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## Article

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# IT-based Lean Six Sigma implementation in civil registration: lesson learned from an Indonesian context

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## ABSTRACT

This research paper focuses on the integration of Lean Six Sigma (LSS) with Information Technology (IT) in the public sector, specifically in the context of developing countries, using the City Office for Population Administration and Civil Registration (COPACR) in Surabaya, Indonesia, as a case study. Previous studies on this integration have shown positive results, but often lack detailed insights into the implementation process, context, and challenges faced. The paper adopts an action research methodology, observing processes at COPACR through IT, considering the unique challenges of developing countries. The study focuses on the application for birth certificates and follows the DMAIC (Define, Measure, Analyze, Improve, and Control) framework. Key challenges identified include low employee competencies, minimal investment, and a rigid organizational structure. These challenges were measured in the form of speed and quality of services based on the parameters of process capability analysis and Sigma level. Based on the problems identified during the analysis, corrective steps to reduce and eliminate waste were applied for better performance. The system achieved an improved completion time from 17.12 to 0.48 days with the sigma level from -6.46 to 4.09. The sigma level improvement corresponds to an improvement from -2.15 to 1.37 in Cpk parameter. The findings are valuable for public agencies in other cities in Indonesia and developing countries looking to implement IT-based Lean Six Sigma, emphasizing the importance of considering local context and challenges.

## ARTICLE HISTORY

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## 1. Introduction

Due to the changing landscape of various industrial sectors, and further exacerbated by the COVID-19 pandemic, digitization of the public sector has become a necessity. (Waranggani, 2022). What makes the public sector unique is that all public service providers must provide inclusive and high-quality services to all public demographics, which means they cannot choose a target customer to serve in their business processes and must address a variety of different concerns, understanding levels, and regulation awareness. Conversely, citizens, as customers of public services, do not have an assortment of choice on service providers and must rely on the services provided by the government. Public services with administrative characteristics are generally monopolistic, unlike the private sector, where service providers compete to attract customers (Wasistiono, 2022). The unique condition of public services that cannot be transferred to other entities is a challenge for low-quality public service providers because it can lead to low customer satisfaction and lower trust in government service providers (Khan et al., 2015; Mohd Wahid et al., 2020; Wynen et al., 2014). Building public trust in government agencies and providing high-quality services are the primary goals of most city governments. In the context of population

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administration services, expectations of service quality are increasing. This is aligned with the increasing public understanding and awareness of the importance of essential citizenship documents. Innovation in the public sector is also driven by the limitations and scarcity of resources when responding to service quality demands (Vickers et al., 2017).

The implementation of digital and information technology (IT) is considered a tool to improve the public services sector. According to Jonathan (2020), the main benefits of information technology are expressed in terms of improved accountability, transparency, and productivity. Digitalization requires a change in the way the public sector delivers, organizes, and produces services for its citizens (Ruud, 2017; Walport & Craig, 2014). For governments, IT leads to high-level policies that aim to provide benefits to the community (Magna & Irfan Maulana, 2023), reduce service costs (Omar et al., 2016), and increase time efficiency (Gijo & Antony, 2014). IT implementation without a robust, systematic, and integrated plan leads to insignificant results. A relevant and systematic guide related to business process improvement in the public services sector is Lean Six Sigma (LSS) (Juliani & Oliveira, 2021). LSS has been widely applied in the public sector, with positive results. LSS has been implemented by local governments in the United Kingdom (UK) (Antony et al., 2016), municipal governments in the Department of Public Works (DPW) in the USA (Kim, 2020), government financial management in 13 countries (Furterer & Elshennawy, 2005), outpatient departments (OPD) in India's hospitals (Gijo & Antony, 2014), and non-profit organizations in the field of assistive device centers in Taiwan. Applying LSS in the public sector requires the assistance of digital technology for public records, budget efficiency, integrated systems, and accelerating service times (J. Fletcher, 2018). Therefore, implementing LSS in the public sector in an integrated manner with information technology is crucial.

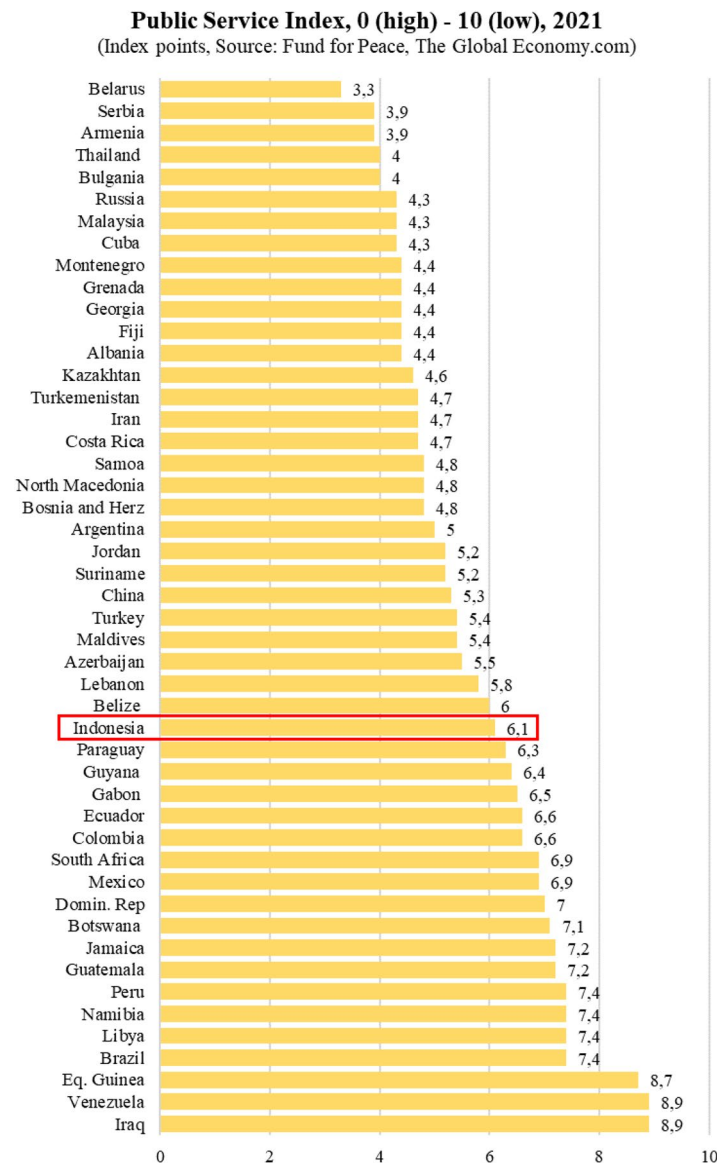
The integration of information technology in LSS implementation is promising to accelerate the achievement of expected efficiency and service integration. The recommendation given by Antony et al. (2017) highlighted that LSS methodology combined with IT can be adopted by all public sector organizations to create efficient and effective processes with lower operational costs. Several cases reported in the literature provide evidence of the integration and ubiquity of the results. For example, the combination of LSS and IT applied in software firms has been proven to increase revenue by up to 80% in five years (Byrne et al., 2007). Another example shows that IT-based LSS deployment has contributed to project management in the design of business information systems and is used by more than 30% of IT-based companies (Duarte et al., 2012). Another case shows that applying LSS with IT has succeeded in reducing the number of customer service rejections in the banking sector (Sunder, 2016). Despite the multitude of benefits observed in the cases presented in previous studies, these instances of IT-based LSS have not yet considered the specific characteristics and limitations of developing countries.

Developing countries experience various limitations that cause the integration of IT into public sector services to be an impediment rather than a tool for optimizing services and processes. Due to limitations that include but are not limited to culture, IT access and literacy, societal class, and large population, there is a significant disconnect between the evidence and cases presented in various papers discussing IT-based LSS with what is experienced by public agencies and governments in developing nations. Developing nations cannot simply adopt IT integration in their processes and must overcome some internal and external challenges before the benefits of IT-based LSS can be experienced, as previously reported. Subsequently, with their current impediments, developing nations' public sectors have difficulty adopting concepts like a sustainable approach to LSS. Consideration and concern regarding sustainable LSS, such as Green Lean Six Sigma, is still an afterthought for these agencies. The integration of IT as rudimentary as converting written forms to typed forms may still be hindered by redundant operations and limitations. This study attempts to fill the existing research gap by providing a reference that can be used as universal guidelines for the implementation of LSS in the existing public sectors of developing nations.

As a developing country with an upper-middle-income category, Indonesia is ranked 25th out of 48 countries with a public services index of 6.10 out of 10.0 (the score on the public service index uses the range score 0 for the highest score and 10 for the lowest score) (Figure 1). This score is worse than the world average of 5.67 (The Global Economy, 2021). The Indonesian public sector is trapped in an array of complex and challenging situations. The low index score is attributed to, among other things, overwhelming demand driven by a large and diverse population, low employee competence, a lack of civil servants, minimal investment, limited technology resources, and no clear incentive and punishment

system due to bureaucratic and organizational inflexibility. The first attempt at a breakthrough was the mandate set by the central government to implement IT to address various limiting factors and as a foundation to improve operations. However, IT implementation alone is not sufficient to overcome these challenges. Because of Indonesia's unique circumstances in embodying the array of challenges faced by developing countries, it has been determined to be an ideal representation of how developing countries may struggle to adopt IT-based LSS. Therefore, the implementation of IT-based LSS, as mandated by the central government, with an action research approach was conducted, and the process, findings, and insights are presented in this paper for benchmarking other similar agencies working in Indonesia or other developing countries.

The selection of the City Office for Population Administration and Civil Registration (COPACR) as the first pilot project for IT-based LSS in the context of Indonesian public services is considered appropriate since all citizens with different demographic backgrounds and different levels of IT proficiencies, access, and resources need COPACR services. This allows us to present findings that properly encapsulate the challenges provided by IT-integration LSS. The contribution of this study is that it provides detailed information on IT-based LSS interventions within the realistic lens of a developing society and the impact of the implementation. This research offers an example of implementing IT simultaneously



**Figure 1.** Public service index for upper middle-income countries category. Source: (The Global Economy, 2021).

with LSS as a bundled solution in process improvement and will serve as a helpful reference for future implementations in a similar context as, up to now, all reported cases of IT-based LSS implementation have been in developed countries with an already robust existing infrastructure for their public sector.

