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Productivity improvement in the operations of a port operator located in Peru, through the synergy of Lean Service and S&OP

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Abstract*– Port terminals play a key role in articulating economies, trade, and community development. Their competitiveness depends on the coordination between the different actors in the supply chain, such as customs, port authorities, shipping lines, logistics operators, and foreign trade agents, which makes the market more dynamic through the exchange between exporters and importers. Maritime trade represents around 80% of global trade, in the context of growing containerized cargo at global and regional levels. In the case of Peru, this scenario is enhanced by the entry into operation, as of November 2024, of a mega-port financed with Asian capital. It is necessary to implement strategies to ensure the sustainability and value of the port under study. In addition, since the pandemic, foreign trade has become more expensive globally due to the shortage of ships and containers, marking a price trend different from that of the previous period. Therefore, this research focuses on reducing the economic impact related to opportunity costs, and operational costs in receiving and shipping costs of containers to a port operator. In the first phase, the level of accuracy in the forecasts of the containerized volume of TEUs (Twenty-foot Equivalent Units) was improved; in the second phase, an improvement in the processes was designed through the use of tools of the Lean philosophy and the leveling of loads through the implementation of S&OP (Sales & Operations Planning). The use of this methodology will allow the achieve of a cumulative incremental volume of 86,250 additional containers to the average capacity, with an additional economic income of 6.9 million dollars for the company in a three-year horizon.

***Keywords*-- Lean Service in port operations, sales & operation in port resource allocation, process improvement in port operations.**

I. Introduction

In 2008, according to the National Port Authority (APN), the volume of containers moved in port terminals represented approximately 50% of the total volume of maritime trade in the port of Callao, reflecting the concentration of cargo flow that is operated in port terminals designed for containers. According to MINCETUR, in its national strategic export plan 2025 (PENX), ports are placed as pillars for the facilitation of foreign trade and efficiency of the logistics chain, this has been evidenced by public or private investments made in logistics infrastructure and through the support to port concession processes, to reduce logistics costs in the supply chain [1]. In the period from 2003 to 2023, container throughput, TEUs, increased by 352%, from 697,836 to 3,153,934 TEUs [2].

Between 2014 and 2023, Peru had moderate growth of 2.3%, with one-third of the population in poverty, in contrast to the 6.4% growth and poverty reduction between 2004 and 2013. This setback is attributed to institutional deterioration, a less favorable economic environment, the impact of COVID-19, and political instability and social conflicts since 2018. In 2024, the Peruvian economy will recover from the previous contraction, with expected growth of 3.1%, driven by higher confidence, better mining prices, public investment, and looser monetary measures. Growth of 2.5% is expected for the period from 2025 to 2026, and a 3% reduction in the Peruvian poverty rate [3]. The multisectoral strategy estimates that it will reduce the level of unemployment and the reduction of poverty indicators. For this it is necessary to strengthen and articulate trade, intrinsically it refers to the growth of the volume of exports and the volume of imports, which are developed via sea and air. Currently, maritime transport is the one with the highest volume of trade.

In Peru, port terminals generate new investments and industries, given that worldwide more than 80% of trade is moved by the oceans [4]. Ports are a nerve center in the Peruvian economy, given that it imports around 50% of what it consumes and that this enters through seaports, and in Lima, more than 75% of the total national cargo is mobilized [5]. Therefore, it is of vital importance to have ports with an efficient infrastructure, with operations that guarantee the correct flow of merchandise exchange.

The port operator under study is located in the Constitutional Province of Callao and has been operating in the region for approximately 19 years. It has improved its service, surpassing each year the previous year's record in terms of the number of containers mobilized, even surpassing the goal of its entry into Peru, the million (1'000,000) TEUs (Twenty-foot Equivalent Unit). During the year 2023, the port under study managed to mobilize more than 1.64 million TEUs [6], due to the implementation of operations optimization policies within the port operator and in the storage terminals, and the acquisition of new infrastructure such as quay gantry cranes and yard cranes. Therefore, the hypothesis for the development of the research is as follows: If we improve the time of reception and shipment of containers, as well as the elimination of processes that do not add value, it will increase the level of perception of customer service and therefore a greater return to the utility.

Given the growth trend in the volume of containers moved at the national level and the priority given by the government to the ports' investment agenda, the relevance of this study for Peruvian society can be deduced, which aims to find a contribution to the search for efficiencies in logistics operations in the face of the hypothesis of originating high opportunity costs, operating costs and a negative impact on the level of customer satisfaction, with the sales and operations planning process as the axis.

II. State of Art

This section describes the concepts that have supported the research.

A. 5 WHY

It is a technique frequently used in the analysis phase, which by asking questions at least 5 times at different levels of the why of the problem, the most probable root cause can be determined [7]. To perform the analysis, it is recommended to have the following steps:

- Conduct a brainstorming of the possible problems.
- To raise at least 5 whys at different levels to find the root cause of the problem.
- Avoid answering the "who", since the problem is sought and not the person responsible.

The objective of this technique is to find the true cause of all ills, and not to remain with superficial symptoms (see table 1). It is worth mentioning that there will not always be 5 levels of causality, sometimes they can be lower or higher, as required by the analysis and complexity of the processes [8].

Table I
5 Whys

Problem	Why does A happen?	Why does B happen?	Why does C happen?	Why does D happen?	Why does E happen?
Problem A	Answer: because B happens.	Answer: because C happens.	Answer: because D happens.	Answer: because E happens.	Answer: because ….

