Application of value stream mapping to improve service in The Departure Terminal at Halim Perdanakusuma Airport

(*Implementasi value stream mapping untuk meningkatkan kualitas pelayanan pada Terminal Keberangkatan Bandara Halim Perdanakusuma*)

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Received 03 October 2021, Revised 05 April 2022, Accepted 07 April 2022, Published 13 May 2022

Abstract. This study aims to identify and reduce waste in the passenger flow process at the Halim Perdanakusuma Airport departure terminal, so that passenger service remains good even with limited terminal capacity. This research used a qualitative method with a case study approach. The method stages are the observation of the departure passenger flow process mapped through current state Value Stream Mapping (VSM), distribution of questionnaires to obtain critical waste with Borda analysis, and fishbone diagrams to find out the rooting causes of critical waste, the proposing process improvements, and the future state of VSM, The results showed that critical waste in the flow of departure passengers is 22.11%, which includes passenger activities waiting for the Security Check Point 1 and Point 2 queue. Furthermore, based on the current state of VSM, the lead time for departure passengers is 33 minutes 47 seconds and VAR is 20.22%. While form the future state of VSM, the lead time is 28 minutes 22 seconds with a VAR of 20.36%, resulting in time efficiency of 5 minutes 24 seconds.

Kata kunci: lean service, value stream mapping, borda method, fishbone diagram

Abstrak. *Penelitian ini bertujuan untuk mengidentifikasi dan mengurangi pemborosan dalam proses pelayanan penumpang di terminal keberangkatan Bandara Halim Perdanakusuma, agar tetap memuaskan meski kapasitas terminal terbatas. Penelitian bersifat kualitatif dengan pendekatan studi kasus. Tahapan penelitian diawali dengan observasi pada proses alur penumpang keberangkatan melalui Diagram VSM, penyebaran kuesioner yang dianalisis dengan Metode Borda dan Diagram Fishbone untuk mengetahui akar permasalahan, sehingga dapat diusulkan perbaikan melalui pemetaan VSM kembali. Hasil analisis menunjukkan adanya pemborosan pada waktu antrian keberangkatan penumpang sebesar 22,11%, meliputi proses di titik pemeriksaan keamanan 1 dan 2. Selanjutnya, berdasarkan usulan VSM yang baru diketahui waktu pelayanan alur penumpang keberangkatan dari sebelumnya sebesar 33 menit 47 detik dan VAR 20,22%, setelah perbaikan menjadi 28 menit 22 detik dengan VAR 20,36%, sehingga terjadi efisiensi waktu sebesar 5 menit 24 detik.*

Keywords: lean service, value stream mapping, metode borda, diagram fishbone.

1. Introduction

Halim Perdanakusuma Airport (HPA) is located in DKI Jakarta Province and is managed by PT. Angkasa Pura II (Persero). This airport is a civil enclave airport, so it serves VVIP, military (TNI AU), and commercial flights. Since 10th January 2014, HPA has temporarily operated as a commercial airport to assist flights at Soekarno-Hatta Airport, which is already in congestion. Since opening as a commercial airport, the numbers of aircraft and passengers flying to and from this airport have increased. However, with a terminal area of 21,000 m^2, it must be able to accommodate passengers that continue to increase from 1,650,083 passengers per year in 2014 to 7,388,288 passengers per year in 2018, according to Figure 1.

Figure 1 Aircraft and Passenger Data Per Year.
Source: International Air Transport Association (2019)

Based on a study conducted by Miharja & Puspaningrum (2017) regarding the Development Potential at HPA as a commercial airport, it is known that the most critical limiting factor for the development at HPA is the land side factor due to the limited space for the development of various facilities needed to meet the service standards. In addition, the study states that based on the projected growth of passengers at HPA, it can accommodate 2,750,369 passengers per year which will be achieved in mid-2021 to 2022. When compared to the current conditions, in 2018 HPA alone has served 7,388,288 passengers per year which exceeds the estimate from the results of the study, so it can be said that HPA is currently exceeding its carrying capacity. The increased movement of passengers at HPA and the limited capacity of the terminal space can affect the passenger service process (Table 1).