The remainder of this paper is organized as follows. An overview of LSS, its implementation in the public sector, and its integration with IT is presented in [Section 2](#). This is followed by a description of the research methodology in [Section 3](#). The results and analysis are provided in [Section 4](#), followed by the lessons learned and managerial implications in [Section 5](#). Finally, a brief conclusion is presented in the final section.

## 2. Literature review

### 2.1. Lean Six Sigma (LSS)

Various management methods can be considered to improve service efficiency and effectiveness, such as Total Quality Management (TQM), Lean, Six Sigma (LSS), Business Process Re-engineering (BPR), and ISO 9001 (Arnheiter & Maleyeff, 2005; Rohini & Mallikarjun, 2011; Tupkar et al., 2016). In the past, Lean Six Sigma (LSS) has become a recommended method of process improvement in the public sector, such as in the fields of health, education, and police services (Antony et al., 2017; Kregel & Coners, 2018). LSS is a combination of two suitable methods for problem solving (Sodhi, 2020). LSS first emerged as a concept, method, and tool to improve processes (Snee, 2010). Improvements can produce better work and reduce waste and costs, resulting in improved efficiency and increased customer satisfaction (Snee, 2010; Zefaj, 2017). LSS is used for process improvement and is one of the most prominent quality philosophies, because implementing LSS in quality management has been highly successful in the manufacturing and service industries (Eriksson, 2016; Kregel & Coners, 2018). According to Juliani and Oliveira (2021), the application of LSS as a New Public Management (NPM) method in an organization will provide the best results, as it is sustainable and compatible with other innovations.

Lean is a Western adaptation of the Toyota Production System that seeks to reduce or eliminate overburden (*Muri*), inconsistency (*Mura*), and waste (*Muda*) in all operational and industrial processes (Antony et al., 2017; Shah & Ward, 2007). According to Sodhi (2020), lean usually begins with understanding the added value received by customers and then examining the process in detail using Value Stream Mapping (VSM). In its application, Lean has not been able to answer the problem of overcoming the variations generated in the process and, at the same time, does not have the tools to reduce variations in the process represented by statistical control. Under this condition, Lean will need Six Sigma, which can answer problems through statistical control, and both are customer-focused (George, 2003; Yang, 2005). In Six Sigma, problems are handled using a structured methodology called Define-Measure-Analyze-Improve-Control (DMAIC) and statistical control to implement operational process improvements (Antony et al., 2017; Kim, 2020; Snee, 2010). These two methods complement each other and are needed for repair and problem-solving (Snee, 2010). They can increase productivity and create balanced and organized solutions to save time and cost and produce more accurate products (Summers, 2011).

### 2.2. Lean Six Sigma (LSS) for public sector

The lean approach in the public sector is designed to reduce processing time and costs, meaning that it can maximize the time and resources owned (Smith et al., 2007). LSS can increase shareholder value through improvements that focus on customer satisfaction, cost, quality, speed, and investment capital (George, 2003). The results of several public sector projects show that the LSS method is a powerful tool for continuous improvement (Cheng & Chang, 2012), reducing the number of stages in the service processes to be more concise and can reduce operational costs (Antony et al., 2017), reducing the waiting time and delay in the process (Gijo & Antony, 2014), and increasing the sigma level, which represents a decrease in the variation that occurs in the process and reduces the number of defects (Sari et al., 2020) ultimately optimizing overall public service operations.

Utilizing the waste guidelines provided in the LSS can help public sector organizations find waste from service processes (Marr & Creelman, 2014). Problems can be identified from waste identification



with the help of the lean tool guidelines. According to Bonaccorsi et al. (2011), waste classification is divided into ten categories and described with examples, as shown in Table 1, and is a pertinent tool to identify and classify waste that must be eliminated.

Public sector institutions can also benefit from Six Sigma as a statistical data-based process improvement methodology to achieve stable and predictable process results and reduce product variations and defects in processes through statistical calculations (Laureani & Antony, 2012). Six Sigma has evolved into a management philosophy based on continuous improvement to improve customer-centric strategic targets and product development standards (Cheng & Chang, 2012; Pande et al., 2000). Six Sigma involves the use of tools such as Voice of Customer (VOC), quality function deployment (QFD), workflow diagrams, and cause-and-effect diagrams. There is a methodology named DMAIC which includes Define, Measure, Analyze, Improve, and Control to pursue continuous improvement in a cyclical mode.

### 2.3. Integration of information technology into Lean Six Sigma

Information Technology (IT) collects, stores, organizes, and processes data into information. This information includes text, graphics, numbers, and sounds (Hamidi et al., 2011). IT plays a significant role in improving an organization's performance and productivity. IT has also been implemented and integrated with several quality improvement methods, including LSS. This method has been applied in various sectors such as industrial services, supply chains, education, banking, health (hospital), and the public sector. Additional examples of integrating LSS with IT include reducing the level of complaints and increasing awareness (Sunder & Mahalingam, 2018), reducing customer service rejection (Sunder, 2016), increasing time efficiency in the outpatient department (Gijo & Antony, 2014), and finding effective solutions for emergency call centers (Laureani et al., 2010). Therefore, the chance of successfully implementing LSS in the public sector in an integrated manner with information technology is substantial (Tay & Loh, 2022). According to Shahin et al. (2020) and Zefaj (2017), implementing Lean Six Sigma with the help of digital technology in the public sector can guarantee transparency, service speed, user satisfaction, and data security. Thus, LSS integration with IT is considered a powerful means to increase speed and enhance service quality.

However, the literature has outlined several challenges in developing countries regarding technology access. Factors such as politics, culture, economics, technicality, the fast pace of software development, and lack of people competencies are identified as challenges (Hamidi et al., 2011; Hanson & Narula, 1990). In Indonesia, inequality between regions has become the main issue. While IT education and resources are very advanced in big cities, the situation is drastically different in the remote parts of the country. Being a large archipelago also contributes to the vast inequality in resources. Other factors, such as public servants' IT competencies, technology affordability, and inequality of technology infrastructure and resources, are also obstacles to implementing IT in different regions.

### 3. Research methodology

This study adopted an action research methodology that consists of planning (problem formulation), building, evaluation, intervention, reflection, and learning stages. The researcher was directly involved in the process as the actor, observer, and interventionist in the existing conditions, and to address the

**Table 1.** Waste service classification.

Waste classification	Examples of waste in COPARC
Defect	Data entry errors; Lost files; Lost or damage goods;
Duplication	Data re-entering; Multiple signatures; Unnecessary reporting; Multiple queries;
Incorrect Inventory	Stock out; Wasting time finding what was needed; Unnecessary copies;
Lack of customer focus	Unfriendliness; Rudeness; Poor attention to the customer;
Overproduction	Reports no one ever read; Processing paperwork before time;
Unclear communication	Incorrect information; Lack of standard data format; Unclear workflow;
Motion/Transportation	Poor layout; Ineffective filing; Poor ergonomic;
Underutilized Employees	Inadequate tools; Excessive bureaucracy; Limited authority;
Variation	Lack of procedures; Lack of standard formats; Standard time not defined;
Waiting/Delay	Waiting for approvals; Downtime; Waiting for supplies

Source: (Bonaccorsi et al., 2011).

issues observed. Figure 2 shows the study framework for the IT-Based Lean Six Sigma project. This study uses DMAIC (Define, Measure, Analyze, Improve, and Control) because the organization and business processes exist to improve efficiency and effectiveness (Yadav et al., 2023). The LSS DMAIC is used to enhance the service level in System 1 (e-Lampid) to System 2 (Klampid) in the City Office for Population Administration and Civil Registration (COPACR) of Surabaya City. We selected Surabaya City as the research subject because it is the second-largest city in Indonesia, with a population of 3,157,136 people, and is known as a city with progressive improvement in many aspects.

This research intends to enhance the service performance of COPACR by designing and developing business processes with IT. Birth certificate processing was selected as the pilot service for the analysis. It was expected that the implementation cycle of this pilot would establish standard step-by-step guidance for other services. This study involved human participants, specifically COPACR officers and respondents who have experience in applying for birth certificates. Each participant is required to read the consent form, and participation in this study is entirely voluntary without any coercion. The consent and approval were obtained in written form. This research has obtained ethical clearance under reference number 381/IT2.XXII/T/TU.00.08/VIII/2024. Additionally, it has been published by the Research Ethics Committee of Institut Teknologi Sepuluh Nopember, chaired by Josaphat Pramudijanto.

The business process improvement stages were conducted using the LSS DMAIC method. DMAIC is a common method in LSS; thus, utilizing this common method would ease the monitoring of continuous improvement progress measurably and systematically. This methodology was ultimately selected as the appropriate methodology to improve efficiency and operations in this study because its key principles allow for widespread applicability to a variety of different services that the public sector may provide.