B. Principles of Lean Thinking

According to James Womack [9], and Novau Dalmau & Suárez Regalado [10], Lean thinking can be summarized in 5 principles:

B.1. Specify precisely the concept of value for each product

The value that the customer needs and is willing to acquire is defined. This is a fundamental step for lean thinking and can only be defined by the final consumer. Value is created by the producer.

B.2. Identify the value stream for each product

Identify the value chain that encompasses a set of processes and activities necessary to transform raw materials into products, or to generate services, which will be delivered to the customer. Identifying the entire value stream for each product helps to identify a large number of wastes, such as processes that unambiguously create value, processes that create no value but are unavoidable, and additional processes that create no value and can be immediately avoided.

B.3. Making value flow without interruption

The mechanisms performed by the organization articulate the processes that a product needs from its conception to its design, manufacture, and distribution. After identifying the activities that add value to the product, mapping the value flow of the organization's entire process, and eliminating processes in which waste is evident, the next step is to ensure a continuous flow in the stages that create value for the product through a complete reorganization.

B.4. Pull - Letting the consumer attract (pull) the value coming from the manufacturer

The pull strategy is defined as a system that addresses both transformation systems and sending/receiving systems (downstream to upstream). When flow is introduced, the time required to go from conception to launch, from sale to delivery, and from raw material to consumer, drops significantly.

B.5. Pursuing perfection

The above 4 principles form a circle, which means that there is always room for improvement, i.e. perfection is the radical elimination of MUDAS in the sequence of operations in the value chain. The most important point to reach perfection is transparency. Each person involved in the production process can see everything that is being done, and instant feedback is produced to improve the methodology (see Figure 1).

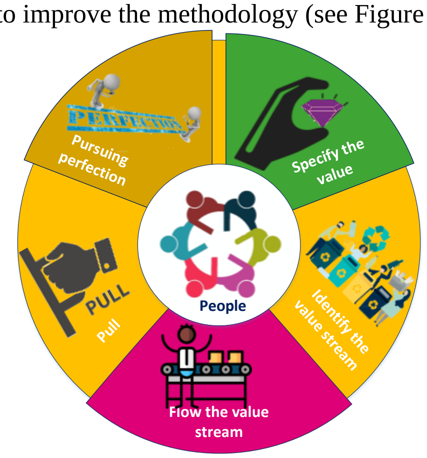

Fig. 1 - LEAN Circle of Perfection

C. Lean Manufacturing Tools

For the identification and elimination of waste in the processes there are tools, and these can be grouped into three levels: 1) demand, the level at which the customer's needs for their products or services are understood, also considering the delivery time and price; 2) continuous flow, allowing there to be a continuous flow within the production process so that customers, both internal and external, can receive the required products and resources; 3) leveling, focuses on the uniform distribution of work, by volume and variety, allowing the realization of small orders by decreasing the inventory of product in process and final product [11].

Fig. 2 - LEAN tool
Source: (Tapping & Shuker, 2003) [12].

D. Value Stream Mapping (Value Stream Mapping)

This tool is used at the demand level. According to Locher, the value map is the set of all actions that are required for the production of a product or service through critical management tasks [13]. Figure 3 details the recommendation for the use of process mapping.

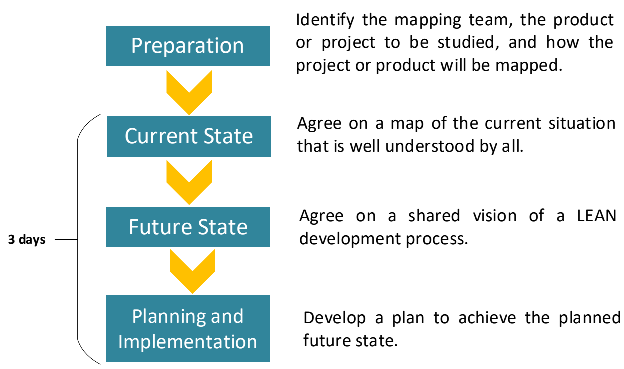

Fig. 3 -. The value mapping process
Source: (Locher, 2008) [13].

E. 5S's

The 5S's are five Japanese principles that are used within workshops and offices to reach order and cleanliness and detect anomalies within the workplace [14]. The 5 principles are:

- ***Sort:*** Everything is organized, separating what is useful from what is not useful and then classifying these elements.
- ***Set:*** Everything that is not useful is discarded and rules are set for the order of each tool, making it easily accessible for use.
- ***Shine:*** An initial cleaning of the workplaces is carried out so that the operators can identify with their assigned workstation and machinery.
- ***Standardization:*** Using indicators and controls. These standards should be simple and visible at all times.
- ***Sustain:*** Frequent self-inspection of the workstation should be encouraged with the help of check sheets so that progress in order and cleanliness can be seen.

