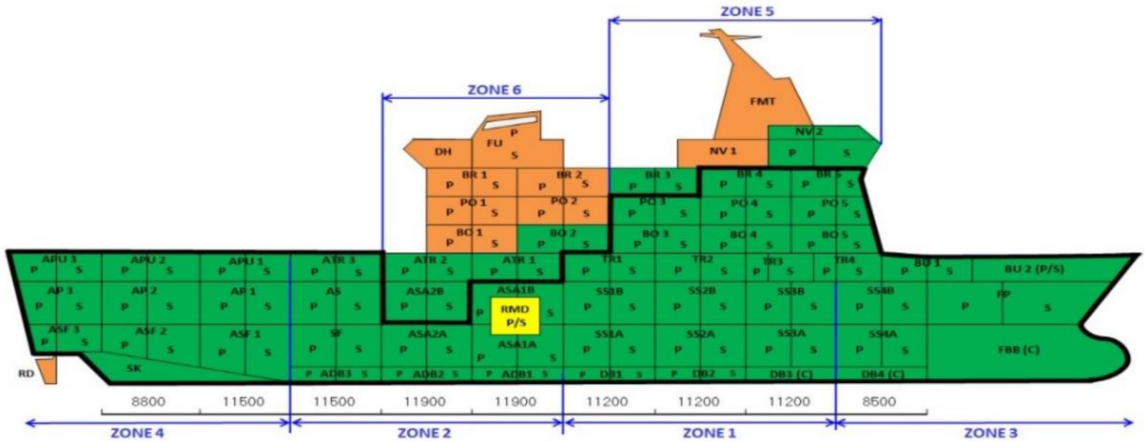
NO. SHIP : W.000292

SHIP W000303

BLOCK INSPECTION AT ASSEMBLY SHOP (Accepted By Owner / Class)

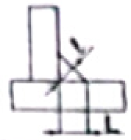
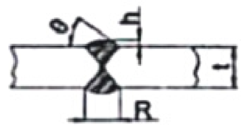
No	Nama Blok	No	Nama Blok	No	Nama Blok	No	Nama Blok
1	Block DB1 (P)	32	Block ASF 3 (P)	63	Block TR4 (P)	94	Block PO2 (S)
2	Block DB 1 (S)	33	Block ASF 3 (S)	64	Block TR4 (S)	95	Block PO3 (P)
3	Block DB 2 (P)	34	Block SKEG	65	Block ATR1 (P)	96	Block PO3 (S)
4	Block DB 2 (S)	35	Block SS 1B (P)	66	Block ATR1 (S)	97	Block PO4 (P)
5	Block DB 3 (C)	36	Block SS 1B (S)	67	Block ATR2 (P)	98	Block PO4 (S)
6	Block DB 4 (C)	37	Block SS 2B (P)	68	Block ATR2 (S)	99	Block PO5 (P)
7	Block ADB 1 (P)	38	Block SS 2B (S)	69	Block ATR3 (P)	100	Block PO5 (S)
8	Block ADB 1 (S)	39	Block SS 3B (P)	70	Block ATR3 (S)	101	Block BR1 (P)
9	Block ADB 2 (P)	40	Block SS 3B (S)	71	Block APU1 (P)	102	Block BR1 (S)
10	Block ADB 2 (S)	41	Block SS 4B (P)	72	Block APU1 (S)	103	Block BR2 (P)
11	Block ADB 3 (P)	42	Block SS 4B (S)	73	Block APU2 (P)	104	Block BR2 (S)
12	Block ADB 3 (S)	43	Block FP (P)	74	Block APU2 (S)	105	Block BR3 (P)
13	Block SS 1A (P)	44	Block FP (S)	75	Block APU3 (P)	106	Block BR3 (S)
14	Block SS 1A (S)	45	Block ASA 1B (P)	76	Block APU3 (S)	107	Block BR4 (P)
15	Block SS 2A (P)	46	Block ASA 1B (S)	77	Block BU 1 (P)	108	Block BR4 (S)
16	Block SS 2A (S)	47	Block ASA 2B (P)	78	Block BU 1 (S)	109	Block BR5 (P)
17	Block SS 3A (P)	48	Block ASA 2B (S)	79	Block BU 2 (P)	110	Block BR5 (S)
18	Block SS 3A (S)	49	Block AS (P)	80	Block BU 2 (S)	111	Block NV1 (C)
19	Block SS 4A (P)	50	Block AS (S)	81	Block BO1 (P)	112	Block NV2 (P)
20	Block SS 4A (S)	51	Block AP1 (P)	82	Block BO1 (S)	113	Block NV2 (S)
21	Block FBB (C)	52	Block AP1 (S)	83	Block BO2 (P)	114	Block FU (P)
22	Block ASA 1A (P)	53	Block AP2 (P)	84	Block BO2 (S)	115	Block FU (S)
23	Block ASA 1A (S)	54	Block AP2 (S)	85	Block BO3 (P)	116	Block DH
24	Block ASA 2A (P)	55	Block AP3 (P)	86	Block BO3 (S)	117	Block FMT
25	Block ASA 2A (S)	56	Block AP3 (S)	87	Block BO4 (P)	118	RUDDER (P)
26	Block SF (P)	57	Block TR1 (P)	88	Block BO4 (S)	119	RUDDER (S)
27	Block SF (S)	58	Block TR1 (S)	89	Block BO5 (P)	120	M/E SEAT(P)
28	Block ASF 1 (P)	59	Block TR2 (P)	90	Block BO5 (S)	121	M/E SEAT (S)
29	Block ASF 1 (S)	60	Block TR2 (S)	91	Block PO1 (P)		
30	Block ASF 2 (P)	61	Block TR3 (P)	92	Block PO1 (S)		
31	Block ASF 2 (S)	62	Block TR3 (S)	93	Block PO2 (P)		