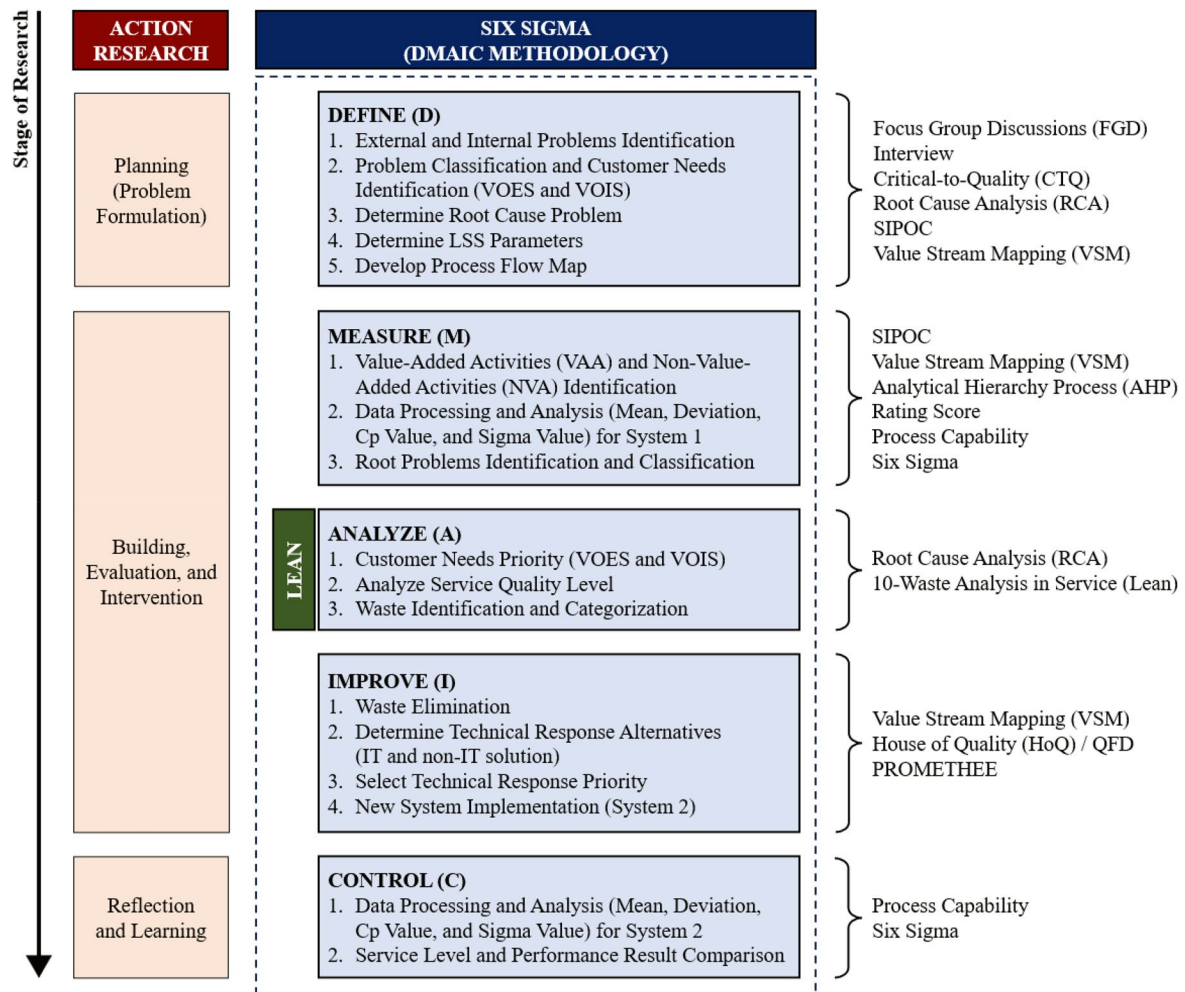


Figure 2. Study framework for IT-based Lean Six Sigma project implementation.



### 3.1. Define phase

The Define phase aims to identify external and internal problems in COPACR that need to be solved using an IT-based LSS. The government referred to the standardized community satisfaction survey that is distributed annually to measure the service performance of each city office or agency to capture problems identified by customers externally. Interviews and focus group discussions (FGDs) were conducted to identify internal problems. The identified problems were categorized using the Critical to Quality (CTQ) tree to classify them into customer needs. The categorized problems were then divided into two types: IT- and non-IT-related problems. The problems were further investigated using Root Cause Analysis (RCA) to identify the underlying causes across all categories and types.

The next activity in the Define phase was to establish the main parameters that were expected to be seen or experienced by the community and by the internal institution. The time, quality, cost, and flexibility are commonly identified as the main parameters. All the identified root problems were mapped to the expected parameters. Next, a Supplier, Input, Process, Output, Customer (SIPOC) and Value Stream Mapping (VSM) were developed to accurately map and understand the process flow, identify inefficiencies, set priority, and trigger process improvement in the processing and issuance of birth certificates in Surabaya COPACR.

### 3.2. Measure phase

The Measure phase processes the output from the Define phase into quantitative measures. The percentages of Value-Added Activities (VAA) and Non-Value-Added Activities (NVA) were measured by referring to the main targeted parameters. The mean processing time, standard time deviation at each step of the service process, and process capability analysis were measured as part of implementing the Six Sigma methodology. Data processing and analysis for this phase were assisted by the Minitab statistical software. All these measures were tested using the normality test, control chart (Xbar-S Chart), and process capability analysis. In this study, the Cpk index is used for process capability and performance analysis because there is only one specification limit (unilateral tolerances, maximum time duration). The number of Defects per Million Opportunities (DPMO) was also calculated. DPMO is a size parameter that can be used to determine the sigma level of the process by comparing the defects resulting from a process with one million opportunities.

The calculations assessed the process capability to deliver targeted Key Performance Indicators (KPIs). Furthermore, the customer feedback collected during the Define phase with both VOES (Voice of External Stakeholder) and VOIS (Voice of Internal Stakeholder) were weighted using the Analytical Hierarchy Process (AHP) method and Rating Score. This process filtered the most important underlying issues that must be prioritized in the first round of improvement.

### 3.3. Analyze phase

The Analyze phase was separated into two possible subphases. The first phase scrutinizes the service performance of birth certificates from the application to issuance based on the results of the previous phase. The second part is to find the root causes of the underperforming processes and identify areas for improvement. The analysis was started by evaluating the value of the mean and time variation of the process, and the sigma level. Improvement in sigma level corresponds to an improvement in Cpk index. The same parameters from the Measure phase became indicators of the system performance. Based on the outcomes, the Analyze phase must determine the performance of the business process. The mean processing time and time variations were then compared with the KPIs of the service. The sigma level is also evaluated during this phase. A higher sigma level indicated that the system performed better. Meanwhile, if the Cpk value is greater than 1, it can be surmised that the service system can produce the expected output and meet specifications (Grant & Leavenworth, 2007).

The second sub-phase occurs when the expected output is not produced. To understand the determining factor for underperformance, an analysis was conducted by comparing the relationship between

VOES and VOIS to the 10-waste guidance provided by Bonaccorsi et al. (2011). Based on the root cause analysis, the dominant waste affecting the system performance could be mitigated.

### 3.4. Improve phase

The Improve phase aims to provide alternatives for the root causes identified in the Analyze phase. In the COPACR context, alternative solutions must comply with government regulations. The multi-criteria decision-making named PROMETHEE method is utilized in making decisions based on priority. PROMETHEE is a method for evaluating alternatives concerning the determined criteria and is characterized by preference types used for assigning the differences between alternatives in judgments (Abdullah et al., 2019). According to (Celent et al., 2022), PROMETHEE contemplates quantitative and qualitative criteria to rank factors to establish a decision-support system.

The alternative solutions are selected based on their ability to eliminate the most waste or non-value-added activities. The more waste that is eliminated, the better the solution alternative.

### 3.5. Control phase

The Control phase guarantees that the improved system can effectively overcome the problems and maintain sustainable improvement. Typically, a Standard Operational Procedure (SOP) is developed in this phase to ensure adaptation of the solution. This study also compared the sigma level (corresponds to DPMO value) and process capability analysis index (Cpk) to determine the performance of the system changes before and after improvement. Three parameters were used as indicators of the success of birth certificate processing to issuance in the COPACR service. The proposed and improved system (System 2) is considered feasible when the sigma level and Cpk value are higher than those of System 1.

## 4. Result and analysis

The City Office for Population Administration and Civil Registration (COPACR) in Surabaya City provides 67 services for the community in the form of issuance of population documents and civil registration. A birth certificate service was selected as the first pilot project. The selection is based on the number of applications for each service. From 2014 to 2019, the number of applications for birth certificate services significantly outnumbered other services. This study presents the results of the first pilot project on birth certificate services at the COPACR of Surabaya City.

### 4.1. Define phase

The COPACR of Surabaya City used the e-Lampid System (System 1) between 2014 and 2019. Table 2 shows the project profile, including the project title, background, system name, project aims, targets, and expected outputs. The general process of the project was developed using a Supplier, Input, Process, Output, Customer (SIPOC), as shown in Table 3. The leading concern that became the motivation for this project was that the service completion time ( $17.12 \pm 2.42$  days) for birth certificate issuance exceeded the maximum expected standards.

To determine process waste or inefficiencies, the business process for birth certificate issuance in System 1 is presented using Value Stream Mapping (VSM), as shown in Figure 3. Surabaya citizens who wanted to obtain a birth certificate had to visit the sub-district, district, or the COPACR to apply and obtain a completed birth certificate document. According to the regionally regulated Standard Operating Procedure (SOP), the maximum processing time for birth certificate issuance should be one day (24 hours). The processing time includes the process performed through the centralized National Population Administration Information System or the Sistem Informasi Administrasi Kependudukan (SIAK) in Bahasa.

The completion and deviation processing times were not collected before the pilot project began. When the average completion and time variation were first measured during this project, it was revealed that the completion time in System 1 was  $17.12 \pm 2.42$  days. This result is incredibly substandard and

must be addressed to meet this requirement. In the context of LSS, the completion and deviation times can be reduced by eliminating waste in business processes.

Further, in the Define phase, the results of the community satisfaction survey conducted annually by the Surabaya City Government were analyzed. The community satisfaction survey was an external performance evaluation of each City Office. The criteria were rigid, according to the national performance evaluation system. This survey involved 109 respondents who had experience in applying for birth certificates. They were asked to evaluate services based on several parts, including the application mechanism, competence of the officers, final document requested, and service quality.

Based on the survey, there were 11 external customer voices (VOES) for system improvement and development. In this study, the perspective of COPACR employees as internal users was also collected. The Voice of Internal Stakeholder (VOIS) was collected by distributing a questionnaire to 102 employees through open-ended questions about their experiences and evaluation when operating the e-Lampid (System 1). Based on the survey results, 14 internal needs were identified. External and internal needs were then weighed during the Measure phase to determine priority.