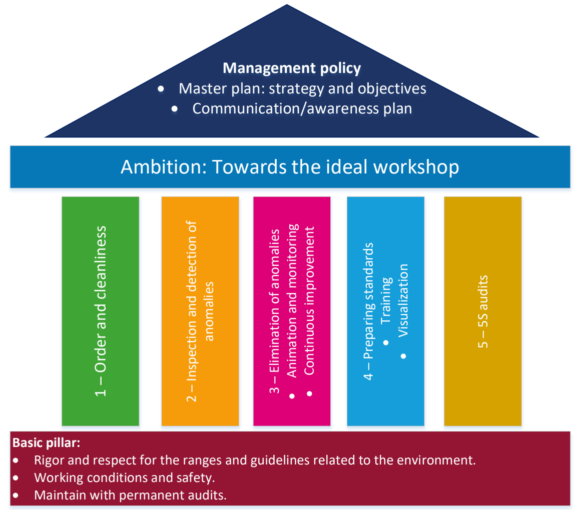

Fig. 4 – Iteration of the 5S
Source: (Rey, 2005) [15]

F. Total Preventive Maintenance (TPM)

TPM is a comprehensive approach to the continuous improvement of production resources designed to improve corporate economic performance. It is comprehensive in that it concerns the entire company, both the manager and the operators. This Lean methodology is used to improve equipment uptime and reliability. It is an approach to equipment maintenance, involving teamwork of maintenance personnel and operators focusing on elimination of equipment-related breakdowns and defects [16]. According to Agustiady & Cudney, six losses can be prevented within a factory [17]: Breakdowns, Setups and Adjustments, Downtime, Minor Stoppages, Quality, and Rework. According to Bufferne, the main objective of TPM is to obtain the maximum efficiency of the equipment, to reduce the cost of the products, and to optimize the cost of operation of the equipment (Life Cycle Cost) [18].

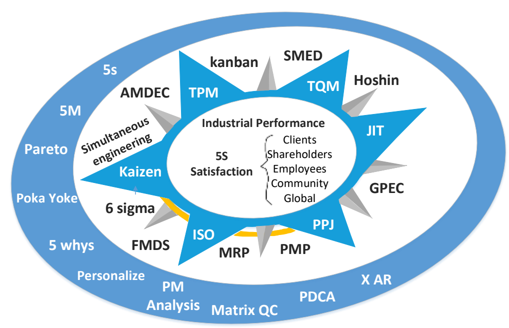

Fig. 5 - TPM tools
Source: (Bufferne, 2006) [18].

G. Sales and Operations Planning (S&OP)

Sales and operations planning (S&OP) requires the involvement of managers from all functions of the company to ensure commitment to the project and the timely flow of information between departments [19]. The ultimate goal is an agreement between various production links on the best course of action to achieve the optimal balance between supply and demand [20].

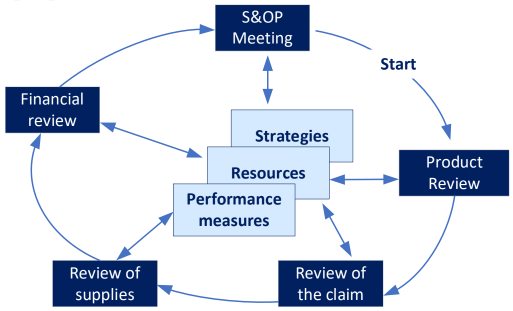

Fig. 6 - S&OP base model
Source: (Palmatier & Crum, 2002) [21].

III. Diagnosis of the Current Situation

This section presents the current situation of the company where the research will be carried out. For reasons of confidentiality of the information, the pseudonym OPM will be used.

A. Sector and economic activity

OPM is a world-class port operator and container terminal. OPM is part of the portfolio of an international leader in the development of port terminals, present in 40 countries where it operates more than 78 marine terminals. Its economic activity is associated with providing services related to maritime transport in the logistics sector.

B. Customer and product conception

The main service is the mobilization of containers for unloading and loading from and to container ships, respectively.

B.1. Vessel Services

Vessel services provided at the terminal include the provision of berthing through secured windows; lashing and unlashing; stevedoring and unstowing; and data transmission and processing via EDI.

B.2. Cargo Services

Includes unloading and/or loading services, internal cargo transfer, handling, as well as the use of the terminal infrastructure and any other service applicable to cargo moved at the terminal.

C. Entities participating in the business model

OPM has a business model typical of a concession in which governmental and customs entities, customers, unions, and companies, both customers and suppliers, participate. Figure 7 shows the main actors in the business model.

D. Production levels of the main process

The company handles around 28,000 TEUs (20-foot containers) per month for export services. Each gateway handles 75 containers per hour for all types of operations (export and import services).

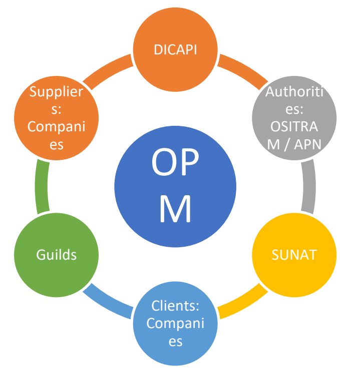

Fig. 7 - OPM business model

The gantry cranes perform 30 movements per hour, and the level of attention to the main process is good since 100% of the containers are loaded. The capacity of the dock used in the last six months was 60% due to the demand, which did not warrant more resources in the yard. Under normal conditions, dock capacity is used at 74%, as recommended by the port authority (APN). Given these considerations, there are plans to expand a third dock for the following year.

One of the main factors affecting productivity is the availability of RTGs (yard cranes) since these cranes serve the processes in a segmented manner; for example, there are 7 cranes for container dispatch and 12 cranes for ship service (unloading and loading containers), 1 for empty container transactions, and 1 backup for maintenance or washing. Another factor that affects productivity is the windows of attention of the lines, i.e., if one of them has a delay in its arrival time, the attention of the next ship will be affected. Another factor is the dock capacity; there are only 2 berths and 7 QCs (gantry cranes) to attend to the arrival of the ships.