Hospital Auxiliary Ship Block - TNI AL



BLOCK	
102	BLOCK ERECTION IN DOCK
17	BLOCK READY TO ERECTION
0	BLOCK ON BLASTING/PAINTING PROCESS
0	BLOCK ON FAIRING PROCESS
2	BLOCK ON ASSEMBLY PROCESS
0	BLOCK ON SUB-ASSEMBLY PROCESS
0 +	BLOCK ON FABRICATION PROCESS
121	

PAL INDONESIA	QC CHECK SHEET 7 WELDING / PENGELASAN	
		NOMOR / FILE NO. : 289 /223EO/UPP/303/XI /202
		TANGGAL / DATE : 15-11-2021
		HALAMAN / PAGE : 2
PROJECT : BRS – TNI AL	BENGKEL / SHOP : LAS 2	DIVISI / DIVISION : KANIA
PROJECT NO. : W000303	NAMA BLOK/BLOCK NAME : Po9 PtS	NAMA REGU : LAS 2

GRADE	PEMERIKSA / YANG DIPERIKSA	GL JUMLAH CACAT	QC JUMLAH CACAT
A	RETAK / Crack	-	
	KESALAHAN PAKAI ELEKTRODA / Misuse of electrode	-	
	BELUM DILAS / Welding omitted	-	
B	PANJANG KAKI LAS / Leg length  Standard : L ≥ 0.9 Dwg, ℓ ≥ 0.9 Dwg	-	
	LAIN-LAIN		
C	LAS MEMUTAR / Return weld (RW)	-	
	BENTUK HASIL LAS / Bead appearce a. Low bead  Standard : ≥ t	2	
	b. Reinforement  Standard : θ ≤ 60°, h ≤ 0.2 R	-	
	c. Short Bead (SB) — CAST ST: SB ≥ 50; MILD ST: SB ≥ 30	-	
	d. Surface Porosity	7	
D	PERBAIKAN CACAT BEKAS STOPPER Repair defect ex. stopper	11	
	PERCIKAN LAS (Arc strike)	9	
	LAIN-LAIN (Other)	-	

TOTAL GRADE GL	A	B	C	D	TOTAL GRADE QC	A	B	C	D

GL COMMENT : Sudah diperbaiki sesuai comment

QC COMMENT : Ok

ASMAN QC	QC INSPECTOR	GL / SHOP CHIEF
		M. SHOHIB ANSHORI
Tanggal / Date :	Tanggal / Date :	Tanggal / Date : 15-11-2021

KUISIONER PEMBOBOTAN *WASTE*

Responden Yth,

Saya M. Rizki Kurniawan mahasiswa semester VIII (delapan) Fakultas Teknik Program Studi Teknik Industri UPN "Veteran" Jawa Timur. Saat ini saya sedang melakukan penelitian untuk Tugas Akhir/ Skripsi sebagai prasyarat kelulusan mencapai gelar Sarjana Teknik (S.T) dengan judul **Implementasi *Lean Six Sigma* Untuk Meminimasi *Waste* Pada Proses Produksi Kapal Di PT PAL Indonesia (Persero).** Kuisioner ini bertujuan untuk mengetahui tingkat *waste* pemborosan dalam proses produksi kapal yang berada di lingkungan produksi PT. PAL Indonesia (Persero), agar penelitian ini dapat berlangsung dengan baik, saya mengharapkan kesediaan dan bantuan dari responden untuk mengisi kuisioner ini dengan tepat dan benar. **Adapun data dan identitas yang terkumpul dalam kuisioner ini akan dijaga kerahasiaannya.** Atas perhatian dan waktunya saya ucapkan terima kasih.

Petunjuk Pengisian Kuisioner:

1. Bacalah semua defenisi pemborosan yang terjadi menurut Konsep *Lean Six Sigma*
2. Sesuai dengan kondisi nyata lapangan, berilah *scoring* untuk setiap *waste* dengan ketentuan sebagai berikut:
   - Skor maksimum untuk setiap pemborosan adalah 5
   - Skor minimum untuk setiap pemborosan adalah 0

Contoh Pengisian:

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	4
2	Waktu Tunggu (*Waiting*)	3
3	Transportasi (*Excessive Transportation*)	5
4	Proses yang tidak sesuai (*Inappropriate processing*)	4
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	3
6	Gerakan yang tidak perlu (*Unnecessary motion*)	2
7	Cacat Produk (*Defect*)	1
Total		

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Penjabaran yang lebih detail mengenai ketujuh pemborosan (*waste*) yang disebutkan diatas dapat dilihat pada penjelasan dibawah ini:

Tipe Pemborosan:

1. Produksi Berlebihan (*Over Production*)
   Stasiun Sebelumnya memproduksi terlalu banyak atau terlalu cepat sehingga terjadi *inventory in process* serta titik-titik penyimpanannya
2. Waktu Tunggu (*Waiting*)
   Material menunggu bukan material yang mengalir. Orang-orang yang menunggu barang sisa adalah sumber daya yang paling kritis, dan mengakibatkan tingginya *lead time* (waktu produksi) seperti kondisi dimana produk menunggu operator untuk diproses atau sebaliknya, operator menunggu produk yang akan diproses
3. Transportasi (*Excessive Transportation*)
   Gerakan material, informasi dan manusia yang tidak meningkatkan nilai dari produk dan mengakibatkan boros terhadap waktu, usaha dan biaya kepada pelanggan.
4. Proses yang tidak sesuai (*Inappropriate processing*)
   Terjadinya kesalahan proses yang diakibatkan oleh kesalahan penggunaan tools dan kesalahan prosedur atau sistem kerja (prosedur kerja dengan kondisi lapangan)
5. Persediaan yang tidak perlu (*Unnecessary Inventory*)
   Terjadinya persediaan yang berlebih baik berupa raw material, maupun finished good. Material membutuhkan ruang, biaya dan berpotensi mengalami kerusakan.
6. Gerakan yang tidak perlu (*Unnecessary Motion*)
   Apapun gerakan yang tidak menambah nilai (*Non value added*) kepada produk merupakan barang sisa. Hal ini sangat terkait dengan nilai ergonomis dan tata letak komponen atau mesin terhadap material sehingga terjadi gerakan berlebihan pada operator dalam melakukan tugasnya.
7. Kecacatan (*Defect*)
   Dapat berupa proses pekerjaan ulang, produk cacat yang dihasilkan baik *work in process* atau *finished good* atau dapat juga berupa complain customer terhadap produk.

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Kuisioner Pembobotan Pemborosan

Nama	: TJIPTO SANTOSO, ST, MM
Jenis Kelamin	: L / ~~P~~
Usia	: 50 Thn
Jabatan	: KaBiro Engineering QA/QC Harkan

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	2
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	2
4	Proses yang tidak sesuai (*Inappropriate Processing*)	2
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	1
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	2
7	Cacat Produk (*Defect*)	1
Total		12

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: KAMIL MUCHAROM
Jenis Kelamin	(L) / P
Usia	: 35 TAHUN
Jabatan	: INSPEKTUR MUTU

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	2
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	3
4	Proses yang tidak sesuai (*Inappropriate Processing*)	2
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	2
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	1
7	Cacat Produk (*Defect*)	1
Total		13

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: FEBRI KURNIADANI
Jenis Kelamin	: (L) / P
Usia	: 31 Tahun
Jabatan	: QA/QC HARKAN

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	2
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	3
4	Proses yang tidak sesuai (*Inappropriate Processing*)	2
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	2
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	2
7	Cacat Produk (*Defect*)	1
Total		14

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: Heru kurniawan
Jenis Kelamin	: (L) / P
Usia	: 33
Jabatan	: Kabiro Alutsista Harkan.

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	1
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	1
4	Proses yang tidak sesuai (*Inappropriate Processing*)	2
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	2
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	2
7	Cacat Produk (*Defect*)	2
Total		12

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: Ahmad Bahrul Alifudin
Jenis Kelamin	: (L) / P
Usia	: 26
Jabatan	: Inspektur Mutu / Quality Control

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	1
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	1
4	Proses yang tidak sesuai (*Inappropriate Processing*)	2
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	2
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	2
7	Cacat Produk (*Defect*)	2
Total		12

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: DWI PUTRA SUBERKAH
Jenis Kelamin	: (L) / P
Usia	: 26 Tahun
Jabatan	: QA/QC Harian

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	1
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	1
4	Proses yang tidak sesuai (*Inappropriate Processing*)	2
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	2
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	2
7	Cacat Produk (*Defect*)	2
Total		12

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: Joko Sarwono
Jenis Kelamin	: (L) / P
Usia	: 52 thn.
Jabatan	: Ka. biro. Hull Construction Dept QA/QC Bangkap.

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	1.
2	Waktu Tunggu (*Waiting*)	1.
3	Transportasi (*Excessive Transportation*)	2.
4	Proses yang tidak sesuai (*Inappropriate Processing*)	1.
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	1.
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	2.
7	Cacat Produk (*Defect*)	4.
	Total	12

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: ADAM W
Jenis Kelamin	: (L) / P
Usia	: 28
Jabatan	: Inspektur Mutu

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	1
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	1
4	Proses yang tidak sesuai (*Inappropriate Processing*)	1
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	1
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	1
7	Cacat Produk (*Defect*)	2
Total		9

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama : BANDA AGUNG P

Jenis Kelamin : (L) / P

Usia : 36

Jabatan : INSPEKTUR MUTU III

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	1
2	Waktu Tunggu (*Waiting*)	1
3	Transportasi (*Excessive Transportation*)	2
4	Proses yang tidak sesuai (*Inappropriate Processing*)	1
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	1
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	1
7	Cacat Produk (*Defect*)	1
Total		7

Surabaya, 15 Maret 2022

Responden

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Kuisioner Pembobotan Pemborosan

Nama	: DJODY ABEDAH.
Jenis Kelamin	: L / P
Usia	: 51
Jabatan	: KA BIRO ED. QA/QC

No.	Pemborosan	Skor
1	Produksi Berlebihan (*Over Production*)	1
2	Waktu Tunggu (*Waiting*)	2
3	Transportasi (*Excessive Transportation*)	3
4	Proses yang tidak sesuai (*Inappropriate Processing*)	1
5	Persediaan yang tidak perlu (*Unnecessary Inventory*)	1
6	Gerakan yang tidak perlu (*Unnecessary Motion*)	2
7	Cacat Produk (*Defect*)	4
	Total	14

Surabaya, 15 Maret 2022

Responden

Program Studi Teknik Industri
Fakultas Teknik
Universitas Pembangunan Nasional "Veteran" Jawa Timur

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Study on Implementation of Lean Six Sigma in Hospital Auxiliary Ship Block Construction Process