#### 4.2. Measure phase

The Measure phase processes the output of the Define phase. In this phase, the duration of each process, process capability analysis (Cpk), Defects per Million Opportunities (DPMO), sigma level, and weight of customer needs were measured. System 1 (e-Lampid) has nine (9) stages for birth certificate issuance, which are presented in the Value Stream Mapping (Figure 3). In the Measure phase, the completion time (12-month data) was 17.12 days, and the standard deviation of the completion time was 2.42 days. According to the Standard Operating Procedure (SOP), the completion times of birth certificate issuance in System 1 exceed the required processing time of one day (24 hours).

The example data processed for System 1 (e-Lampid) was obtained from the birth certificate completion time in Month-1 2019 (System 1). All service completion time sample data collected were categorized into 10 subgroups and subsequently subjected to uniformity testing using an Xbar-S chart. Figure

**Table 2.** COPACR surabaya city project profile.

Project title	:	Reducing completion time and improving service quality for the service of creating a birth certificate
Background for the selected project	:	The number of applications for birth certificates was much more significant than other similar services. The baseline completion time for the birth certificate was $17.12 \pm 2.42$ days, which was exceeding the expected completion time of one day (24 hours).
System Before Improvement	:	System 1 (e-Lampid)
System after improvement	:	System 2 (Klampid)
Aim of the project	:	1. To reduce the completion time and deviation for birth certificate issuance 2. To increase the capability and performance for issuing a birth certificate 3. To increase the Sigma level for creating a birth certificate
Project duration	:	36 Months (3 Years)
Target	:	Maximum completion time is one day (24 hours)
Expected output	:	Reduction of the completion time, reduction of the deviation, and increase of the sigma level

**Table 3.** SIPOC.

Suppliers	Inputs	Processes	Outputs	Customers
Surabaya City Citizen	Documents of application as required	Verifying documents of application according to the requirement	Full version and the published version of the birth certificate	Surabaya City Citizen
	Application data	Approval of the required documents Printing the proof of application Inputting application data to the SIAK system Printing the full version and the published version of the certificate Checking the correctness of certificate and the application data Legalizing the certificate by e-signing Sorting out the certificate that has been legalized		
	Issuance the birth certificate	Sending the published version of the certificate to the Sub-District Office		

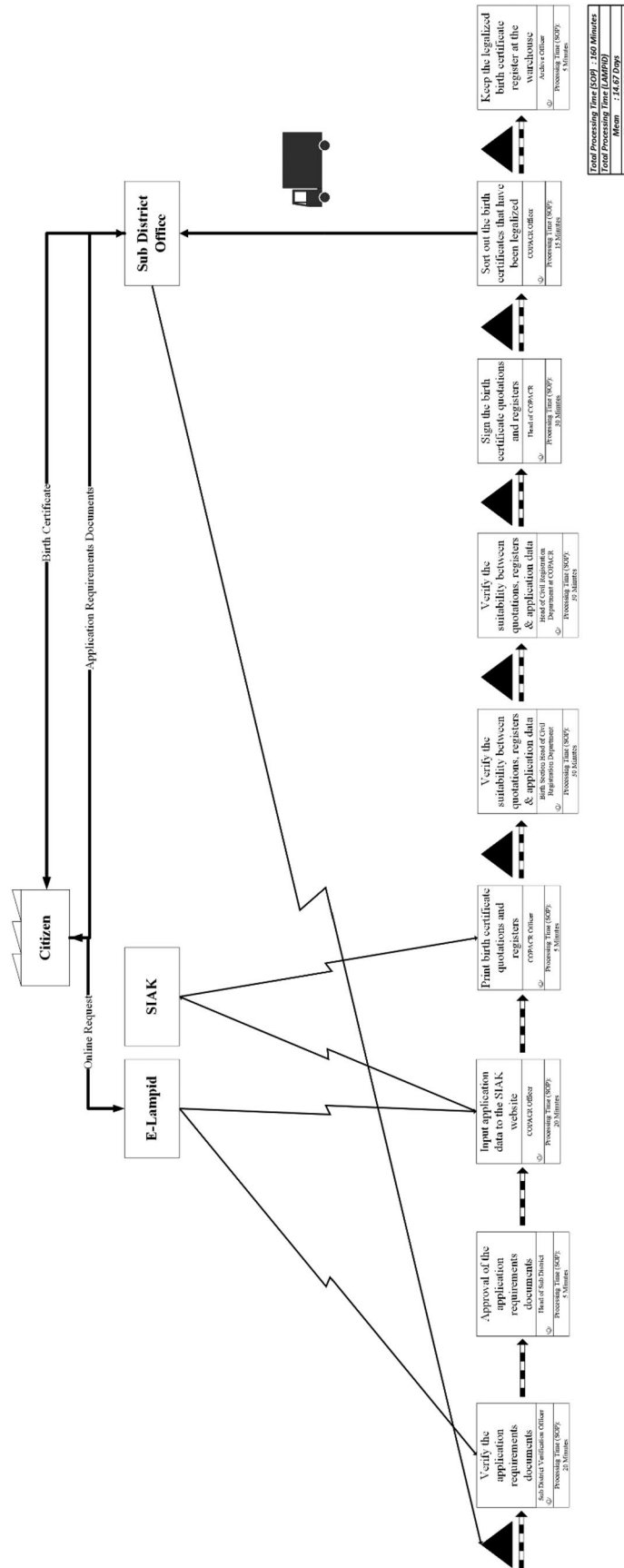


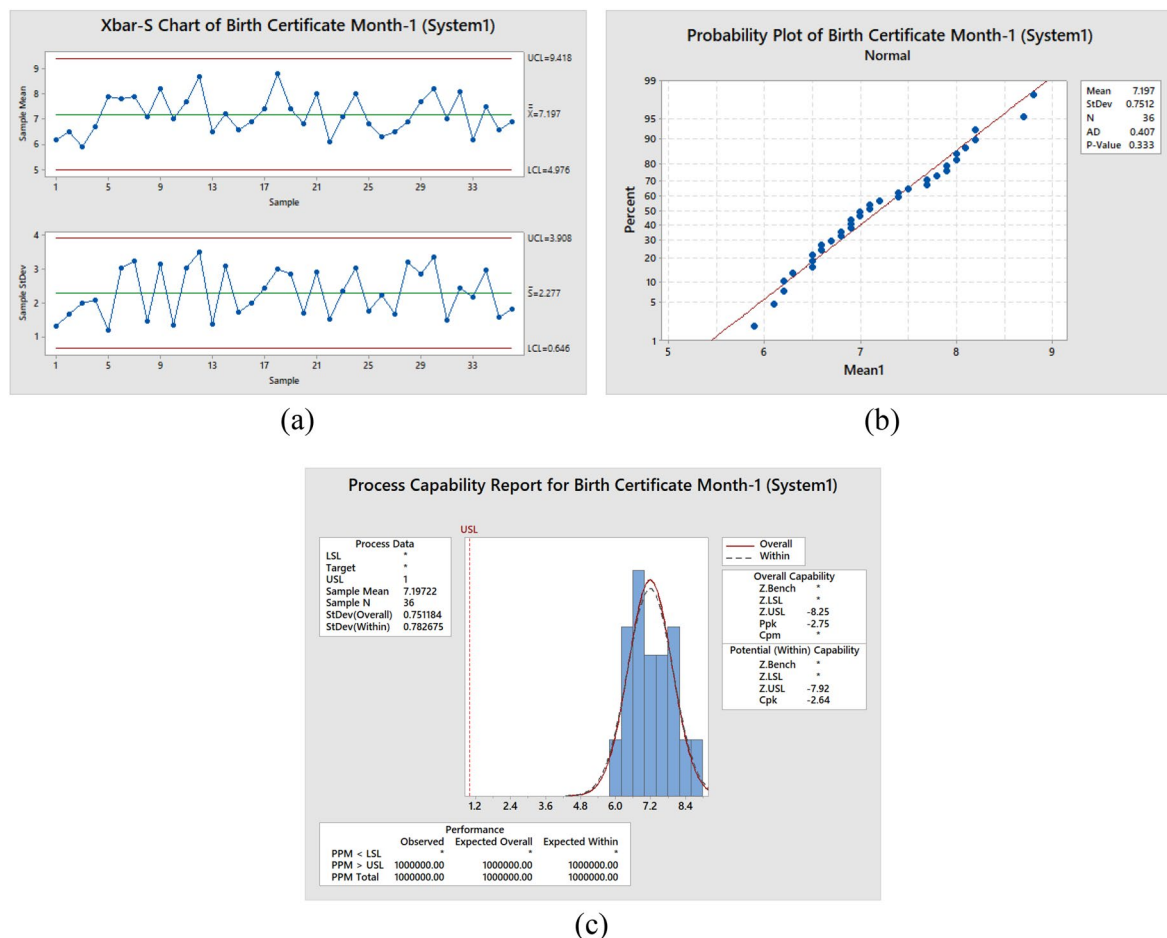
Figure 3. VSM of the business process for birth certificate issuance in system 1.

4(a) shows the results of the mean and variation in birth certificate completion times. The control chart was used to ensure that the data were under statistical control before proceeding with capability calculation. Figure 4(b) demonstrates that the data follow a normal distribution with a p-value greater than 0.05 (5%). Using Minitab statistical software, the process capability analysis results (unilateral assessment, USL = 1 day) for the birth certificate issuance completion time using System 1 is -2.64 (Cpk), indicating that the system is not capable and does not meet the required regulated standards (Figure 4(c)). The Defects per Million Opportunities (DPMO) are calculated using the formula in Equation 1 to determine the Sigma level. It should be noted that these parameters reflect the same degree of improvement, so that the improvement in the Sigma level corresponds to process capability improvement (Cpk).

$$DPMO = \frac{\text{Total Defect Observed}}{\text{Total Opportunity}} \times 1,000,000 \quad (\text{Equation 1})$$

As the process capability analysis of System 1 for all months is -2,15 (Cpk) (Table 4), this suggests that System 1 exceeds the specification limit (service completion time) of one day. System 1 has a DPMO value of 11,561.81, which indicates that the process is at a -6.46 sigma level. Based on the Measure phase results, System 1 must eliminate waste and standardize the service system to improve performance and service quality.