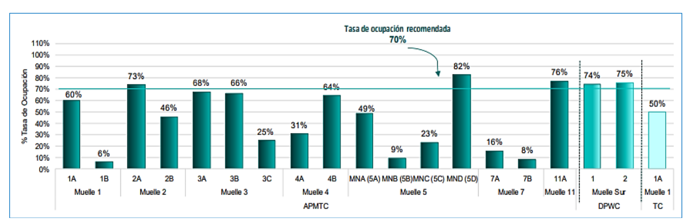

Fig. 8 - Dock occupancy rates - Callao
Source: Autoridad Portuaria Nacional

Figure 9 shows the stages of the diagnosis.

First stage: Understand the situation. Fully and objectively understand what the problem is. What is happening, where is it happening and when is it happening? In this case, the main problem observed was the long queues of trucks at the port, which was generated by the deficient assignment of appointments during peak hours (8 am to 11 am and 4 pm to 6 pm).

Second stage: Investigate the causes. Identify and understand all the cause-effect relationships at play. The main causes identified were the following:

- Scarce tools to correctly project the demand of containers to be served so there were not enough appointments at peak times.
- Erroneous projections based on crane capacity: by taking RTG cranes as a limiting factor, the demand for containers in the gates was not considered.
- Low capacity of container reception RTG cranes: Since the RTGs are distributed by operation: dispatch, reception, loading, and unloading, there is not enough capacity for the reception of full containers, since the maximum time for container unloading is 30 minutes, otherwise there is a SUNAT penalty.

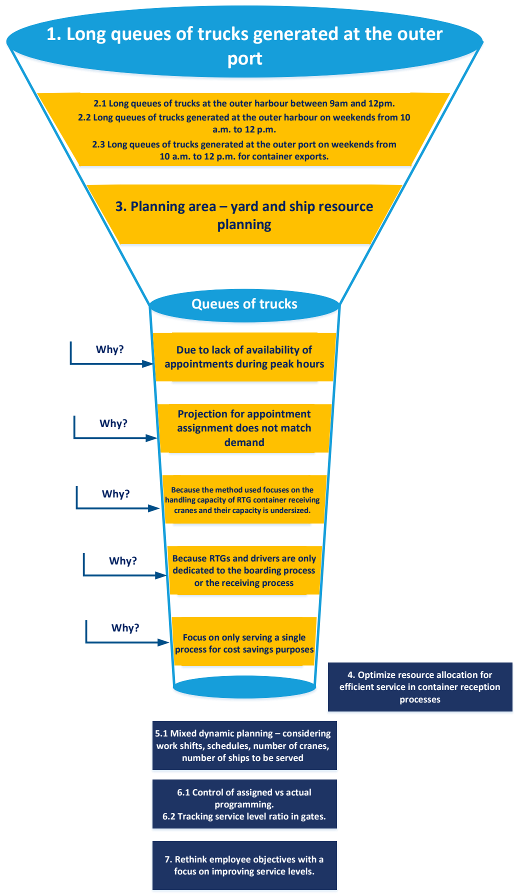

Fig. 9 - Problem-solving method

Third stage: Establish actions and standardize. Once the causes have been identified, it is time to apply measures. If they are effective, they should be standardized and should be part of the process of solving similar problems.

- It is suggested to perform a mixed dynamic planning - considering work shifts, schedules, number of cranes, and number of vessels to be attended. Also, to standardize crane scheduling, it is recommended to use mathematical scheduling tools (RTG crane scheduling).

We will use the Ishikawa diagram to determine the main causes that have a direct bearing on the problem encountered.

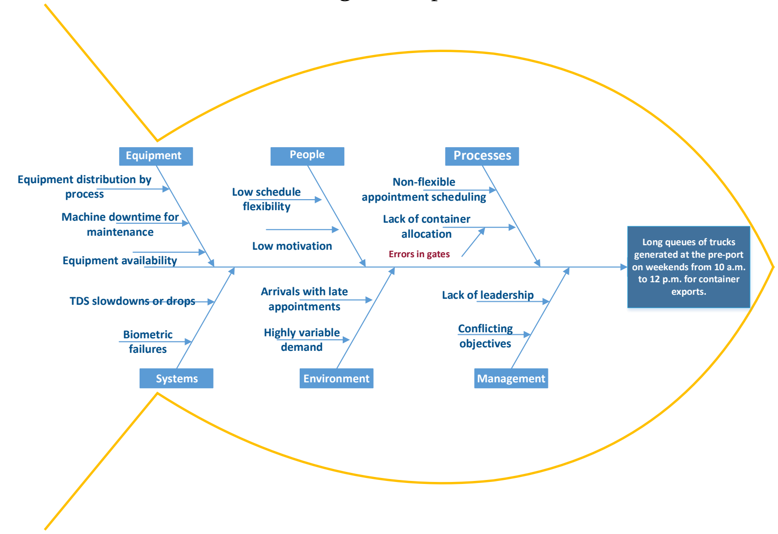

Fig. 10 - Cause and effect analysis

The root cause of "Conflicting Objectives" reflects the contradiction between the focus on reducing costs derived from the use of energy and fuel and at the same time seeking to improve the level of service by reducing long queues in the morning hours. According to the analysis of OPM's process families in terms of volume and usefulness, the main process identified was the reception of full containers. Under a quantitative analysis this represents the highest profit margin with an estimated $ 2M per month, and under a qualitative analysis of process criticality, export (reception of full containers) is key for the country's competitiveness given the high opportunity costs involved in this economic activity and the potential to favor the country's economic growth. Figure 11 shows the VSM of the loading/unloading processes.