Table 1 Level of Service at Departure Terminal

No	Form of Service	Indicator	Standard size	Results (Minutes)	Information
1	Passenger and baggage checks (SCP 1 and 2)				
	▪ Passenger Check Queue	Time	< 7 minutes	11.54	Not qualify
	▪ Passenger and Goods Inspection Process in Normal Condition	Time	< 3 minutes	3.02	Not qualify
	▪ Passenger and Special Condition Goods Inspection Process	Time	< 8 minutes	13.21	Not qualify
2	Check-in service				
	▪ Queue for Check-In Services	Time	< 20 minutes	13.57	Qualify
	▪ Check-In Service Process	Time	< 2 minutes 30 seconds	2.40	Not qualify

Referring to PM 178 of 2015 of concerning airport service user standards, the form of service in the passenger departure process at HPA consists of checking passengers, baggage and check-in services. In Table 1, it can be seen that at the peak of the 2019/2020 holiday season (1st January 2020) where there was an increase in passengers, for passenger and baggage inspection services the minimum service standard value (Level of Service) was not met. In addition, based on observational data there is a build-up of passenger queues at the departure terminal during peak hours which can be seen in Figure 2. The accumulation of passenger queues occurs at every departure flow process, starting from the security check point 1 process, the check-in process to the security check point 2. Therefore, it is necessary to organize the flow of passengers by identifying and reducing waste, so the service process remains good although it is limited terminal capacity.

Figure 2 Documentation of Passenger Queues during Peak Hours.

Lean is a continuous effort to eliminate all problems that occur in company activities such as waste. Based on a study conducted by (Maria et al., 2019). It shows that the lean principle can be applied in the airport service industry (Setiawan et al., 2021). The study implements and evaluates the effectiveness of using a lean approach in the departure area of King Khalid International Airport (KKIA) to improve service levels (LoS) and customer satisfaction. The results of this study show that there has been an increase in passenger service after the implementation of the lean principle, namely a reduction in the total waiting time for passenger services from 54.74 to 34.87 minutes.

Lean application can use tools, one of which is Value Stream Mapping (VSM) (Ikatrinasari et al., 2018; Hartanti & Singgih, 2020). VSM is a lean management technique that helps companies visualizes processes to define and optimize the steps involved in getting a product or service from start to finish (Ikatrinasari & Haryanto, 2014). Therefore, to optimize the flow of departure passengers will be carried out by implementing lean principle, especially using VSM, which allows identification of obstacles and makes models with the output of the passenger flow process method into a lean condition at the departure terminal at HPA (Stadnicka & Ratnayake, 2017; Bait et al., 2020).

The purposes of this research are to identify and reduce wasting time in the flow of passengers in the departure terminal at HPA, so passenger service remains good even with limited terminal capacity. The objectives of this study are: (1) to evaluate the current flow of passengers at the HPA departure terminal; (2) to analyse the flow of passengers at the HPA departure terminal using the lean principles; and (3) to analyse the optimization of the passenger flow process at the HPA departure terminal using the concept of lean principles.

2. Method

The method used in this research is a qualitative research method with a case study method (Ahmadi, 2005). In this study, researchers chose respondents or informants by non-random sampling with purposive sampling. Purposive sampling is a technique of sources data sampling with certain considerations (Sugiyono, 2017). Referring to Bouyssou et al. (2006), researchers determine informants or participants based on several criteria for consideration, including the informant must master or understand something through the enculturation process. In this study, the researcher determined 50 informants consisting of internal and external parties of the company.

The research will limit the focus of the discussion of the main problem, namely: (1) the research will only be carried out on the passenger flow of the land side of the Departure Terminal which is the most critical limiting factor for the development of HPA. These are including passenger inspection queues, passenger and goods inspection processes, check-in service queues and check-in service processes, (2) this research will be limited to observational data on existing service time measurements by using historical data during the peak season, namely the 2019/2020 Christmas and new year holiday season, because the highest number of passenger movements is in that season, 3) this study is limited only to the subject of departure passenger flow to passengers with luggage and using a conventional check-in process.