During the Define phase, the VOES (Table 5) and VOIS (Table 6) were gathered. Each external and internal need was weighted to determine the system improvement priorities. For VOES, weight was calculated based on the number of complaints and requests received from users. The VOIS was weighed based on the Analytical Hierarchy Process (AHP) method and Rating Score, which involves the upper



**Figure 4.** Xbar-S Chart (a), Normality Test (b), and Process Capability Analysis (c) of Birth Certificate Before Improvement in Month-1 (System 1).

**Table 4.** Data output of measure phase for birth certificate issuance using System 1.

Month	p-value	Distribution	Mean (Days)	Deviation (Days)	Cpk	Sigma Level
Month-1	0.85	Normal	7.20	0.75	-2.64	-7.92
Month-2	0.05	Normal	10.65	0.19	-1.58	-4.73
Month-3	0.08	Normal	23.21	1.62	-1.75	-5.26
Month-4	0.07	Normal	11.03	1.72	-2.82	-8.47
Month-5	0.50	Normal	17.58	1.94	-2.79	-8.38
Month-6	0.24	Normal	17.44	1.69	-3.19	-9.57
Month-7	0.07	Normal	23.02	0.08	-3.94	-11.82
Month-8	0.71	Normal	17.72	2.17	-2.50	-7.50
Month-9	0.10	Normal	14.10	0.13	-2.99	-8.97
Month-10	0.13	Normal	17.63	0.87	-2.22	-6.65
Month-11	0.11	Normal	6.66	1.57	-1.52	-4.57
Month-12	0.66	Normal	8.14	1.98	-1.43	-4.29
All Months	0.09	Normal	17.12	2.42	-2.15	-6.46

**Table 5.** Voice of External Stakeholder (VOES).

VOES (Voice of External Stakeholder)			
Code	External Voice	Causes (5M + E)	Weight
E1	Detailed requirement for application is not available	Method	24.89%
E2	Staff are not friendly in doing service	Man	1.93%
E3	The civil registration application procedure is complicated	Method	8.15%
E4	There is no information of the standard operating procedure of the application process	Method	43.78%
E5	The call center staff is unresponsive	Man	1.72%
E6	Error in inputting data due to unclear information of required data	Machine	1.29%
E7	Error and technical problems during online access to System 1 (e-Lampid)	Machine	1.93%
E8	The operating service hours is unknown	Method	4.29%
E9	There is no user manual for the System 1 (e-Lampid)	Method	1.50%
E10	The availability of the application form is limited and hinders the application process	Material	10.52%

**Table 6.** Voice of Internal Stakeholder (VOIS).

VOIS (Voice of Internal Stakeholder)			
Code	Internal Voice	Causes (5M + E)	Weight
I1	Limited access hours and access restrictions for certain roles to the IT system	Machine	11.94%
I2	The size of the uploaded file or document is limited	Machine	2.99%
I3	Lack of data entry accuracy at the Sub-District which resulted in inspection and re-entry at the COPACR	Method	2.99%
I4	Errors often occur on the input data feature in the application	Machine	4.48%
I5	COPACR system is not integrated to the national information system	Machine	1.49%
I6	Errors often occur on the network server	Machine	13.43%
I7	Inadequate information for users in accessing the service	Machine	17.91%
I8	Input feature of the COPACR application is not integrated with the national system (SIAC)	Method	13.43%
I9	Uneven number and quality of facilities at the Sub-District	Material	1.49%
I10	No progress tracking in the application	Machine	1.49%
I11	No adequate Standard Operating Procedure (SOP) for the operator	Method	5.08%
I12	User interface is complicated and not easy to navigate	Machine	22.39%
I13	Signature approval and authorization cannot be conducted automatically	Method	1.49%

management of COPACR. From the ten VOES, there were three selected priorities that were included in the development of System 1: the standard operating procedure of the application process is not available (43.78%), detailed requirements for applications are not available (24.89%), and the civil registration application procedure is complicated (8.15%). Meanwhile, five priorities were selected from the VOIS: the user interface is complicated and not easy to navigate (22.39%), inadequate information for users to access the service (17.91%), errors that often occur on the network server (13.43%), the fact that the input feature of the COPACR application is not integrated with the national system (SIAC) (13.43%), and limited access hours and access restrictions for certain roles in the IT application (11.94%). More VOIS priorities were selected than VOES priorities because internal stakeholders, which are the employees of COPACR, have a better understanding and familiarity with the service, and thus can provide more insights for the further development of the system.

#### 4.3. Analyze phase

This phase analyzes the service performance of birth certificate issuance, the main waste, and the underlying causes. The long processing time with large variations yielded by System 1 (e-Lampid) had to be



improved to meet the requirements of the government regulation, which is one day (24 hours). Completion time is longer because COPACR employees run the process through semi-digital processes. Therefore, Information Technology (IT) implementation should be an appropriate solution to reduce the processing time.

However, it was also determined that IT alone cannot effectively accelerate and optimize the process. Employee competencies play a critical role. In Indonesia as well as in other developing countries, the competence of government employees and available supporting resources vary dramatically across different regions. Due to a variety of reasons, including a lack of access to technological apathy, many civil servants from the older generation pre-2000s are still technologically illiterate. Cultural and societal paradigms also contribute to employees' resistance to change and lead to apathy towards digitization. It is also incredibly difficult to encourage improvement as the bureaucratic rigidity of government agencies makes it difficult to develop an internal incentive and punishment mechanism. Without an incentive to improve performance metrics and the inability to terminate employment or instate punishments when underperforming, top-down pressure to improve employee performance and service operations is difficult.

The longer completion time was confirmed by the process capability analysis results of System 1 ( $C_{pk} = -2.15$ ), which shows that System 1 is incapable of delivering good processes. In addition, the sigma level of -6.46, indicated that improvement and standardization of services were needed to accelerate the completion time and reduce time variations.

The ten VOES and 13 VOIS collected during the Measure phase need to be categorized according to the 10-waste analysis to obtain the root causes of the problems. As mentioned in the Measure phase, based on the survey and expert assessment, there are three priorities of external needs (VOES) and five priorities of internal needs (VOIS). In this phase, 'clearer and easier to find application procedure' was identified as the core component that must be improved in System 2. Additionally, the procedure for birth certificate applications must be digitally improved and accompanied by a systematic user guide as a supporting tool. It was also found that the user interface of System 1 was considered unintuitive for newer users. Features for notifications or self-corrections when users make mistakes in completing and uploading files must be added to simplify the online application process.

To verify these improvements, all identified problems were mapped onto the waste list developed by Bonaccorsi et al. (2011). As shown by the complete map in Table 7, the order of the waste in System 1 based on its percentage was waiting or delayed (17.24%), variation (17.24%), underutilized employees (6.90%), motion or transportation (13.79%), unclear communication (6.90%), overproduction (0.00%), lack of customer focus (3.45%), incorrect inventory (10.34%), duplication (13.79%), and defects (10.34%).

#### 4.4. Improve phase

In the Analyze phase, alternative solutions were formulated to tackle the underlying cause of the problems and identify the dominant waste. The Improve phase began by removing non-value-added activities and waste to increase time efficiency. The team developed a modified state of VSM that consolidates nine processes into six processes (Figure 5). Moreover, there are 20 proposed alternatives to eliminate technical waste, as listed in Table 8. These alternative solutions consider government regulations as the main reference. The selection of the most suitable technical responses was carried out using the PROMETHEE method involving COPACR upper management. PROMETHEE utilized four parameters to determine priority: funding, officers' competencies, regional regulation, and upper management's policy.

Among the 20 solution alternatives, there are 15 alternatives involving IT and five alternatives that do not involve IT. The PROMETHEE process produced 15 technical response solutions of the 20 alternatives that were prioritized for the immediate improvement of System 1. The 15 technical response solutions are listed below, according to their rank:

1. Provide clear and succinct instructions for birth certificate applications on the website interface. The pop-up feature was developed to guide users step-by-step to avoid mistakes.

**Table 7.** Voice of stakeholders and waste categorization.

Code	Voice of Stakeholders (VOES and VOIS)	Waste Category (Bonaccorsi et al., 2011)
E1	Detailed requirement for application is not available	Unclear Communication
E2	Staff are not friendly in doing service	Lack of Customer's Focus
E3	The civil registration application procedure is complicated	Duplication
E4	There is no information of the standard operating procedure of the application process	Lack of Customer Focus, Unclear Communication, Variation, Waiting
E5	The call center staff is unresponsive	Waiting/Delay
E6	Error in inputting data due to unclear information of required data	Defects, Duplication, Incorrect Inventory
E7	Error and technical problems during online access to System 1 (e-Lampid)	Waiting/Delay
E8	The operating service hours is unknown	Unclear Communication, Variation
E9	There is no user manual for the System 1 (e-Lampid)	Unclear Communication
E10	The availability of the application form is limited and hinders the application process	Lack of Customer Focus, Waiting
I1	Limited access hours and access restrictions for certain roles to the IT system	Motion/Transportation, Underutilized Employees
I2	The size of the uploaded file or document is limited	Motion / Transportation, Variation, Waiting/Delay
I3	Lack of data entry accuracy at the Sub-District which resulted in inspection and re-entry at the COPACR	Duplication
I4	Errors often occur on the input data feature in the application	Defects, Duplication, Incorrect Inventory
I5	COPACR system is not integrated to the national information system	Duplication, Motion/Transportation, Variation, Waiting/Delay
I6	Errors often occur on the network server	Waiting/Delay
I7	Inadequate information for users in accessing the service	Lack of Customer Focus, Unclear Communication
I8	Input feature of the COPACR application is not integrated with the national system (SIAC)	Defects, Duplication, Incorrect Inventory, Motion/Transportation
I9	Uneven number and quality of facilities at the Sub-District	Waiting/Delay, Underutilized Employee
I10	No progress tracking in the application	Defects, Duplication, Incorrect Inventory
I11	No adequate Standard Operating Procedure (SOP) for the operator	Unclear Communication, Underutilized Employee
I12	User interface is complicated and not easy to navigate	Lack of Customer Focus, Variation, Waiting/Delay
I13	Signature approval and authorization cannot be conducted automatically	Waiting/Delay