Table II

Value Stream Mapping valued

Process	Volumen (TEU)	Profit ($/TEU)	Total, monthly profit ($)
Dispatch of full containers	30,000	$ 60	$ 1,800,000
Reception of full containers	20,000	$ 100	$ 2,000,000
Return of empty containers	20,000	$ 40	$ 800,000
Empty container dispatch	5,000	$ 40	$ 200,000
Transshipment of containers	25,000	$ 30	$ 750,000

E. Value chain activities

E.1. Value Chain Support Activities

- ***Infrastructure:*** the terminal and the proper maintenance of the facilities allow maintaining port operations.
- ***HR:*** having qualified personnel for cargo handling is fundamental to the business. The skills required for key positions such as RTG and gantry crane operators are constantly being developed.
- ***Technology:*** every process in the port is digital or partially digital. The availability of systems becomes a very important factor for the continuity of operations, as every system stoppage or downtime immediately causes the

service to stop until a solution is found or while a temporary manual process is carried out.

- ***Purchasing:*** this allows for the acquisition of the equipment, spare parts, and supplies necessary to provide port services. In addition, several key services are provided by suppliers, such as forklifts and forklifts in the gauging area and inter-terminal transportation for container transshipment.

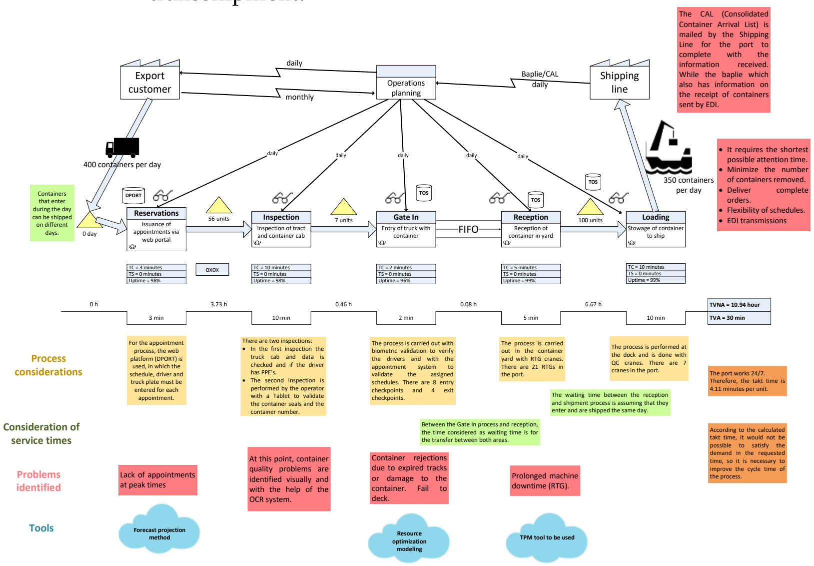

Fig. 11 - Current VSM OPM

E.2. Operational activities

- ***Inbound logistics:*** includes receiving trucks by appointment and storing containers in the yard.
- Outbound logistics: includes the loading of containers onto vessels (export) and the dispatch of full containers (import).
- ***Marketing and Sales:*** contractual commercial management with shipping lines and commercialization process with onshore customers through import and export commercial agreements.
- ***Customer Service:*** supports customer inquiries and requirements before, during, and after the service is carried out every day of the year 24 x 7.

This value chain is a proposed version considering the macro-processes approach previously shown in chapter one, and it can be seen that this proposal reflects well the flow that exists in the containerized cargo export process.

IV. Improvement Proposals

This section details the proposed improvements that will have a positive impact on the organization's performance.

A. Implement Lean

For the proper implementation of Lean, the foundations must be laid in the organizational culture, which is why in the first instance it is proposed to establish an organizational structure, to involve all members of the organization and to initiate synergies between all the strategies of the operations, in this way they will be considered in the future value stream mapping.

A.1. Organizational approach

Commitment of top management, employees and organizational structure.

a) Organizational structure

- The company is organized by functions such as operations, finance and human resources, which allows for specialization and facilitates training. However, this structure is not sustainable in the long term, as it limits the management of larger projects and challenges.
- Coordination is based on rules, hierarchy and planning, with clear top-down communication at the strategic and tactical levels. Despite this structure, the flow of information is effective and maintains a horizontal organizational culture.
- The company will plan a training investment plan to achieve long-term objectives. Moving towards a matrix structure that combines functions and projects, focusing on results and evaluation by objectives. In addition, the creation of the commercial planning area seeks to optimize coordination through the S&OP methodology.

b) Commitment of senior management and collaborators

- Senior management shows a strong commitment, reflected in the fulfillment of functional objectives, and maintains effective communication with employees through daily, weekly, and monthly meetings.
- Managers from different departments meet three times a week in "Morning meetings" to share information, generate synergies, and take advantage of business opportunities.
- There is room for improvement in aligning employees with organizational projects, as departmental objectives do not always reflect these initiatives. For example, operational staff do not consider the implementation of the TOS system as their own objective, but only as a support.