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Abstract

During the current pandemic, a means of transportation is needed to support the evacuation of patients through waterways; therefore, PT PAL Indonesia (Persero) has carried out a project called the Hospital Auxilary Ship. Based on this, to increase productivity in the construction of new ships, a good production process is needed to produce quality ships. The research aims to find out the production system, especially the construction of ship blocks used as objects and waste in the process using the lean six sigma method and the proposed approach to improvement failure mode effect and analysis (FMEA). The research results with lean six sigma obtained a six sigma value of 3.073 sigma. They obtained the value of process activity mapping (PAM) with the highest percentage of 67.82% in operating activities. The analysis of the causes of wastage using FMEA obtained several factors: block material that is not up to standard, lack of machine maintenance, inadequate surrounding environment, and less skilled operators. Proposed improvements to the defect wastage resulted in improved material inspection, conducting operator training, scheduling machine maintenance, and regularly reworking the defective block construction.

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1. Introduction

The tight competition in industrial activities in the current era triggers companies to be able to show competitive advantages, which are divided in terms of quality, price, on-time delivery, and flexibility[1]. Therefore the company must manage and produce materials well to generate maximum profit[2].

In addition to paying attention to product quality, companies are also required to be able to preserve the environment. With the increasing number of defects in the production process, there are indications of environmental impacts that occur in a production process[3]. Humans are not the main factor in increasing productivity, but other factors such as machines, work methods, materials, location, and company buildings need to be considered[4].

PT Pal Indonesia is one of the companies in the maritime manufacturing sector that produces ships for both the state and the private sector. The company's project is being built on the Hospital Auxiliary ship, which can be seen in figure 1. but there is still much waste that is not added value. As a result, the production cycle time becomes longer than the company's target. Based on initial observations, a production lead time of 19200 minutes has been found, so a lean six sigma method is needed to reduce the lead time to increase productivity.

In recent years, the lean six sigma method has become popular because of who can apply it to continuous product improvement in manufacturing and services[5]. The lean approach focuses on speeding up a process by reducing waste and the environment, while six sigma helps achieve higher product or service quality. The principle of the existence of lean is that waste is reduced from a value stream, while six sigma aims at the target of the value stream[6]. With the improvement process carried out repeatedly through the DMAIC approach, namely (define, measure, analyze, improve, and control), the process can be reduced so that the output decreases and the number of products matches the quality[7]. A tool called value stream mapping (VSM) is used to help identify the flow of physical and material information. In addition, with the help of VSM, we can find out all value-added activities or non-value added activities during the production process, from raw materials to consumers[8]. In addition to the proposed improvement, the FMEA approach identifies and prioritizes potential problems (failures) in the production process[9]. Below Figure. 1 shows the process of building a ship.

Figure 1. Ship Production Process.

2. Methods

2.1 The object of research

This research integrates lean and six sigma methods to analyze the waste that occurs during the construction process of the Hospital Auxiliary ship block. Using the lean six sigma method, we can find out the causes of block defects, especially surface texture defects and dimensions that require rework and additional cycle time to repair. The lean six sigma results are in the form of lead time values so that the initial lead time values can be compared with the proposal to increase productivity and cycle time of ship block construction. Figure 2. represents the types and number of ship blocks built by PT PAL Indonesia (Persero).

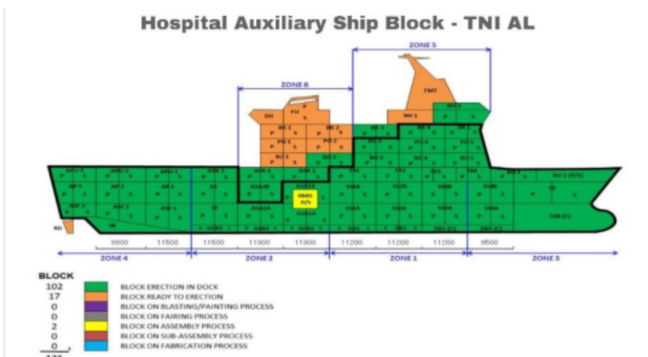

Figure 2. Ship Block Type.

2.2 Treatment of research object

This study uses a comparison of cycle times for each activity in the shipbuilding process by measuring value-added activities (NVA), non-value-added activities (NVA), and an necessary but not value-added activity (NNVA). After all, activities are measured, it can be seen that the lead time value in the ship block construction process causes long cycle times.

2.3 Method

The method used during this research was carried out non-experimentally with the data that had been provided. The data used are secondary data obtained from companies and primary data obtained through questionnaires. To solve this problem, a lean six sigma framework is used, namely DMAIC (Define, Measure, Analyze, Improve, Control). However, the control phase is not carried out and is only limited to a proposed improvement design to increase the productivity of the block development process. The analysis was carried out to answer the purpose of this research, namely to reduce the level of waste in terms of defects and shipbuilding cycle times. Furthermore, draw conclusions and suggestions for further research. Figure 3. below shows the flow of problem-solving for research.

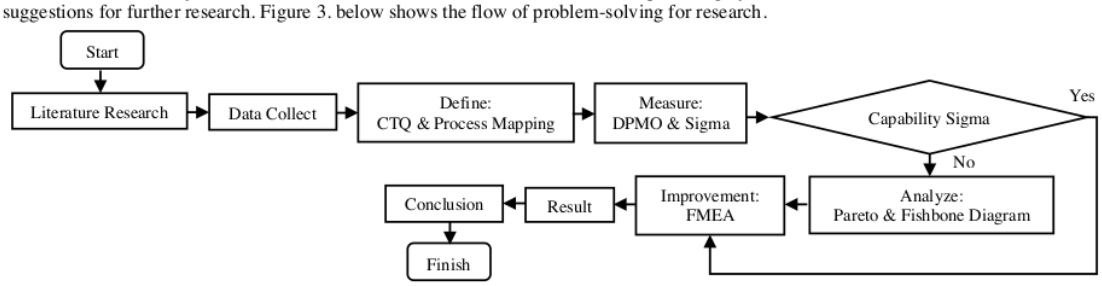

Figure 3. Research Flow Process.

