranes periodically based on operating hours
Too many spreader failures --> Improper maintenance	Review spreader job plans based on breakdown logs of 2021 and add what needed to avoid repeated failure
Too many spreader failures --> Mishandling ops + not always correct data provided, unreliable analysis of repeated failures + prevention	Frequent operator training based on failures (TBT + add to training manual)
Too many spreader failures --> Coordination with PM	Daily report on reliability of QC through Maximo + system to identify & report frequent failures with codes.
After spreader more gantry issues, which take longer time. --> Not enough gap - over travel - close bay to	Periodic training & Tool box to stop crane within limits. Train vessel supervisor to avoid over travel

bay operation	when moving from gantry station
EM work order closing – data not always provided to CRO, unreliable analysis of repeated failures + prevention	1. EM work order need to verify by EM supervisor. Shift reports covers deviation 2. work order closing by EM supervisor on Ipad.

Table-2 Problem –Solution matrix for MTTR

Problem	Solution
Too many emails and calls to EM supervisor for updates from multiple people for same issue delaying actual solving issue and crane back to operation. No visibility status. No information with ops team. Waiting for information.	1. Real time visibility of status open breakdown SRs for CRO - que like IT Maximo dashboard/ MacDonald's ordering 2. Screen to show live status of crane breakdown in operations 3. Escalation matrix - one point of contact between ops & tech
No efficient way of reporting breakdown. Too much communication – too many steps (6) & people (5) to get info to technical after breakdown, delaying start of fixing	QC operator push button on touch screen, automatic SR creation direct to CRO + call from QC operator to CRO
Sometimes operator not responding once Technical at QC. Not picking crane channel.	Tool box talk - operator should keep on QC channel during breakdown (should not change)
CRO directly informing technician, not EM supervisor, not knowing location/ current job	CRO always report to EM supervisor to reduce many parallel communications.
- 2 breakdown logs Tech/ Ops – spent time debate which one correct - Too many manual entries in EM work order - Multiple SR for 1 breakdown. Create again if reason change/ delay	QC operator push touch screen, auto SR creation. After acceptance CRO automatic T1+WO. WO closing on IPad by EM Supervisor with operational/technical breakdown. 1 report for OPS & TECH
Some material like V1 relay programming during breakdown delays fix --> Delay due to unconfirmed device	Identify, configure and make ready all configurable devices at store. Add to tool box talk & technical procedure.
Technician attending breakdown without tool bag/ radio	Order belt type tool bag
Time to arrange materials Sometimes 2 technicians going.	1. TBT on one person on top and one person in car when attending QC breakdown to support for parts

Sometimes EM supervisor unavailable, then no number. No Maximo system access.	2. Material issuance - support from PM supervisor when EM supervisor unavailable
When 2-3 breakdowns, only one pick up for multiple breakdown	1 more pick up for EM team
Waiting for confirmation which spreader is ok to change. Tech does not know, no visibility	keep spreader status at spreader and white board in spreader workshop
Waiting for spreader change	Keep ready spreader close to operation area

Table-3 Completed activities during KAIZEN event

Overall action	Completion Date
Tool box talk to train vessel supervisor to avoid Gantry over travel when moving from gantry station	**Closed**
1. BD reporting process to be simplified. 2. Operator to inform technical first instead of foreman. Toolbox Talk	**Closed**
Tool box talk - CRO will report to EM supervisor through radio	**Closed**
Tool box talk on using one type of communication - Radio, no intercom. sticker note inside cabin	**Closed**
Tool box talk - operator should keep on one channel (should not change)	**Closed**
To keep spreader status at spreader and white board in spreader workshop	**Closed**
1. Send frequent operational breakdowns to operations 2. Request HR to add to training manual etc.	**Closed**
Raise PR for belt type tool bag	**Closed**
TBT on one person on top and one person in car when attending QC breakdown to support for parts	**Closed**
Configure and make ready one configurable devices at store.	**Closed**
Create Escalation matrix - one point of contact between ops & tech	**Closed**