Data Triangulation

In qualitative research, it is necessary to validate the data in an effort to increase the degree of the data's credibility. The researcher will triangulate the data to maintain the data's validity that has been collected, including the following (Heale & Forbes, 2013):

1. **Triangulation of sources**
   The researcher will be re-checked the data by comparing the information obtained from one participant with another against the actual data or an incident phenomenon.
2. **Triangulation of data collection methods**
   Researchers used several methods in collecting data in order to test the data's quality. Data are obtained from observations, in-depth interviews, unstructured interviews, weighting questionnaires (waste), review of documents and documentation. Then, the researchers analyse the data systematically to solve the found problems, so that they were in accordance with the objectives of this study.

Data Analysis Method

1. Draws the current VSM of the existing products and analyzes the entire repair process for selection.
   - Identify and map al involved processes in the entire passenger of flow process at the departure terminal,
   - Describe each process in a Value Stream Mapping and identify the direction and type of information for each of existing process,
   - Record the number of operators at each of process station,
   - Get information about the time used which consists of CT (Cycle Time), LT (Lead Time), VA (Value Added Time), and NVA (Non Value Added Time),
   - Make a diagram of value-added time and non-value added time. Next, calculate the value-added ratio (VAR), with the following formula:

   $$Value\ added\ ratio = \frac{value\ added\ time\ (process\ time)}{total\ process\ cycle\ time} x100\% \quad (1)$$

   This ratio is used as an effective tool to track how much progress is in eliminating waste. If the VAR increases, the total cycle time for the service process will decrease. Therefore, it means that there is acceleration in the delivery time of products (goods/services) to customers (Gaspersz, 2002).
2. Identify critical waste in the passenger flow process
   At this stage, waste identification is carried out in the passenger flow process at the departure terminal by interviewing informants for waste assessment. The goal is to determine the level of frequency of types of waste according to the lean concept that occurs based on observations and experiences of officers in the field. The results of the waste assessment will be analysed by the Borda method. This method is a method for analysing the diversity of the studied variables. The principle of the Borda method is to rank the alternatives (Bouyssou et al., 2006). Furthermore, the alternative that has the highest ranking will be given the highest value and so on decreasing until the lowest rank is given a value of 0 or 1, so that it can be determined which critical waste among the 8 types of waste.
3. Finding the root cause of critical waste
   After the types of critical waste in the departure passenger flow process are determined, the researcher will identify the root cause through in-depth interviews with selected informants with a fishbone diagram or Ishikawa diagram, which is a diagram that shows the causes of a specific event. This method is one of the used methods in root cause analysis in order to solve problems, namely finding the root of a problem or the cause of a defect in order to get to the root cause of the problem. Fishbone diagrams are prepared on the basis of observations which are clarified by interviews with the officers involved.
4. Gather and propose improvement ideas
5. Draw a new VSM (future state map)
6. Make conclusions on the research that has been done.

3. Result and Discussion

Identification of HPA Departure Passenger Flow

Based on observations, the departure of passenger flow at HPA consists of several passenger routes. However, in this study it is limited to research the flow of passengers with luggage and check in conventionally (Figure 3).

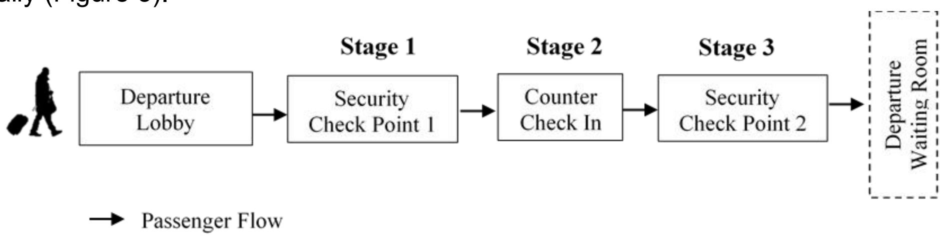


Figure 3 Mapping of Conventional Departure Passenger Flow Process Stages with Baggage and Check-in.

Consistency and Data Adequacy Test

Before compiling the current state of VSM, it is necessary to collect data in the form of measuring the time of the departure passenger service flow through observation. The data collected is a recapitulation of the time of each process in the departure passenger flow. The obtained time data is taken using the stop clock method which is then recapitulated, but not all processing times can be carried out directly. Data collection is obtained by calculating the required time based on CCTV video data. From the observational data that has been collected, the calculation is continued to see the consistency of the data and the adequacy of the observation time data. An outline of the time measurement data for each process can be seen in Table 2.