2.4 Tools and materials used in research

The tools or tools used during the waste analysis process are Value Stream Analysis Tools (VALSAT), Big Picture Mapping (BPM), and Failure Mode Effect and Analysis (FMEA), which are described below.

1. Value Stream Analysis Tools (VALSAT)

In measuring the level of waste, data is collected on all activities from the production process to find out the waste that occurs in each activity. The data was obtained by distributing questionnaires containing the various kinds of waste that existed later, and the respondents measured the highest score ranking of the waste that occurred.

2. Big Picture Mapping (BPM)

Waste data determined is then processed by describing the production system as a whole. This can be done by visualizing the flow of information and physical flow into a big picture mapping (BPM)[10].

3. Failure Mode Effect and Analysis (FMEA)

After determining the cause of waste, it is necessary to make suggestions to minimize the waste. Therefore, failure mode effect and analysis (FMEA) tools are used to observe the occurrence of failures so that they can be measured and analyzed to minimize the failure rate and its effects on other factors.

3 Results and Discussion

The construction of the Auxiliary Hospital ship block has a relatively long stage; therefore, accuracy is needed in building the ship block. Below, an analysis will be carried out to determine the causes of waste and the factors that influence it. The lean six sigma method and other supporting data are used in the analysis phase.

3.1 Define

This stage identifies the causes of waste during the ship block construction process. Identification is made by describing the main process map as a whole, consisting of a map of the information flow and physical flow through value stream mapping. Many things can cause waste; for example, waiting time is long enough between processes, causing block queues. The existence of lead times in the block construction process can result in high costs for maintenance and supervision activities of the ship block. This is what causes the company to carry out the production process effectively and efficiently and improve lead times in the ship block construction process.

a. Information flow of block building activity
   1) Materials stored in warehouses are transferred to workshops to be processed into ship blocks
   2) After the material arrives, it is necessary to identify the quality by the QA/QC division and make a report for the warehouse supervisor.
   3) Sorting is done for the material to be used, separated between plates, and raw profiles are ready to be processed according to the design.
   4) The steel stock house (SSH) stage performs the blasting process to obtain materials that meet the standards.
   5) Furthermore, the materials that have been blasted are labeled to distinguish between materials.
   6) While waiting for the following process, the labeled material is stored temporarily.
   7) Materials are transferred to the fabrication stage by using a forklift.
   8) Before the material is processed, it is necessary to set up and control the material and machines used.
   9) At this stage of fabrication, the material is marked in the form of a line pattern according to the design size; the aim is to make it easier to cut at the next stage.
   10) After the material is marked, the material is cut according to the line pattern. At this stage, the cutting is done manually for small materials and by machine for large enough materials.
   11) The material that has been cut is then smoothed on the edges to make it neat and ready for further processing.
   12) After that, the material is waiting and labeled for the next stage.
   13) Materials are transferred to the sub-assembly stage by using a forklift.
   14) Before the material is processed, it is necessary to set up and control the material and machines used.
   15) Materials that have been processed are re-sorted.
   16) At the subassembly stage, the process carried out is welding the material to form a ship block.
   17) The initial ship block that has been processed is then smoothed.
   18) After that, the ship block is taken to the assembly workshop using a forklift.
   19) Before the material is processed, it is necessary to set up and control the material and machines used to avoid failure.
   20) Materials that have been processed are re-sorted.
   21) The material to be processed is adjusted or fit-up.
   22) The last stage is assembly by welding all the materials used as ship blocks.
   23) Accuracy check stages are carried out in the form of checking dimensions according to the design to maintain the ship block's quality.
   24) Quality control of the finished ship blocks is carried out by the QA/QC to determine the standard of blocks that are ready for further processing. If the block is defective, it needs to be reworked.
   25) The finished block is moved to the following process for erection.

a. Physical flow of block building activity
   1) Materials in the form of plates and profiles come from a storage warehouse
   2) Materials are inspected by the QA/QC division to identify their quality, which is inspected in the inspection of dimensions, types, and quantities of materials.

3) During the block construction process, the QA/QC division continuously monitors the quality of the built blocks, especially during the welding process, which is prone to defects.

Table 1. Value Added (NVA) and Non-Value Added (NVAA) Activities

No	Process	VAA (minutes)	NVAA (minutes)
	Steel Stock House (SSH)		
1	Material Receipt		120
2	Control Material		120
3	Sortir		120
4	Blasting	480	
5	Labelling		60
6	Buffer		120
7	Transportation Transfer		60
	Fabrication		
8	Set Up & Control		60
9	Marking		60
10	Cutting	1440	
11	Grinding	1440	
12	Labelling		480
13	Trans to Sub Assembly		960
	Sub Assembly		
14	Set Up & Control		960
15	Sortir		480
16	Sub Assembly	2400	
17	Grinding	2400	
18	Trans to Assembly		240
	Assembly		
19	Set Up & Control		960
20	Sortir		480
21	Fitt Up	2400	480
22	Assembly	2400	
23	Check Accuracy		
24	Quality Control		240
25	Trans to Block Blasting		240
	Total	13020	6180
Lead time		**19200**	

Based on Table 1. then the process cycle efficiency (PCE) value can be determined using the eq. 1[11]:

$$PCE = \frac{value\ added}{lead\ time} \times 100\% \quad (1)$$

Estimating the process cycle efficiency (PCE) in Equation 1 is PCE = (13020/19200) × 100% = 67,81%. The total power required is 67,81%%. Therefore, the process of building block ships is still not running efficiently and effectively, so improvements are needed. Based on the Table 1. current value stream mapping is made based on the information flow data and physical flow, as shown in Figure 4. below..