Table-4 30-Day Implementation list

Overall action	Completion Date

Planning process for spreader in middle cranes to be rotated on external cranes periodically based on operating hours	20-07-21
Review spreader job plans based on breakdown logs of 2020	30-07-21
QC operator training on frequent operational breakdowns, how to prevent + identify + report issue - add to training manual etc.	30-07-21
Tool box talk - QC operator to directly call CRO when Breakdown	10-07-21
QC operator push button on touch screen, automatic SR creation - after acceptance CRO automatic T1 + WO.	17-07-21
Screen to show live status of cranes from breakdown to close in operations	26-07-21
Real time visibility of status of open breakdown SRs for CRO - que like IT Maximo dashboard/ MacDonald's ordering	26-07-21
1 more pick up for EM team - justification + PR	28-07-21
Order belt type tool bag	08-07-21
Send email on Material issuance - support from PM supervisor when EM supervisor busy	08-07-21
Special trailer for 2 spreaders - check budget	30-07-21
Ready spreader location to be identified near QC	26-07-21
Identify, configure and make ready all configurable devices at store. Add to tool box talk & technical procedure.	30-07-21
Create & communicate Escalation matrix - one point of contact between ops & tech	15-07-21
Send email - Tool box talk - one extension to contact ops planning in case of EM breakdown	08-07-21
Review completion of EM work order process (e.g. Every shift end EM supervisor to CRO to confirm activities, name hours, etc.)	17-07-21
WO closing with operational/technical breakdown. 1 report for OPS & TECH	17-07-21
IPad for breakdown reporting and WO completion - EM team	30-07-21
Daily report on reliability of QC through Maximo + system to report frequent failures	30-07-21

IX.RESULTS & DISCUSSION

Even though some of the activities are being Implemented it is always worth to measure the performance and track the results for already implemented activities. In Kaizen event generated Ideas are implemented on the basis of impact and effort analysis. High impact on performance and less effort tasks are prioritized for implementation.

Progress will be shared at monthly steering committee using the below template to track implementation and sustainment

- New process implementation for QC breakdown reporting& rectification
- Performance Results will be tracked for MMBF & MTTR

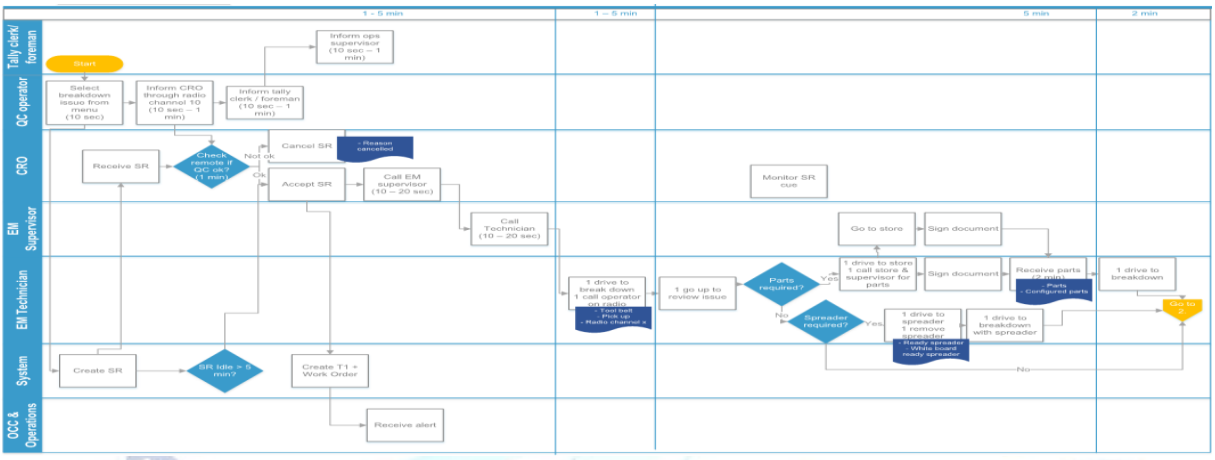


Fig-5New process (Contd.)