2. Assign officers as customer care specialists at sub-district offices to help residents directly. Customer care specialists can assist and direct citizens if they encounter problems during registration and submission.
3. Eliminate the requirement for physical document submission. In System 2, an integrated data center will be developed to complete the documentation requirements without physical submissions.
4. Provide a digital receipt for birth certificate applications that can be printed at the nearest sub-district offices.
5. Implement electronic signatures and eliminate the requirement for physical signatures.
6. Introduce a complaint service feature consisting of chatbots, social media, and live website chats. Operators can handle and address complaints and questions live during operating hours.
7. Add a feature to simplify the registration and submission of documents. If there is an uploading error, the system can provide an alert and a suggested solution to the problem.
8. Facilitate birth certificate applications through omni-platforms or omni-channels.
9. Develop a web service to bridge COPACR's data server with the national data server to reduce document verification and validation.
10. Provide a tracking system so that applicants can monitor the status of their applications. If there are errors or additional information required, applicants can immediately be notified to revise their application. This feature allows for prompt problem detection and resolution without the need to restart the application.
11. Shift the development of System-1 to System-2 by an internal team, so that there is no dependency on third parties. This solution is also effective for increasing data security.
12. Introduce a feature that can produce a unique code in the form of a barcode to facilitate rapid checking, verification, and validation.
13. Provide data back-up through a colocation server at a trusted third party to ensure the continuity of services when the COPACR server is rendered unusable.
14. Add a search feature for document status so that applicants can check their application status without login (similar to an e-connote system in a postal package system).
15. Add a feature that records the name of the officer in charge at each stage of the birth certificate application process. This feature can provide detailed information when there is a problem with document processing and keeps employees accountable.

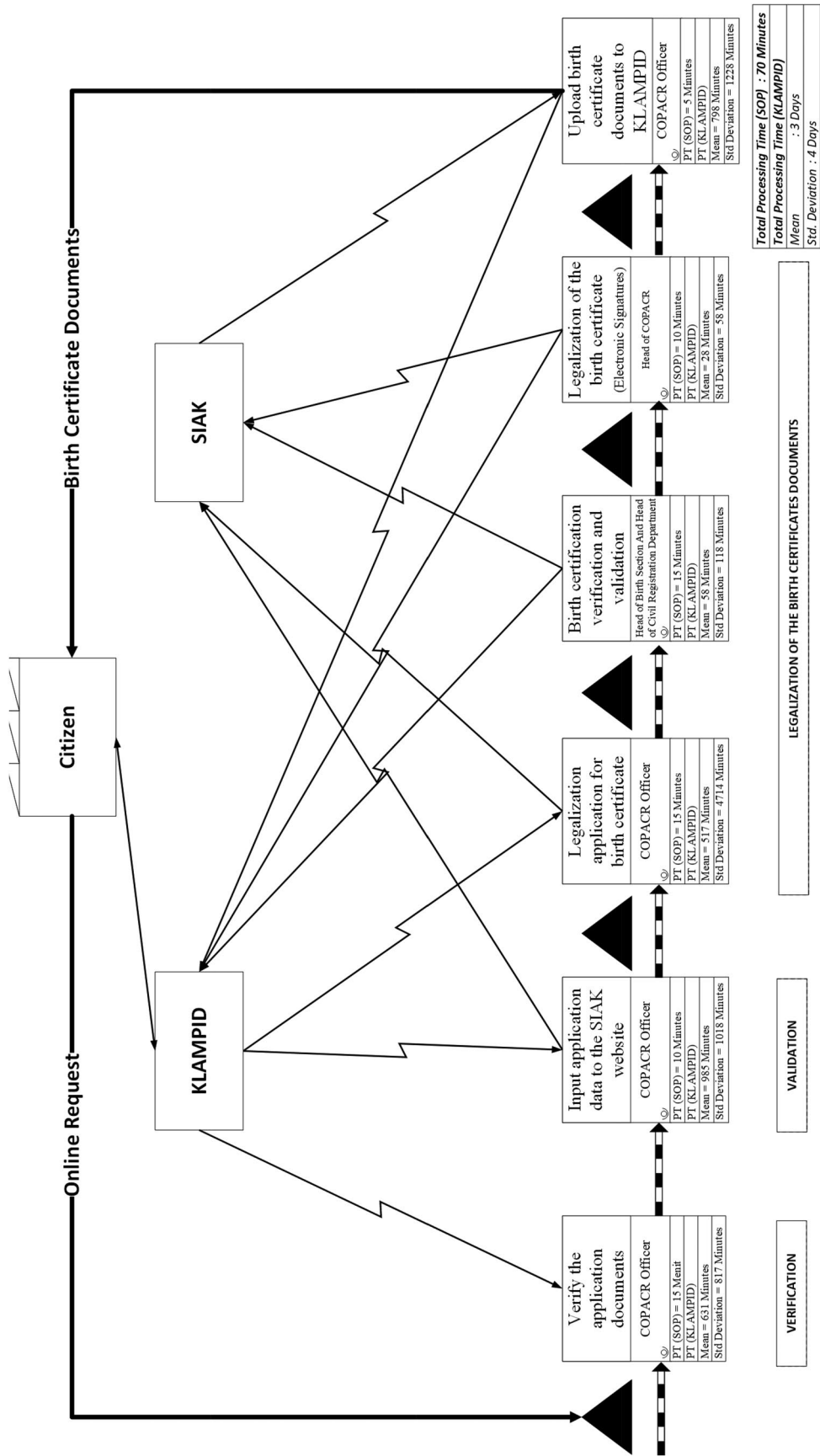


Figure 5. Modified VSM of business process improvement for birth certificate issuance.

**Table 8.** Technical response alternatives for system 1 (e-Lampid) improvements.

No	Technical response alternatives	Weight	Ranking priority	Voice of Stakeholders (Table 7)
1	Developing web service to bridge the COPACR's data server with the national data server to reduce document verification and validation <sup>(a)</sup>	5.0%	9	E3, E7, E8, E9, I1, I4, I5, I6, I9, I13
2	Shifting the development of System-1 to be System 2 by an internal team so that there is no dependency to third parties <sup>(b)</sup>	4.9%	11	E3, E6, E7, E9, I1, I2, I4, I5, I6, I8, I9, I12, I13
3	Facilitating birth certificate applications through omni-platforms or omni-channels <sup>(a)</sup>	5.4%	8	E3, E5, E8, I1, I3, I8, I9, I13
4	Appointing special officers in sub-districts to guide the registration and application process for birth certificate application <sup>(b)</sup>	12.5%	2	E1, E2, E3, E4, E5, E8, E9, I8, I9, I13
5	Recording the processing time of the application from start to finish <sup>(a)</sup>	0.7%	17	I4, I8, I10
6	Adding a feature that records the name of the officer in charge at each stage of the birth certificate application <sup>(a)</sup>	1.5%	15	E6, I4, I10
7	Providing a digital receipt for birth certificate application that can be printed at the nearest sub-district <sup>(b)</sup>	8.1%	4	E3, I1, I3, I8, I11
8	Eliminating the requirement for physical documents <sup>(b)</sup>	8.2%	3	E10, I1, I8
9	Implementing electronic signatures and eliminating manual signatures <sup>(a)</sup>	7.1%	5	I8, I12
10	Providing a unique code in the form of barcode to facilitate quicker checking, verification, and validation <sup>(a)</sup>	4.2%	12	E10, I1, I3, I8
11	Providing a tracking system so that applicants can monitor the status of their application <sup>(a)</sup>	5.0%	10	E10, I3, I8, I9, I10
12	Adding a self-registration of user accounts <sup>(a)</sup>	0.7%	16	E3, I10
13	Adding a search feature of document status <sup>(a)</sup>	2.0%	14	I1, I4, I8, I10
14	Providing clear direction to assist applicants in submitting application <sup>(a)</sup>	18.2%	1	E1, E3, E4, E5, E8, E9, I9, I10, I11, I12
15	Adding a feature to simplify the process of registering and submitting documents <sup>(a)</sup>	5.6%	7	I1, I7, I8
16	Providing data back up through colocation server at a trusted third party <sup>(a)</sup>	2.8%	13	E7, I6
17	Providing a complaint service feature consisting of chatbots, social media, and live website chat in Mobile Apps <sup>(a)</sup>	7.1%	6	E1, E3, E4, E8, E9, I7
18	Creating a mobile apps version <sup>(a)</sup>	0.4%	19	I12, I13
19	Establishing performance indicators for officers related to the completion time and the service product accuracy <sup>(a)</sup>	0.3%	20	E5
20	Adding a new officer with contract labor status at the sub-district service counter <sup>(b)</sup>	0.4%	18	E2, E5, I11

Information: <sup>(a)</sup> technical response with information technology (IT) and digital system solution, <sup>(b)</sup> technical response involving human factors

As suggested by the action research and LSS DMAIC methodology shown in Figure 2, the 15 solution alternatives were implemented to develop System 2 (Klampid). The new system is an improvement to solve the problems and weaknesses identified in the previous system, System 1 (e-Lampid). The transformation from System 1 (e-Lampid) to System 2 (Klampid) is illustrated in Figure 6. The numbers refer to the technical response alternatives in Table 8. The performance of System 2 is then measured during the Control phase. The performance of System 2 is compared with that of System 1 and is explained in the next section.

#### 4.5. Control phase

In the Control phase, the performance of System 2 (Klampid) was captured and compared to that of System 1 (e-Lampid) (Table 10). The Fifteen technical response solutions were implemented in System 2 to reduce the completion time and improve service quality. The Xbar-S Chart with 10-subgroups (Figure 7(a)) monitored the mean and variation of the process, followed by the normality test (Figure 7(b)) for System 2 (using sample data from Month-1 of System 2). The birth certificate issuance completion time for System 2 followed a normal distribution before proceeding capability calculation. Figure 7(c) illustrates that the process capability analysis results for System 2 were 1.99 (Cpk). Defects per Million Opportunities (DPMO) and Sigma level were calculated using the DPMO formula (Equation 1). The processed data, including the p-value, distribution, mean, variation, process capability analysis, and sigma level for the 12-month in System 2, are presented in Table 9.