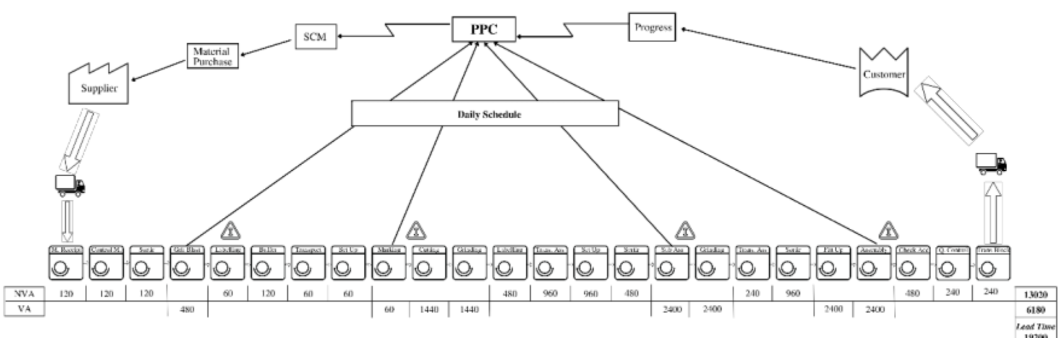

Figure 4. Current Value Stream Mapping

3.2 Measure

The measuring stage performs calculations by measuring the company's current performance conditions so that the company's achievements can be known. The data needed in research on lean six sigma are:

a. Block building waste questionnaire
b. Block sharing
c. Defect per block

Tabel 2. Lean Recapitulation Result

Waste	Weight	Ranking
Defect	2,0	1
Transportation	1,9	2
Waiting	1,8	3
Unnecessary Motion	1,7	4
Innarpropriate Process	1,6	5
Unnecessary Inventory	1,5	6
Overproduction	1,3	7

Based on Table 2. the most significant waste that occurs during the construction of the ship block is a defect because the ship block has many defects in its manufacture, especially during the welding process. Therefore, the operator must consider the accuracy factor to reduce the level of ship block defects. As for the most negligible waste in overproduction, there is no excessive block construction because the ship block construction is under the project needs.

3

Table 3. VALSAT Result

Waste	Weight	VALSAT						
		PAM	SCRM	PVF	QFM	DAM	DPA	PS
Over Production	1,3	1,3	3,9	0	1,3	3,9	3,9	0
Waiting	1,8	16,2	16,2	1,8	0	5,4	5,4	0
Excessive Transportation	1,9	17,1	0	0	0	0	0	1,9
Innarpropriate Process	1,6	14,4	0	4,8	1,6	0	1,6	0
Unnecessary Inventory	1,5	4,5	13,5	4,5	0	13,5	4,5	1,5
Unnecessary Motion	1,7	15,3	1,7	0	0	0	0	0
Defect	2,0	2,0	0	0	18,0	0	0	0
Total Weight		70,8	35,3	11,1	20,9	22,8	15,4	3,4

The calculation results above are obtained by multiplying the results of the wastage weight with the VALSAT scale. Based on table 3. Above, the percentage results of the assessment process are obtained. It can be seen that process activity mapping (PAM) has the highest value, amounting to 70.8, so the tools used in this research waste analysis use PAM. Next, identify the type and number of defects that occur during the construction of the ship block. The observations were used for the preparation of the CTQ, and it was found that the ship blocks have four types of CTQ which are described in figures 5, 6, 7, and 8.


Figure 5. Surface Porosity Defect


Figure 6. Former Stopper Defect

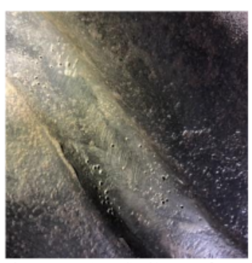
Figure 7. Arc Strike Defect


Figure 8. Low Bead Defect

Table 4. Block Defect Data.

Defect	Total	Percentage
Surface Porosity	7	5,78%
Former Stopper	11	9,09%
Arc Strike	9	7,43%
Low Bead	2	0,82%

The calculation results show that the sigma value is 3.073, which shows that it can compete in the Indonesian industry. Because PT PAL Indonesia is a manufacturing company in the maritime sector, ship block construction standards must be tightened to have quality results. Then the Defect per opportunites (DPO) and Defect per Million Opportunities (DPMO) value can be determined using the Eq. 2[12]& Eq. 3[13]:

$$DPO = \frac{total\ block\ defect}{total\ building\ block \times CTQ} \quad (2)$$

$$DPMO = DPO \times 1000000 \quad (3)$$

The calculation to determine the value of Defects per Opportunity (DPO) in Eq. 2 is DPO = 28/(121×4) = 0,057851. While defects per million opportunities (DPMO) in Eq 3 is. DPMO = 0,057581×1000000 = 57581.To measure the sigma value, tools are used in the form of a sigma conversion table or Microsoft Excel. This study used the help of Microsoft Excel with the formula Eq. 4[14] following.

$$Six\ Sigma = normsiv\left(\frac{1000000 - DPMO}{1000000}\right) + 1{,}5 \quad (4)$$

From the results of Eq. 4 of calculations using the help of Microsoft Excel, it can be seen that the sigma value is 3.073, which shows that it can compete in the Indonesian industry. Because PT PAL Indonesia is a manufacturing company in the maritime sector, ship block construction standards must be tightened to have quality results.