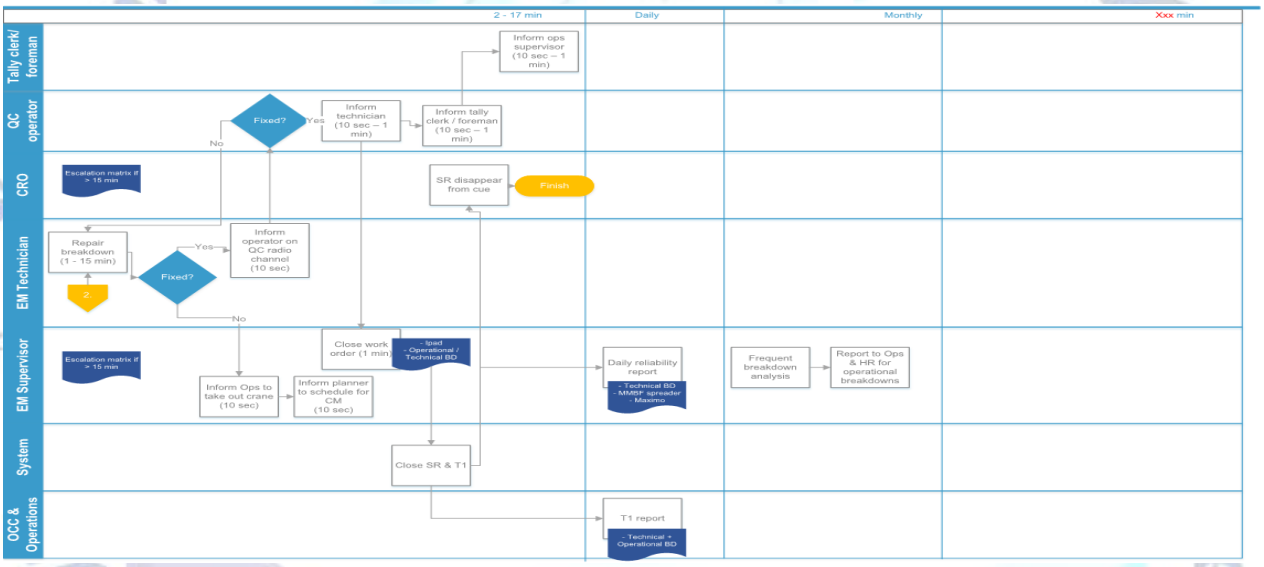


Fig-6New process

As a part of improvement, new process has been resulted which was shown in Fig-5.By removing the Waste, non-value activities/communication from the existing process new simplified process flow evolved.This new process enables the equipment operator to communicate promptly and concisely with Technical team. Communication with in Technical department also stream lined in view of improving the repair time.

In new process, break down report time from quay crane operator to engineering CRO is limited to within 10sec since it's a matter of select the break down tab in I-PAD installed in operator cabin. Rest of process is fully automated by integration of crane PLC to MAXIMO software. CRO will receive SR in his MAXIMO inbox. In remote crane management system CRO will try to rest the fault within 05 min if it's not possible to reset CRO will approve SR which was received in his inbox. Once he approves SR automated email notification T1 message will send to all operation concern parties.CRO will be single point of contact from engineering side for operations team queries hence EM supervisor can focus dedicatedly on repair activities. Once repair activity completed and crane back in operation EM supervisor will complete the workorder and same time service request will be closed and message will be notified to all concern that work has been completed. Breakdown start, end time and duration will be captured in MAXIMO records.