A.2. Implementation of 5S

Top management strongly supports improvement proposals and projects, allowing each department manager to sponsor several initiatives within the project portfolio. To initiate 5S implementation, the following actions will be taken:

- Designation of the Lean team responsible for the project, composed of four superintendents trained in lean manufacturing.
- Determination of the areas where the methodology will be applied, which have already been identified.
- Awareness sessions for management and area managers, with the support of a specialized consultant, highlight the benefits of correct implementation and encourage their commitment.
- Meeting between the Lean team and the leaders of the positions to establish objectives, after analyzing the current diagnosis of the company and the necessary improvements.

The success of these actions depends on the lean team, so it is essential that they are fully committed and can transmit that commitment to the entire company. The actions for each S are detailed below:

a.1) Sort: The first step is to perform a deep cleaning in the areas identified to implement the project. In this step what is sought is to keep in the work areas only the objects that are necessary, for this the following criteria are applied for each of the objects located in the production area:

- Used: Order
- Not used: Discard
- Damaged and will be used: Repair

a.2) Set: which consists of arranging things by assigning a specific place for each tool and material in the work area. This facilitates access and reduces handling and waiting times. The steps are as follows:

- Evaluate the initial situation: the workstation is observed after eliminating unnecessary objects and a list is made of the items needed for each workstation, which the operator must complete and the Lean team will approve.
- Decide on the location of the items, assigning a unique location for each item.
- Determine how the items will be stored, such as shelves, boxes, and labels, among others.
- Maintain order, which is the operator's responsibility to ensure that items remain organized over time.
- It is proposed to expand the warehouse and relocate products in the process to optimize space.
- From the third phase onwards, the company collaborates with Autonomous Maintenance, with the Lean team being in charge of implementation, with regular meetings to monitor progress and receive feedback.

a.3) Shine: As a set of Autonomous Maintenance and the Shine phase, the following steps will be applied:

Step 0: Preparation

It is essential to have a Visual Management Dashboard to evaluate the progress of activities, identify who is responsible for each activity, and encourage employee commitment to the objectives. The example below includes the name of the team, the main Safety, Quality, and Production KPIs, their monthly evolution, a weekly breakdown and the corrective actions to be implemented in case the indicators do not reach the established objectives.

In addition, it is suggested to have lists prepared to ensure adequate control of Maintenance, for which the corresponding formats are presented:

- Lists of abnormalities by equipment: in this list, key data is recorded, such as the detected abnormality, the corrective action to be performed, the priority of the correction, and if the operator can solve it or if the intervention of the maintenance area is required. It is important to note that this list is filled out by equipment or machine.
- Abnormality Card Control Chart: As will be explained later, cards will be used to identify abnormalities, which will be placed in the affected areas. Therefore, it is necessary to keep an inventory of these cards to control and track their status.
- List of contamination sources: This list includes the sources of contamination identified, to make an adequate follow-up.
- List of areas that are difficult to access: This will identify areas that are difficult to access and are often sources of contamination because they are often overlooked by operators due to the complexity of accessing them. This will help to track revisions in these areas and look for solutions to make them more accessible, for example, by installing cameras.

The first two S's must be applied in the Preparation phase since cleaning cannot begin if the objects are not sorted and ordered. The objective of Autonomous Maintenance is to improve equipment reliability by eliminating deficiencies to establish optimal equipment conditions.

Step 1: Initial cleaning

It will start with a thorough cleaning of the equipment so that the operators can detect failures in the future. This cleaning sets the standard for how the equipment should be maintained, being the responsibility of each operator. In addition, abnormalities, such as cracks or deformations, are identified during the cleaning and inspection process. The goal is for operators to understand that each cleaning is also an inspection that can reveal problems, especially in hard-to-reach places and sources of dirt, which can damage equipment. Operators should use their 5 senses to detect any anomalies.

Step 2: Eliminate sources of contamination and inaccessible points.

In this step, the objective is to prevent leaks or spills and improve access to areas that are difficult to clean and inspect. An Action Plan based on the six whys (what? who? when? where? how? why?) is used to identify sources of contamination and the actions needed to reduce them. If this is not possible, an attempt is made to contain it; and if this is also not feasible, critical equipment components are protected and their cleaning and inspection is facilitated by improving access.

a.4) Standardize

Step 3: Establish standards for cleaning, lubrication, adjustment and inspection

This phase focuses on establishing standards of cleanliness and inspection, with training for operators on the maintenance of their machines. It is recommended that visual controls be used to ensure that machines are operating within acceptable ranges, as shown in the example in Figure 12, where the needle should be in the green area to indicate safe conditions.

To meet the third objective of Autonomous Maintenance, which consists of correcting small deficiencies and establishing basic conditions of the equipment, specific requirements are defined that must be met by the operator.

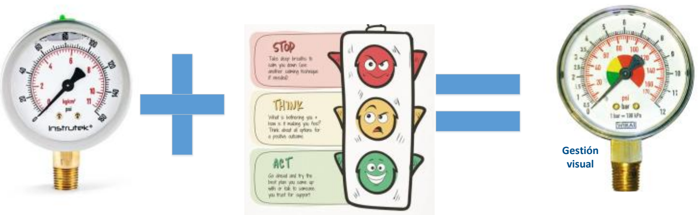

Fig. 12 - Visual control

- ***Cleaning:*** Perform regular cleaning of the equipment while the inspection is being carried out, following the principle that each cleaning is an opportunity to inspect.
- ***Lubrication:*** This is essential to prolong the life of the equipment and prevent wear and tear. Operators should understand its importance and lubricate the equipment when necessary. In addition, they must ensure that lubricant inlets are in good condition and verify the proper functioning of automatic lubrication systems.
- ***Adjustment:*** Machines have bolts, screws, and nuts that loosen with use. The operator must check that these elements are properly tightened because if they are loose, they can generate vibrations that can damage the equipment.