3.3 Analyze

The analysis stage aims to analyze the root cause of the problem. Based on table 3. the waste identified during the ship block construction process is as follows.

a) Defect: occurs because the construction of the block does not comply with quality specifications according to company standards. Usually, defects come from the welding process, fitting design improvements, and processes not following work standards.
b) Excessive Transportation: The layout in the workshop between workstations is far enough so that the movement of people, information, and materials can be delayed. For example, the next step is carried out in finishing material or blocks, but the process is still busy, so it is delayed and returned to the previous workshop and mixed with other processes.
c) Waiting: occurs due to incomplete materials or blocks and results in waiting for the following work. In addition, conditions where humans, materials, and information are inactive for an extended period while waiting for the process.
d) Unnecessary Motion occurs because the operator moves too much in picking up the material, causing fatigue. As well as workplace conditions with non-ergonomic equipment, the operator makes unnecessary movements when carrying out activities.
e) Inappropriate Processing: The flow of information in the design drawings does not match the material sent to the production workshop, causing an increase in lead time because the material process has not been fully processed.
f) Unnecessary Inventory: there are buffers or leftover raw materials throughout the block production process, such as between the fabrication process and the sub-assembly and between the sub-assembly and the assembly, so the blocks should be completed at the same time.

From the activity mapping process, the overall time of the ship block construction process was 19200 minutes, with a total of 25 activities in the process, as shown in tables 5 and 6.

Table 5. Current Time of Each Activity

Activities	Total	Time (minutes)	Percentage (%)
Operation	8	13020	67,82%
Transportation	5	1620	8,44%
Inspection	6	2820	14,68%
Storage	1	120	0,62%
Delay	5	1620	8,44%%

Table 6. VA, NVA, and NNVA

Category	Total	Time (minutes)	Percentage (%)
Value added (VA)	8	13020	67,82%
Necessary Non Value Added (NNVA)	12	4560	23,75%
Non Value Added (NVA)	5	1620	8,43%

Based on Table 4, the causes of the highest defects can be analyzed using a Pareto diagram as in Figure 9. then, analyze the causes of the most dominant defects as follows.

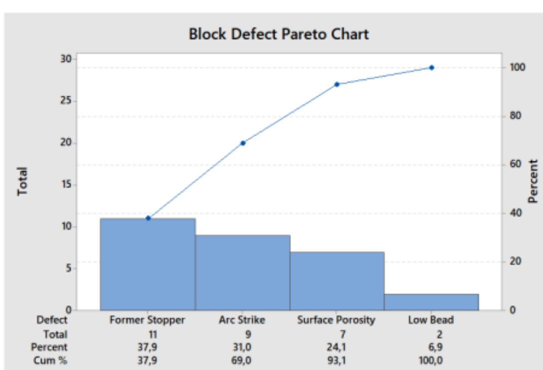

Figure 9. Block Defect Pareto Chart

It can be seen from Figure 9. that the types of defects that occur in the ship block construction process show that the types of defects that are used for stoppers are the most dominant defects, with a cumulative percentage of 37,9%. So it is assumed that 37,9% can represent all types of defects in the block construction process. Then the most dominant type of defect is further identified using a causal diagram such as Figure

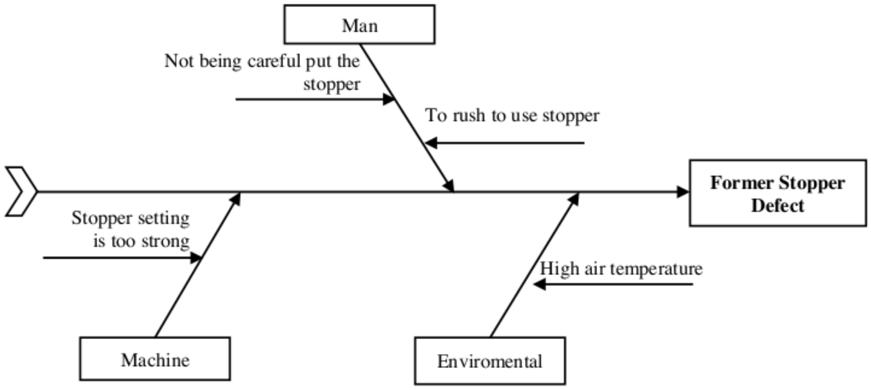

Figure 10. Fishbone Diagram of Former Stopper Defect

Figure 10 is one of the causal diagrams for the type of stopper defect. It can be seen that three main factors are causing these defects, namely humans, machines, and the environment. The cause of the defect from a human perspective is that the operator is not careful in installing the stopper and is too hasty in using it so that the position is not proper. The cause of the defect in terms of the engine is that the stopper setting is too strong, so it is difficult to control and causes defects. Meanwhile, the high air temperature causes the surrounding conditions to be too hot in terms of the environment.