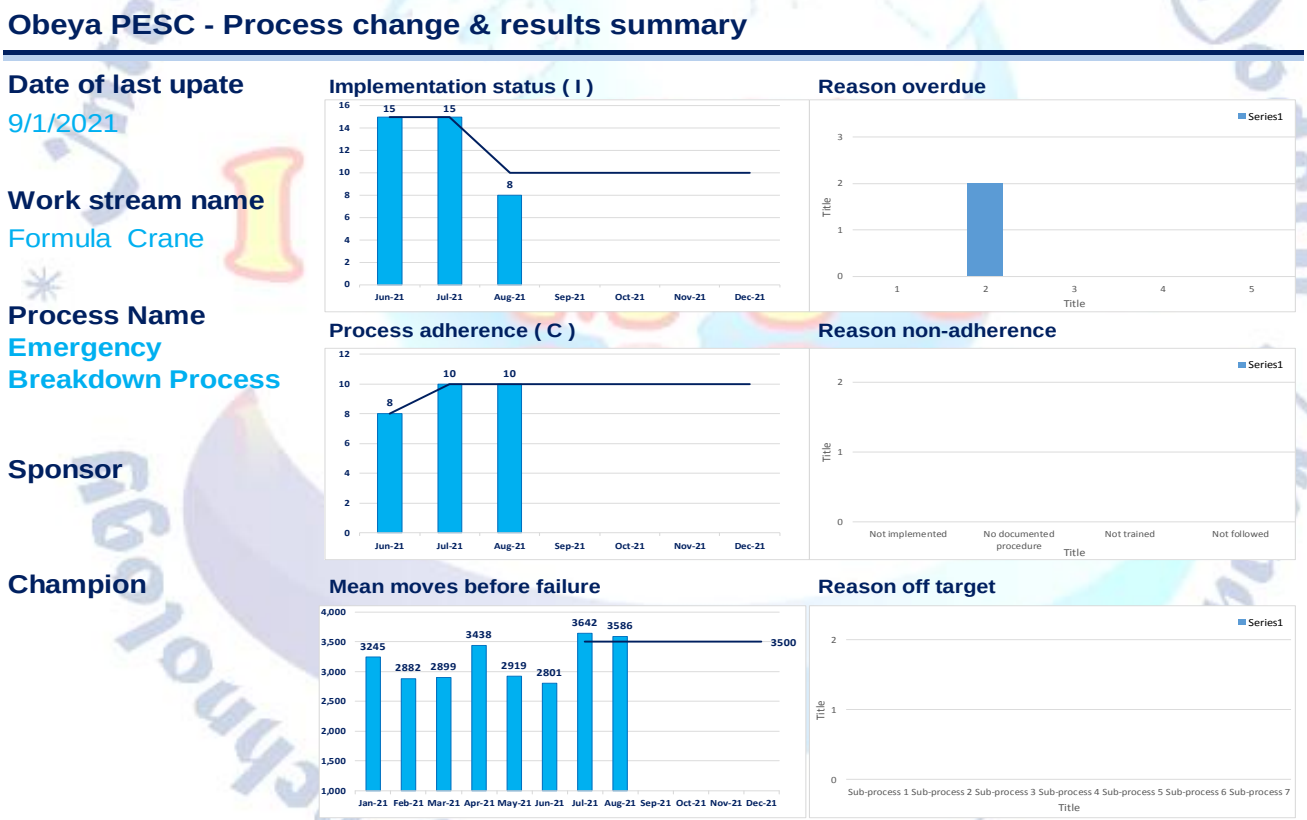
RESULTS:

The tabular form that is presented below clearly indicates the improvement wrt to the existing methods and the proposed methods:

Table-5 Results summary

Anticipated Results	Before	After	% improvement
Mean moves before failure per month	Min 2801 Av 3031 Max 3438	3614	19
Mean time to repair in min	Av 20	16	20

Table-6 Steering Committee report



X.CONCLUSION

Improve the Quaycrane reliability & reduction of break downs are vital for container terminal operators. In this work, reliability is measured through metric Mean move between failures i.e MMBF. Lean –kaizen methodology applied to improve the MMBF rapidly in a cost effective manner. Action points from the outcome of Lean -Kaizen implemented and proved that significant improvement in MMBF and MTTR.Planning process established for spreader in middle cranes to be rotated on external cranes periodically based on operating hours.Spreader Jobplans reviewed and PM plans amended by incorporating the tasks from the outcome of break down analysis.By this Approachbreakdown counts are minimized.

Focused on QC operator training on frequent operational breakdowns, how to prevent, identify & report issue - incorporating to training manual etc.Tool

box talk given - QC operator to directly call CRO when Breakdown occurred thus create single point of contact between operations and technical.QC operator facilitated by push button on touch screen to report break downs, automatic SR creation - after acceptance by Technical control room officer (CRO) automatic T1 + work order will be generated. Simplified the break down reporting process and new future state flow chart prepared and circulated over the cross functional departments to follow in future.Arrange the Special trailer to handle double spreaders at a time and always keep the Ready spreader in specified location near to the QC. Technical team Identify, configure and make ready all configurable devices at store. Add to tool box talk & technical procedure as well to sustain the process in long run. Real time visibility of status of open breakdown SRs for CRO - queue like system inMaximo dashboard implemented alike to MacDonald's ordering system. One more pickup assigned to EM crew for promptly responding to breakdowns and special tool bag (belt type) provided to EM crew for easy handy to carry the tools at work spot.I-Pad providedto EM crew/EM supervisor for breakdown reporting and WO completion on the spot. By Implementing the above tasks MTTR improved significantly. Overall MMBF & MTTR improved by 19% and 20% respectively.

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