The results of the measurements are compiled and presented in Table 10. The active research project was continuously conducted for 36 months, and the researchers were directly involved in monitoring and improving the processes as the project progressed. After all the solutions were implemented, a drastic improvement was observed in the processing completion time. The birth certificate issuance completion time was reduced to 0.48 days, which was well within the regionally regulated standard. The variation of the completion time was also improved from 2.42 days to 0.13 days. This successful

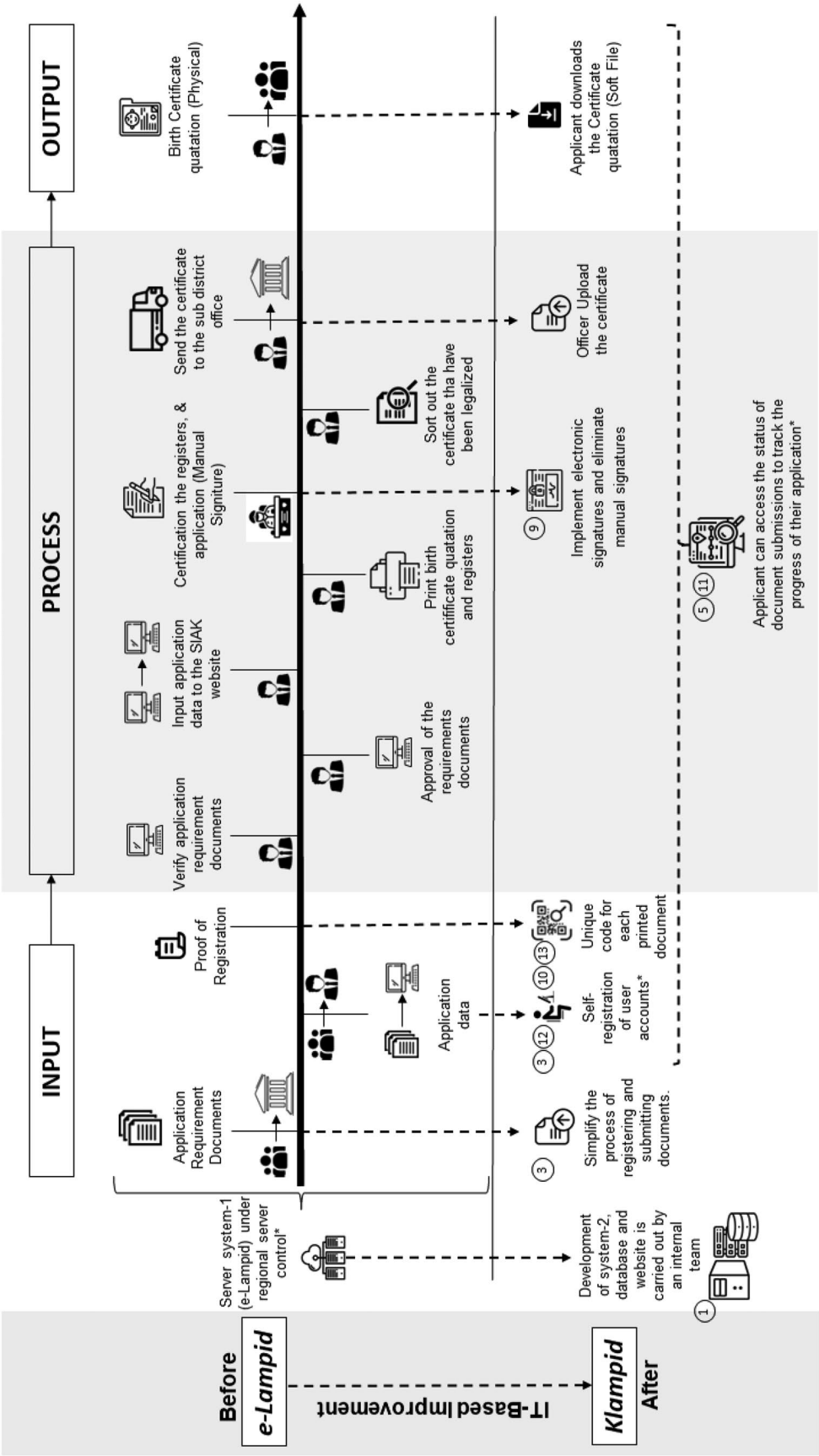


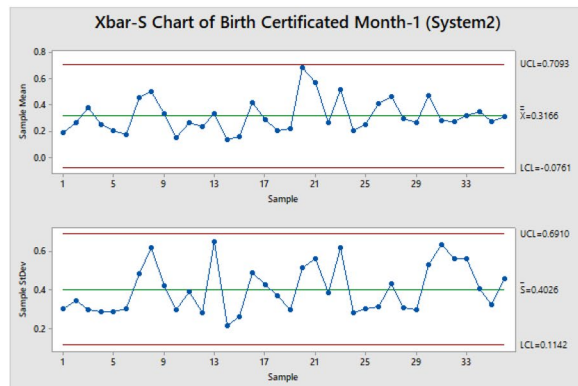
Figure 6. Transformation from system 1 (before) to system 2 (after).

holistic implementation of the IT-based LSS was further validated by the improved process capability and performance, as indicated by the resulting parameters Cpk (from -2.15 to 1.37). System 2 was proven to make birth certificate issuance service times faster, below the maximum standard time (USL) of one day (24 hours). This study demonstrated the effectiveness of implementing IT-based Lean Six Sigma and enhancing the system capability through a holistic approach. System 2 also successfully lowered the DPMO and improved the sigma level from -6.46 to 4.09. Based on this result, these parameters (Cpk and Sigma level) are corresponding values of the same degree improvement. Furthermore, the research team proposed a new Standard Operating Procedure (SOP) to ensure that the system and its performance are sustainable.

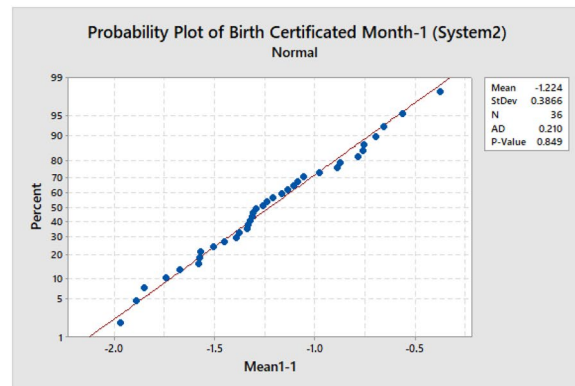
The result for the performance was acceptable and robust, the system proven to accommodate the dynamic changes and uncertain condition. In this case, a new policy was introduced regarding the

**Table 9.** Data output of control phase for birth certificate issuance using system 2.

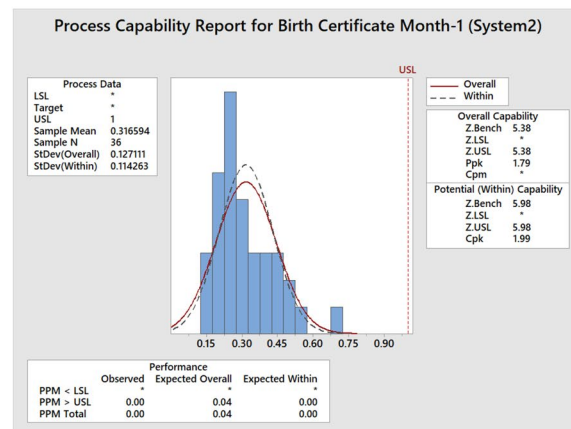
Month	p-value	Distribution	Mean (Days)	Deviation (Days)	Cpk	Sigma Level
Month-1	0.85	Normal	0.32	0.39	1.99	5.97
Month-2	0.05	Normal	0.32	0.12	2.08	6.24
Month-3	0.08	Normal	0.49	0.17	1.11	3.33
Month-4	0.07	Normal	0.49	0.41	1.20	3.60
Month-5	0.50	Normal	0.43	0.10	1.86	5.57
Month-6	0.24	Normal	0.50	0.14	1.24	3.72
Month-7	0.07	Normal	0.46	0.14	1.36	4.08
Month-8	0.71	Normal	0.52	0.13	1.25	3.76
Month-9	0.10	Normal	0.44	0.09	1.94	5.81
Month-10	0.13	Normal	0.48	0.13	1.29	3.86
Month-11	0.11	Normal	0.59	0.13	1.24	3.71
Month-12	0.66	Normal	0.60	0.12	1.18	3.54
All Months	0.12	Normal	0.51	0.13	1.37	4.09



(a)



(b)



(c)

**Figure 7.** Xbar-S Chart (a), Normality Test (b), and Process Capability Index (c) of Birth Certificate After Improvement in Month-1 (System 2).



**Table 10.** Performance results for system 1 (before) and system 2 (After).

	CTQ	Mean (Days)	Deviation (Days)	Cpk	Sigma Level
Before	Completion Time	17.12	2.42	−2.15	−6.46
After		0.48	0.13	1.37	4.09

requirement for citizens to report civil documents to avoid a fine. This policy astronomically increased the number of birth certificate applications compared to typical monthly expectations. As the system capability dynamically changes in the public sector throughout the year, unlike in a manufacturing setting, considering the human element is critical, as it is usually the main driver of fluctuations. The anomalous conditions illustrated that other mitigation efforts within the LSS framework must be implemented to maintain operations, as shown in the research paper. The key findings and implementation of the IT-based LSS in this study are transferable to other public sectors with similar circumstances and contexts.