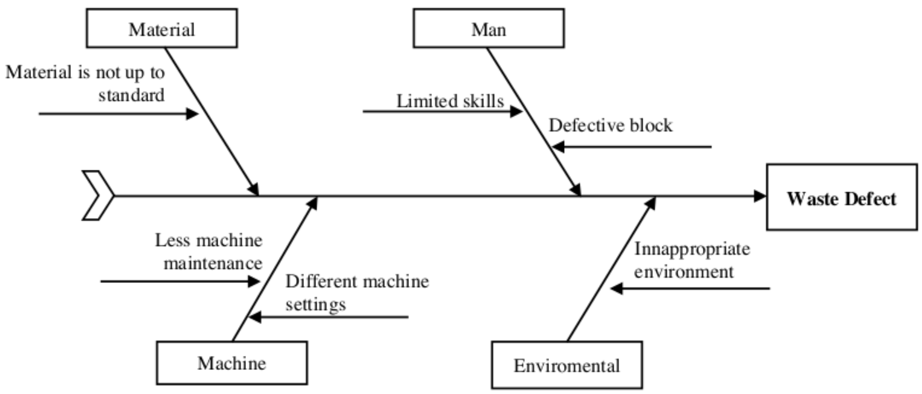

Figure 11. Fishbone Diagram of Defect

The cause-and-effect diagram of the causes of wastage of defects is in Figure 11. shows four factors that cause wastage of defects: human, material, machine, and environmental. The root cause of wastage of defects in terms of material, namely materials, especially plates and profiles that do not meet company standards, can be in the form of differences in dimensions and material quality. The cause from a human perspective is the operator's lack of skill and expertise when building blocks; besides, there are defective blocks that need to be reworked to be repaired. The cause in terms of the machine is that the machine or production support equipment is quite old and needs to be treated; besides that, different types of machines have different settings. In comparison, the causes that are viewed from the environment are high air temperatures that can affect the production process and the operator in operating the machine.

3.4 Improvement

The improvement stage is carried out to reduce waste in the ship block construction process; the method is to determine an improvement plan during the block construction process and identify the priority of the repair plan.

Table 7. FMEA of Former Stopper Defect

Potential Failure Mode	Potential Effect of Failure	S	Potential Cause	O	Curent Control	D	RPN
Former stopper Defect	Cracks will occur because it affect the resistance of the ship's block	8	Not being careful put the stopper	7	Supervise the operator	6	336
			Setting stopper is too strong	8	Recalibrate the stopeer	8	512
			To ush to use stopper	5	Stopper inspection	4	160
			High air temperature	4	Waiting air temperature to normal	3	96

Based on FMEA table 7. on the type of stopper used defect, it can be seen that the highest RPN value is 512. The proposed improvement that needs to be done is to recalibrate the stopper tool before using it on the welding machine.

Table 8. FMEA of Defect

Potential Failure Mode	Potential Effect of Failure	S	Potential Cause	O	Curent Control	D	RPN
Proses pembangunan blok	Waste Defect	9	Material is not up to standard	8	Material inspection	8	576
			Limited skills	7	Training the operator	8	504
			Defective block	8	Rework block defect	6	432
			Less machine maintenance	6	Schedule machine maintenance	7	378
			Different machine setting	7	Recalibrate the machine	5	315
			Innappropriate environment	5	Anticipating the environment	5	225

Based on FMEA table 8 on the waste of defects, it is known that the highest RPN value is 576. The proposed improvement that needs to be done is to inspect the dimensions and quality of the material, especially plates and profiles that will be used as blocks to maintain company standards.

Table 9. Time of Each Proposed Activities

Activity	Total	Time (minutes)	Percentage (%)
Operation	8	13020	74,07%
Transportation	5	1620	9,21%
Inspection	4	2220	12,63%
Storage	1	120	0,68%
Delay	2	600	3,41%

Based on table 9. It can be seen that there are 25 activities during the ship block construction process. After improvements have been made to the ship block construction process, the proposed activities amount to 20 activities originating from station merging and reducing non-value added activities because these activities are inefficient and affect the process. So that the proposed value-added is 13020 minutes and the non-value added value is 17580 minutes, then the proposed lead time is reduced by 1620 minutes, and the PCE value is increased by 74.06%. The future state VSM diagram depiction is shown in figure 12.

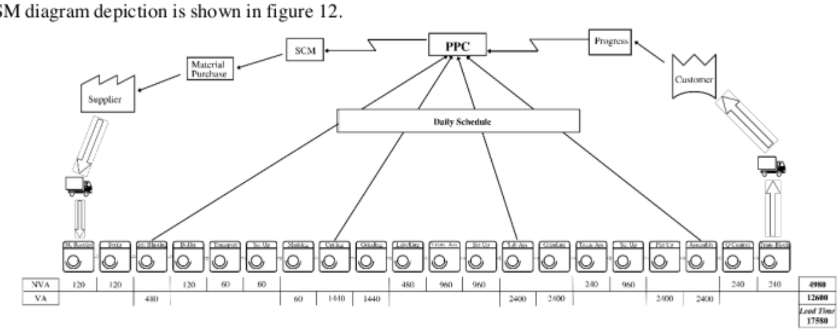

Figure 12. Future State Mapping

3.5 Control

The control stage helps control the improvement of waste that takes place continuously and for a long time. In this study, the control phase could not be implemented because the decision on this research proposal was submitted to the company, so control efforts could not be made.

4 Conclusion

From the results of the identification of waste using the lean six sigma method, it can be seen that the most significant waste is defected by 20%. It is known that the DPMO value and the sigma value are 57581 and 3.073 sigma, respectively. The most significant cause of used stopper defects is the setting of the stopper that is too strong, while the waste of defects is material that does not meet company standards. The proposed improvement is to recalibrate the stopper tool before use and inspect the material dimensions and quality, especially plates and profiles. It is expected to increase the efficiency of ship block construction to 74.06%.

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