Table 2 Recapitulation of Time Measurement Data

No	Process	Average Time (Seconds)	Observation time to - (seconds)									
			1	2	3	4	5	6	7	8	9	10
1	Security Check Point 1 Process	556.90	580	537	609	546	562	589	575	530	530	511
2	Check In Process	907.60	827	889	820	984	943	990	838	919	962	904
3	Security Check Point 2 Process	562.60	557	552	555	598	544	614	599	539	541	527

The data consistency test is a test that is useful to ensure that the data collected comes from the same system. The formula for calculating the average processing time value:

$$\overline{X} = \frac{\sum X_i}{n} \quad (1)$$

The formula for calculating the standard deviation value:

$$\sigma = \sqrt{\frac{\sum (X_i - \overline{X})^2}{n-1}} \quad (2)$$

Control limit calculation formula:

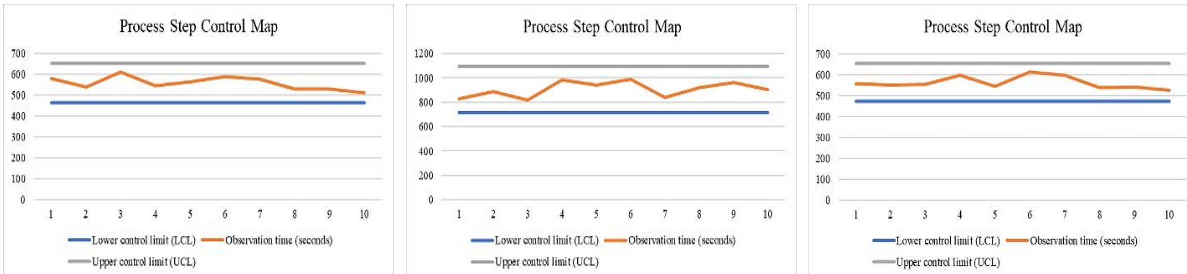
$$Upper\ control\ limit\ (UCL) = X + k\sigma \quad (3)$$
$$Lower\ control\ limit\ (LCL) = X - k\sigma \quad (4)$$

Information:

$\overline{X}$= Average value of processing time (seconds)
X_i = Process time-i (seconds)
n = Lots of data
σ = Standard deviation

k = Confidence level (99% ≈ 3)

From the calculation of obtained control limits as well as from Figure 4, it is known that the data is within the control limit, so that it can be concluded that the data in the Security Check Point 1 process, the Check In process, the Security Check Point 2 process are **consistent**.



Security Check Point* 1** | ***Check In | ***Security Check Point 2***

Figure 4 Control Map of Process Steps at Security Check Point 2.

Observations in this study have accommodated the variability that occurs in data collection. For example, the data is taken during the busy hour on the busiest day like Friday. At each stage of the service process, it describes the variation in the observation time data during the process. Based on time measurement data, it can be seen that the performance of the service process for departure passengers at HPA varies.

The data sufficiency test aims to ensure that the collected data is objectively sufficient. Testing the adequacy of data was carried out based on statistical concepts, namely the level of accuracy confidence. The level of accuracy and confidence is a reflection of the level of certainty desired by the meter after deciding not to take large numbers of measurements.

The data sufficiency test formula uses the following formula:

$$N' = \left[\frac{k/_s\sqrt{N\sum x^2-(\sum x)^2}}{\sum x}\right]^2 \quad (5)$$

Where:
k = Confidence Level (95% ≈ 2)
s = Degree of Accuracy
N = Amount of Observational Data
N' = Amount of Theoretical Data
x = Observation data

The results of the data adequacy test at each stage of the process:

1. Security Check Point 1, where:

$$N' = \left[\frac{k/_s\sqrt{N\sum x^2-(\sum x)^2}}{\sum x}\right]^2 = \left[\frac{2/_{0.05}\sqrt{(10(3{,}110{,}007))-(5{,}569)^2}}{5{,}569}\right]^2 = 4.49$$

Based on calculations because N'< 10 (4.49 < 10), then the data is considered sufficient.