The application of Lean Six Sigma and Information Technology (IT) in the local government sectors, specifically in the City Office for Population Administration and Civil Registration (COPACR), has been proven to accelerate the average completion time and reduce service deviation. The improvement of the new system has led to improved system capability, reduced unstandardized services, and increased sigma level. In previous studies of public hospital cases, the implementation of the Lean Six Sigma strategy managed to decrease patient waiting time by 57% (reduced from 57 to 24.5 min) and standard deviation by 70% (reduced from 31.15 to 10 min) (Antony et al., 2017). On the other hand, the LSS DMAIC methodology implementation in local governments or councils has proven effective in enhancing the fill rate of requested local school data by 35% and increasing cost savings. The Lean Six Sigma implementation can achieve a 50% reduction in waiting time with an enhancement in customer satisfaction in the context of licensing services (Maleyeff, 2007).

## 5. Lesson learned and managerial implications

LSS is a process improvement method that aims to reduce waste, increase efficiency, and increase customer satisfaction, and has been successfully implemented at the City Office for Public Administration and Civil Registration (COPACR) of Surabaya City, Indonesia. The DMAIC method provides systematic steps starting from problem identification, determining, and measuring success parameters, problem analysis, process improvement, and monitoring performance sustainability. The project presented in this study succeeded in integrating LSS with IT to solve the problems experienced by the COPACR. This context is not only applicable and transferable to the Indonesian context but also to the challenges experienced by public agencies in developing nations. In addition to the improved performance presented in Table 10, there are internal and external lessons that can be considered in future research.

### 5.1. Lesson learned for internal organizations

The challenges identified in this project include low competencies of government officers, minimal work ethics, lack of service excellence motivation, a demotivated employment system, scarce well-recorded data, inadequate data integration, and limited and strict budgets, which occur and have been experienced in various city offices for population administration and civil registration (COPACR) agencies in Indonesia. Therefore, the results of this study can also be used by the COPACR in other municipalities. This study can be replicated in other developing countries with similar contexts.

The national government directed city governments to implement digital integration in civil registration services. This effort is intended to speed up service processes and information distribution and improve agency transparency, all of which lead to increased customer satisfaction. However, implementing Information Technology (IT) alone will not provide an effective and tangible solution without the implementation of a systematic and holistic measurement of the current service system based on IT implementation. Therefore, in this project, the implementation of IT-based LSS ensured effective, efficient, and sustainable results.

The project began with orientation and training of government officers to raise awareness of LSS. This step should be replicated in other city offices as an initial 'buy-in' perspective is important for project success. Another crucial issue in Indonesia and other developing countries is the lack of proper and accurate data collection and storage. This was also observed during the pilot project. Data were captured and stored but had no framework and were not analyzed. Very little attention was given to the stored data, reflecting the unawareness of the importance of data as a basis for continuous improvement and decision-making. Therefore, in the first phase of the pilot project, when data were not fully available, the research team applied various methods to obtain the desired data.

The use of the DMAIC methodology to guide the improvement of System 1 (e-Lampid) to System 2 (Klampid) is beneficial for the internal stakeholders. The lessons learned at each phase of the DMAIC during the IT-based LSS implementation at the COPACR of Surabaya City are elaborated below.

- It is pertinent to involve the upper management of COPACR to determine priorities and the root cause of the problem in the Define phase. Additional effort to collect internal perspectives towards the current service is worthwhile, as it leads to easy identification of non-value-added and value-added activities. Observations and questionnaires that collect opinions or perspectives of all internal stakeholders from the sub-districts to the city government are important to understand and define the system well.
- As mentioned above, there was a serious lack of accurate data collection and storage habits. During the Measure phase, the research team had difficulty finding data to measure the system performance. The main reason is that System 1 (e-Lampid) was not designed for process monitoring; thus, data was not recorded properly. This team added features to obtain digitally measurable and valid data. The results of each parameter measured were then analyzed and compared to the national standard operating procedure and national Key Performance Indicators (KPIs). It should be acknowledged that efforts to capture and analyze data are laborious. Therefore, it is advisable that the COPACR of other cities record the application data accurately and in a timely manner.
- To carry out the necessary analysis, it is necessary to properly understand the LSS. As few COPACR management in other cities have sufficient knowledge of LSS, it is highly recommended to provide simple guidance for use in the Analyze phase.
- Based on the results from the Analyze phase, a new system must be developed and implemented in the Improve phase. Doing this entails commitment from the upper managers. The efficiency and performance of the system can be assessed only by improving the newly developed system. At this stage, this pilot project serves an important role as the result of this pilot project can convince the COPACR management of other cities that improvement efforts are attainable and worth pursuing. Utilizing an action research method for this project is critical. By having two cycles, as presented in this paper, the COPACR of other cities can follow these steps and yield similar results.
- During the Control phase, two points must be recognized. First, as national regulations are dynamic, the upper management of COPACR must always monitor whether the issuance process of birth certificates remains in compliance with government regulations and community needs. Second, COPACR management is encouraged to expand IT-based LSS to improve other services. The IT-based LSS should be implemented in death certificate processing, national ID card issuance, and other services that remain unexplored.

## **5.2. Lesson learned for external organizations**

In the organization's external context, the project requires significant effort when integrating LSS and IT to standardize the administrative documents required for the application process. Considering that technology proficiency levels among citizens are not standardized and are influenced by a variety of factors, and that population and civil registration matters are obligatory and are needed by everyone without exception, the application of IT must be comprehensively considered. To be successful, IT implementations must be intuitive and clearly explained. During the pilot project, many documents uploaded to the system did not conform to the required format and standards. Additionally, people's comprehension of the required documents is very diverse; therefore, errors in submitting applications are frequent. This condition resulted in inefficiency of the process, as document validation was persistent.

To achieve maximum efficiency, full data integration between the city and national levels is anticipated. In the context of Indonesian COPACR, full integration is not yet possible. The main reason for this is data security, which has become the main priority; thus, it must be protected by the central government. Therefore, application data from citizens must be re-inputted into the national system and cannot be directly transferred from the local IT system. Similarly, data transfer or updates cannot be performed directly between the two databases.

In this pilot project, the IT-based LSS is only partially flexible because of limited access to the centralized National Population Administration Information System (SIAK). Thus, the successful implementation of an IT-based LSS requires intense communication with other external stakeholders and the upper management of the COPACR of each city. In principle, this improvement shall not violate national regulations.

This study has several implications for researchers, policymakers, and practitioners. The pilot project provides the opportunity for the researcher to implement Lean Six Sigma and IT integration in other cases within service sectors such as banking, healthcare, and education. Policymakers within the scope of local government can learn and replicate the stages outlined in this study to enhance service levels and satisfaction. For practitioners, this study has the potential to facilitate extensive integration and collaboration (one to many) for efficient data verification and validation.

## 6. Conclusion and future research

Several conclusions can be drawn from the IT-based LSS implementation presented in this study. First, implementing LSS integration with the IT City Office for Population Administration and Civil Registration (COPACR) of Surabaya City in Indonesia can increase speed and quality of service. Second, the applicability of DMAIC is convincingly proven to provide systematic and holistic guidance for planning, executing, and monitoring processes in civil registration services. Third, information technology makes it easy for citizens to process their registration, track their progress, and receive their documents, but this must be guided with the appropriate directions both internally and externally.

In summary, the system performance indicators were significantly improved from System 1 (e-Lampid) to System 2 (Klampid). The completion time was improved from 17.12 to 0.48 days, the standard deviation of completion time was decreased from 2.42 to 0.13 days, the system capability was improved from -2.15 to 1.37 (Cpk), and the sigma level was improved from -6.46 to 4.09. Based on this result, these parameters (Cpk and Sigma level) are corresponding values of the same degree improvement.

Previous studies (Jonathan, 2020; Magna & Irfan Maulana, 2023; Ruud, 2017; Walport & Craig, 2014) state that the implementation of digital and Information Technology (IT) in the public service sector is proven to enhance transparency, productivity, and service efficiency. However, IT implementation without a robust, systematic, and integrated plan can lead to inconsequential results. This requires the integration of Lean Six Sigma (LSS) as a reference guide to standardize the processes and stages of system improvement. LSS has been implemented in the public sector with positive results (Antony et al., 2016; Furterer & Elshennawy, 2005; Gijo & Antony, 2014; Kim, 2020). Therefore, integrating LSS with IT is crucial for accelerating service efficiency and effectiveness. Despite the multitude of benefits observed in previous studies (Antony et al., 2017; Sunder, 2016; Byrne et al., 2007; Duarte et al., 2012), these instances of IT-based LSS have not yet considered the specific characteristics and limitations of developing countries. Therefore, this study contributes to the theory that the implementation of LSS with IT integration (IT-based LSS) in the public service sector of developing countries is inconsequential and even a hindrance without considering the context and constraints outlined in this paper. However, the action research methodology is deemed appropriate for application in the public service sector, specifically within COPACR. This is because the process of improvement requires constant reiteration and consistent improvement.

Even though this study is limited in terms of the scope of implementation, the unique circumstances outlined in this paper allow this case to be a good representation of the overall services provided by COPACR, as well as public sector services in developing countries. Several adjustments may be needed to address different service characteristics, such as the number of applications and the complexity of processing, which may influence the LSS implementation. Additionally, public agencies in different cities

may have different contexts and challenges that may influence the results. Therefore, further research should extend this study to other services within COPACR Surabaya and public agencies in other regions to validate and generalize the results.

To conclude, based on the action research approach used in this study, this project will continue by developing System 3 based on the evaluation of System 2. The LSS integration with IT model was tested and validated in three other Indonesian cities. If this model could be implemented successfully in three other cities with different COPACR characteristics, the Ministry of Home Affairs of the Republic of Indonesia could adopt this model to be implemented at the national level.

### Author contributions

All authors contributed to the conception, design, methodology, interpretation, and analysis. Agus Imam Sonhaji was responsible for data collection, research ethics clearance, data analysis, and manuscript writing. Maria Anityasari was responsible for finalizing and completing the writing process. She was also responsible for the formal analysis, investigation, and validation. Mahendrawathi ER contributed to develop research instruments, resources, software, validation, and visualization. All authors have read and agreed to the publication of the final version of the manuscript.

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### Data availability statement

The data that support the findings of this study are available from the corresponding author, Maria Anityasari, upon reasonable request.

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