Step 4: General Inspection of Equipment

The objective is to establish inspection standards for our team to ensure the maintainability of the equipment. This will allow operators to develop the necessary skills to perform a proper inspection and detect deterioration or anomalies in the machines.

Step 5: Autonomous Inspection

Once trained and with the necessary materials and information, the operator can apply the Autonomous Inspection independently, controlling the process and the quality of the products at his workstation.

Step 6: Standardize

The objective of standardizing is to ensure that operators consistently follow the implemented phases, ensuring product quality and eliminating non-value-added activities. This requires considerable effort from personnel, so it is crucial to sensitize them to Lean Manufacturing and their commitment to the company's new objectives.

a.5) Sustain

Step 7: Full practice of self-management

To sustain the changes, it is essential that the procedures become natural habits in the company. Monthly meetings should be held to ensure understanding and commitment, especially from managers, who must lead by example. This stage is key, as without discipline, problems such as the accumulation of unnecessary items and the disorganization of tools will once again lead to delays and wasted time.

B. Demand forecasting and capacity assurance

For the projection of export TEU demand, two forecasting methods will be used, simple linear regression and the Delphi method, effectively achieving a projection with a statistical basis and at the same time a consensus with a panel of experts. For the regression model, the variables used are the GDP index and the market volume in thousands of TEUs, obtaining a correlation coefficient of 0.994, see Table III.

Table III
Regression Summary

Multiple correlation coefficient	0.9941
Coefficient of determination R^2	0.9882
Adjusted R^2	0.9876
Standard error	76.8589
Observations	21

The model obtained is $y_{TEUs} = -877.26 + 12.98X_{GDP\ index}$

Then, the Delphi method is used as a reference, involving a panel of experts from each department of the organization to reach a consensus on the future GDP growth.

Subsequently, the volume of export containers at the terminal is calculated using the additional data from the expert panel according to Table IV and Table V.

Table IV
Consensus data (Delphi Method)

Market Share	58%
TEUs as export volume % TEUs as export	23%
TEU Factor Ratio	1.61

Table V
Container volume

Year	GDP Index	% Annual variation GDP	Volume (Thousands of TEUs Callao)	Volume Thousands of export containers in terminal
22	221.20	-12.00%	2,079	172,230
1P	243.32	10.00%	2,281	189,030
2P	251.84	3.50%	2,392	198,190
3P	260.65	3.50%	2,506	207,670

Finally, in order to transform to monthly volumes, the seasonal index method is applied, given that exports have very marked campaigns in certain months of the year.

C. Implementation of the S&OP methodology

Through the analysis of the current value map, the

In this stage, the goal is to balance capacity with the projected demand for the following years. To this end, synergy was sought between the Lean methodology and the S&OP, to raise the restrictions and thus be able to operate towards a desired volume of between 550 - 600 containers per day (see Figure 13). The key point is that the capacity must obey the seasonality of the forecasted demand, so the capacity plan is monthly following the seasonal indexes of the demand plan (see Table VI).

Tabla VI

Monthly export container capacity plan

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	15592	16006	15645	13371	14421	17041	19485	18575	15914	14206	13970	17398
2	16335	16768	16390	14008	15108	17853	20412	19460	16672	14883	14635	18226
3	17077	17530	17135	14645	15794	18664	21340	20344	17430	15559	15301	19055

A linear S&OP model is developed to calculate the capacity for each month. The model minimizes the container inventory costs, plus the cost of moving TEUs for import, plus the cost of moving TEUs for export. The constraints are capacity balance and demand constraints, as well as determining the capacity of resources to move containers for import/export.

$$Minimmize\ cost = \sum_{i}^{t} I_i\, C\_inv_i + C_{imp\_i}X_{import\_i} + C_{exp\_i}X_{export\_i}$$

$$I_i +\ X_{import\_i} + X_{export\_i} = I_{i+1} +\ D_i$$

$$X_{import\_i} + X_{export\_i} = rate_{operation}(h_i + f_i)$$

Where:

$X_{k,i}$: quantity of k containers imported or exported in period i.

I_i: inventory of containers in period i.

h_i: number of resources to be contracted

f_i: number of resources to lay off

D. Validation of future value stream mapping

Through the analysis of the current value map, the operations that do not add value and the bottlenecks that affect customer service were identified. Then, three Lean tools were proposed and future Value Stream Mapping was used to reorganize operations, significantly reducing service execution time and waste.

- Making the appointment process more flexible by implementing S&OP and statistical modeling methods for appointment allocation. In addition, inspection time is a bottleneck that causes inventories. Although crucial for quality control, this process can be optimized by technologies such as RFID for the automatic reading of container data.
- The gate in the process has reprocessed due to overdue or early appointments and damaged containers, forcing drivers to request new appointments and queue again. In addition, internal errors, such as the lack of container position allocation by the planning team, generate waiting times for the customer, who must request support from the gate supervisors to continue with the flow.
- Stoppages are observed for equipment maintenance, which generates waiting times and unnecessary container transfers. It is proposed to review the maintenance plan and consider the implementation of TPM in Operations and Maintenance. In addition, customer information flows are not fully electronic, which requires time to digitize them. It is suggested that EDI be used for the transmission of information from the shipping lines, a technology already used for reporting empty container shipments.
- The timing of operations is not standardized, so there are inventories between processes. To level the pace of production all processes must be by the tack time, in this case, each operation should last 4.11 min per container.
- In the receiving process, containers are handled under FIFO criteria. To reduce non-value-added time, the level of inventories will be minimized by implementing TPM in the setup changes, with greater availability of the use of port machines.
- All processes receive information from the daily production planning.