2. Check In, where:

$$N' = \left[\frac{k/_s \sqrt{N\sum x^2 - (\sum x)^2}}{\sum x}\right]^2 = \left[\frac{2/_{0.05} \sqrt{(10(8{,}273{,}720)) - (9{,}076)^2}}{9{,}076}\right]^2 = 7.06$$

Based on calculations because N'< 10 (7.06 < 10), then the data is considered sufficient.

3. Security Check Point 2, where:

$$N' = \left[\frac{k/_s \sqrt{N\sum x^2 - (\sum x)^2}}{\sum x}\right]^2 = \left[\frac{2/_{0.05} \sqrt{(10(3{,}173{,}246)) - (5{,}626)^2}}{5{,}626}\right]^2 = 4.07$$

Based on calculations because N'< 10 (4.07 < 10), then the data is considered sufficient.

Existing Process Activity Mapping

Through the Process Activity Mapping, it is mapped which activities add value (value added) and which activities do not add value but are necessary (necessary but non value added), and which activities do not add value (non-value added) but are not necessary. The processes activity mapping is divided such as time, number of operators, and 5 other activities, namely operation (O), transportation (T), delay (D), inspection (I), and storage (S). Based on these activities, data on the number of activities and activity categories can be obtained (see Table 3).

Table 3 Total VA, NVA, NNVA In Each Activity

Category	O	T	D	I	S	Total
VA (value added)	9			8		17
NVA (non-value added)			3			3
NNVA (necessary but non-value added)	5	2				7

Based on Table 3, the largest total time is owned by the NVA (non-value added) category of 1,340.80 seconds which is located in the delay activity consisting of queuing for passengers to SCP 1, check-in queue and SCP inspection queue 2. Time needed in the flow process departure passengers at HPA are 2,027.10 seconds or 33 minutes 47 seconds. This process shows that the percentage of value-added time is 20%, non-value-added time is 66%, and the necessary but non-value added time is 14%. Value added is an activity that provides added value to passengers, non-value added is an activity that does not provide added value to passengers, and necessary but non-value added is an activity that does not provide added value but is necessary.

Table 4 Total Time for VA, NVA and NNVA

Category	O	T	D	I	S	Total Time (Seconds)	Percentage
VA (value added)	232			177,8		409.80	20%
NVA (non-value added)			1,340.8			276.50	66%
NNVA (necessary but non-value added)	194.5	82				1,340.80	14%
Total	426.5	82	1,340.8	177,8	0	2,027.1	100%

Current State VSM

After compiling the existing process activity mapping and VA mapping, NVA and NNVA activities, the next step is to create a current state of value stream mapping. The purpose of using this tool is to focus on exploiting value-added processes and eliminating those that are not value added by considering them as a waste of available resources. The results of VSM and value-added assessment along the departure passenger flow process can be seen in Figure 5. The results obtained were the lead time of 2,027.1 seconds or 33 minutes 47 seconds with a comparison of the VA: NVA values of 409.8 seconds: 1,340.8 seconds and the VAR value of 20.22%.

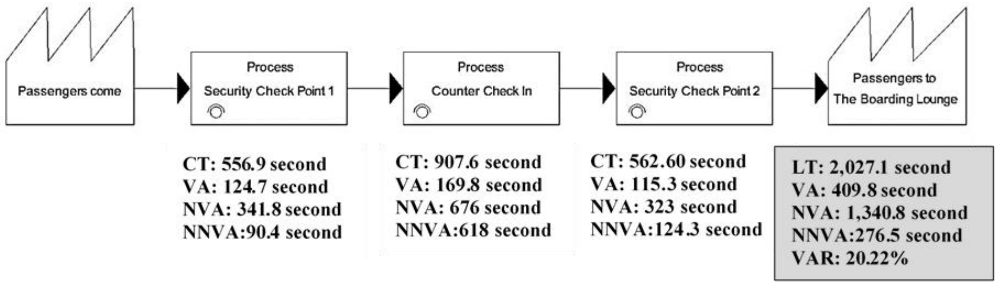


Figure 5 Current State Value Stream Mapping.

Figure 5 shows that the current state VSM is precisely used to provide a big picture of the operating conditions. These operating conditions occur in the current departure passenger flow process at HPA. By describing the entire process from start to finish, it will make it easier than to determine the optimization of the process that it currently happening. Based on this figure, it can be seen that in each departure passenger flow process for most of the time is non-value-added activity (NVA) which is a waste that must be reduced or even eliminated.

Lean Service Design

The next stage is to determine what critical waste occurs in the passenger flow for the departure at HPA. Researchers conducted observations and interviews with informants who had been determined to find out what was included in the 8 types of waste based on the seven types of waste and new waste categories in the study of Rexhepi and Shrestha (2011). The identification of 8 types of waste are as follows:

Table 5 Waste Ranking

Rating	Waste Type	Percentage
1	Waiting	22.11%
2	Motion	20.61%
3	Human Potential/ Untapped competence	17.62%
4	Transportation	14.12%
5	Overprocessing	12.84%
6	Overproduction	6.99%
7	Defect	3.99%

In the Table 5, the type of waste that ranks first is the waiting type with a percentage of 22.11%. It can be concluded that the critical waste that occurs in the departure passengers at HPA is the waiting type of waste. These results are in accordance with the study of Rexhepi and Shrestha (2011). The theory states that the waiting type of waste from a service perspective involves delays in one activity. The waste waiting type is the waste that occurs due to no ongoing activity and the act of doing nothing or working slowly while waiting for the previous step in the process.

The results of weighting using Borda Method are also in line with the result of the analysis that has been carried out before. The result analysis is the existing process activity mapping stage where non-value-added activities with the largest total time is owned by the NVA category. Therefore, the NVA category are located in delay activities which include passenger waiting activities in line for the security checks

SCP 1, the security checks queue SPC 2, and the check-in queue. Regarding the passenger waiting activity for the check-in queue, although it is included as a NVA, it does not enter into waste category. Consequently, this occurs because based on the data collection the average queue time is 12 minutes and 18 seconds. Therefore, it is still in accordance with the minimum service standard or level of service which is 20 minutes.

Analysis of the Root Causes of Critical Waste

The next step is finding the root of the problem that causes waste waiting by using a fishbone diagram. Fishbone diagrams are made based on the results of the interviews.

The existence of waste indicates that the route of departure passengers cannot be considered lean. This section describes the proposed improvements, which are expected to reduce or even eliminate waste, to be used as a basis for making future state value stream mapping. This improvement proposal is obtained from the identification of the fishbone diagram (Table 6).

Table 6 Proposed Problem Repair Design

Source of the Problem	Root of the problem	Proposed Improvement
Human	▪ The number of aviation security personnel (AVSEC) is limited if all check lines are optimized for both SCP 1 and SCP 2.	▪ The need for additional AVSEC personnel in the number and composition is required. ▪ It is necessary to arrange the work schedule of officers by adjusting busy hours, especially when during peak hours, there has to be additional human resources.
	▪ The limited number of security personnel causes officers to work double duty outside of their duties	▪ The need for additional AVSEC personnel in the number and composition is required. ▪ It is necessary to arrange the work schedule of officers by adjusting the busy hours, especially when during peak hours, there has to be additional human resources.
	▪ Airline officers are not always on standby at SCP1 to assist passengers who need to check in immediately (close to the deadline)	▪ The need to assign officers at SCP 1 when there is an increase in passenger queues.
Machine	▪ The operation of the X-Ray Machine is not optimal (there are three X-Ray machines per SCP, but ideally one x-ray only serves to back up if there are any problems)	▪ It is necessary to add one x-ray machine for backup, so that all x-ray machines can be used optimally.
Method	▪ The departure passenger flow process and procedure still consist of several stages that passengers must go through.	▪ The need to simplify and speed up the passenger's flow process. ▪ It is proposed that baggage security checks should be implemented with a security check model after the check-in area, so that there is a process at SCP 1 that can be eliminated.
	▪ Passengers have to wait a long time in the queue because many passengers do not know the security check procedures at SCP.	▪ The need for socialization for passengers regarding security regulations, so that passengers can understand the procedures related to luggage. ▪ It is necessary to have signage / instructions related to passenger and baggage inspection procedures, which are clearly visible from the beginning of the passenger flow process.
Environmental	▪ Insufficient area, resulting in overcrowding of passengers during peak hours.	▪ It is necessary to expand the area or improve the layout of the room. ▪ It needs restrictions or slot arrangements so there are no adjacent flight schedules.