Non-flexible allocation of equipment, such as gantry cranes or RTGs, generates high waiting times. Therefore, an optimization model must be developed to assign equipment and maximize its service flow. To develop the implementation plan, the following points must be analyzed:

- Design of the processes
- Definition of restrictions on the use of each piece of equipment
- Development of mathematical modeling
- Use of the tool and start-up

For the construction of the future VSM (see figure 13), process improvement tools were integrated in the following sequence:

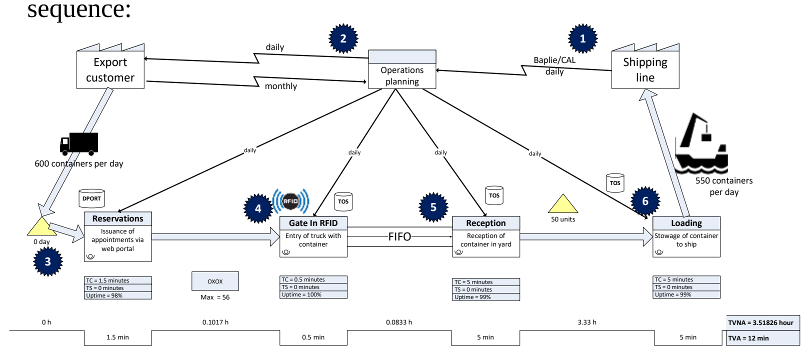

Fig. 13 - Value Stream Design

1. **The transfer of information** from the Shipping Line to the company will only be done through EDI, thus the flow of information will be automated.
2. ***Planning applying SOP*** (Operations & Commercial Planning). It is expected to obtain a better estimation of the mobilized volume.
3. ***Automation of the sending of information*** with the extra-port warehouses to reduce the time for the creation of lists. The automation will be developed through web services, with each depot will be obtained the weights of the container output.
4. ***Automated Gate in process with RFID*** technology (container, driver and badge information read by proximity). Significant reduction of waiting and processing time.
5. ***TPM:*** applied to guarantee the reliability of critical RTG equipment.
6. ***Optimization modeling:*** Optimal allocation of RTG's for maximum container receiving and shipping flow. In addition, the TPM tool will be used to guarantee the reliability of critical QC equipment.

Initially, a variant of the maximum flow model was implemented, where F is the maximum number of containers that can be served during a day. The assignment method was also addressed, replicating the equipment so that they can serve more than one container in the planning period.

Maximum flow algorithm used as initial assignment solution

$$max\ F$$

$$\sum_{j=1}^{n} x_{ij} - \sum_{k=1}^{l} x_{ki} = \begin{cases} F, & i = node\ start \\ -F, & i = node\ end \\ 0, & intermediate\ nodes \end{cases}$$

$$x_{ij} \leq U_{ij} \qquad x_{ij} \geq L_{ij} \qquad \forall x_{ij} \geq 0$$

$Where$
$U_{ij} = maximum\ capacity\ of\ the\ port\ in\ optimal\ conditions$
$L_{ij} = minimum\ capacity\ of\ the\ port\ in\ repairs\ or\ preventive\ maintenance$
$F = maximum\ flow, number\ of\ containers\ served\ per\ day$
$x_{ij} = Container\ allocation\ by\ resources\ ij$

V. RESULTS

This improvement project integrates methodologies whose objective is bipartite: to improve operations to increase the level of customer service, and to achieve incremental profit for the company.

Customer service time was reduced from 11.44 hours to 3.71826 hours. In addition, the synergy of process improvement tools increased the capacity from 350 to 550 containers per day. Table VII shows the expected results in a three-year horizon that generated an additional profit of around 7 million for the company, this benefit was simulated using good, regular and bad scenarios through a Monte Carlo simulation.

Tabla VII
Results

Maximum annual volume mobilized (capacity before improvement)		172,000
Expected margin per container ($/container)		80
Year	**Incremental container volume**	**Incremental utility ($)**
1P	19625	$ 1,570,000.00
2P	28750	$ 2,300,000.00
3P	37875	$ 3,030,000.00

VI. CONCLUSIONS

We detail the main conclusions of our research:

- The support of top management and effective communication with employees are key to implementing Value Stream Design solutions, minimizing the rejection of change through technological initiatives.
- To generate new business opportunities and services, it is essential to guarantee process reliability through TPM in mobile equipment and to apply mixed operations in cranes to reduce restrictions in the reception of full containers.
- Coordination between commercial and operational areas, together with the implementation of S&OP, will align demand with a more accurate availability of appointments in terms of quantity and schedules.
- Since lead times and inventories are high, daily demand is not fully met; therefore, value-added times need to be reduced through future VSD improvements.
- Continuous improvement will assess the currency of the solutions, as the context may change due to political, regulatory and market factors, which may require adjustments in planning and execution.
- Yard and dock capacity will set a limit on the volume of incremental service and utility, so in the long term, expansion should be evaluated based on market growth.
- Collaboration between commercial and operational departments is critical to improve demand visibility in S&OP plans. Leadership from each management is crucial to ensure compliance and encourage continuous improvement.

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