It is hoped that the design related to this proposed improvement will result in a new and more efficient service flow in time than before improvement. After the lean design, the departure passenger flow activity becomes less, so that it affects the reduction in total service time.

Future State VSM

The next step is to create a Future State Value Stream Mapping, which is a proposed improvement of the current state value stream mapping by eliminating activities that are considered waste (Figure 6).

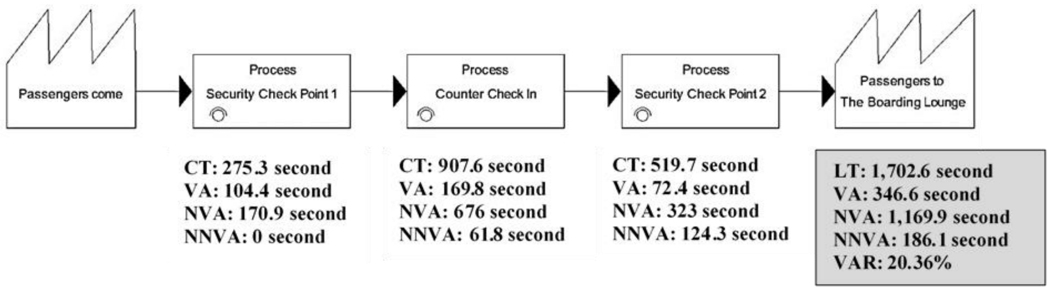


Figure 6. Future State Value Stream Mapping

The total time in the future state value stream mapping on the departure passenger flow process shown in Figure 6 is 1,702.6 seconds. If it converted into minutes, it will be 28 minutes 22 seconds or 5 minutes 24 seconds faster than the previous lead time. In the future state VSM condition, it shows that the percentage of VA time is 20%, while the percentage of NVA time is 69% and the necessary NVA time is 11%. After the design of lean, it is clear that there is a reduction in activity that occurs. Consequently, it reduces service time in the process, which can be seen in Table 7 which shows that the use of lean can effectively reduce the existing lead time.

Table 7 Differences Before and After Lean Application

Category	Before	After
Total value added time	409.8 second	346.6 second
Total non-value added time	1,340.8 second	1,169.9 second
Total necessary but non-value added time	276.5 second	186.1 second
Lead Time	2,027.1 second	1,702.6 second
VAR	20.22%	20.36%

Based on the table above, the difference is clear. For example, in terms of time after the lean design, it can be reduced by 5 minutes 24 seconds. It is due to a reduction in activity at the security check point 1 process in order to be more concise. In the VAR value, there was an increase, namely before the implementation of lean the VAR value was 20.22% and after the application the VAR value became 20.36%. Referring to Gaspersz (2002), through the increase in VAR, the total cycle time for the service process will decrease, so it means that there is an acceleration of the delivery time of products (goods / services) to customers. This shows that the implementation of lean can be applied in the airport service industry because it can increase the efficiency of the processing time in the passenger flow departure at HPA.

4. Conclusion

Based on the results of the research that has been done, In the process of departure passenger flow at HPA, there is a process that is not in accordance with the minimum service standards (Level of Service/LoA). During peak hours, the queue for checking passengers at Security Check Point 1 and 2 based on LoS standards should be under 7 minutes. However, based on the average time

measurement from the observation results, it is 7 minutes 12 seconds for Security Check Point 1 and 7 minutes for Security Check Point 2. These things indicate that the service time is quite long and some exceed the minimum service time standard that should have be.
Based on the results of the waste questionnaire calculation and analysis using the Borda Method, it is known that the critical waste that occurs in the flow of passengers for the departure at HPA. The waste waiting is a value with 22.11% which includes passenger activities waiting in line for the security check at SCP 1 and at SCP 2.

The design of the departure passenger flow for HPA through the implementation of lean resulted in a reduction for activity in the departure passenger flow process. The reduction is in the total service time by 5 minutes 24 seconds. In addition, there was an increase in the VAR value from 20.22% to 20.36%. Consequently, the total cycle time for the service process would decrease and there was acceleration in the delivery time of products (goods/services) to customers.

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