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Cost of COVID-19 Mass Vaccination at Ngampilan Health Center, Yogyakarta

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ABSTRACT

The COVID-19 pandemic has significantly impacted various sectors worldwide. To mitigate the spread of the virus and reduce mortality rates, vaccination programs have been implemented using diverse strategies. One such strategy in Indonesia is the mass vaccination program. This study aims to estimate the unit cost of service delivery for the COVID-19 Sinovac vaccine per dose and per fully vaccinated individual (two doses) at Ngampilan Health Center, Yogyakarta. A costing study was conducted using an activity-based cost approach, incorporating financial data, interviews, and direct observations. The incremental financial cost and full economic cost were calculated from the perspective of the government or service provider. The total cost was then divided by the number of doses administered and multiplied by two to determine the cost per fully vaccinated individual. The incremental financial and economic costs per dose were estimated at USD 12.20 and USD 12.90, respectively. Meanwhile, the cost per fully vaccinated individual (two doses) using the Sinovac vaccine amounted to USD 24.30 and USD 25.90, respectively. Sensitivity analysis revealed that the unit cost per fully vaccinated individual is primarily influenced by vaccine prices and the number of individuals vaccinated per mass vaccination session.

Keywords: mass vaccination, COVID-19, economic cost, financial cost, incremental cost

INTRODUCTION

Indonesia, the fourth most populous country in the world, recorded its highest daily increase in COVID-19 cases on July 13, 2021, with over 47,000 new infections reported (National COVID-19 Mitigation Task Force, Republic of Indonesia, 2021). The surge in cases prompted the government to accelerate the nationwide COVID-19 vaccination program on a massive scale. To achieve herd immunity, the government set a vaccination target of more than 200 million people, approximately 70% of the total population. The national COVID-19 vaccination program was launched in late January 2021, initially prioritizing health care workers, followed by the elderly and public service employees (Center for Disease Control and Prevention, Ministry of Health, Republic of Indonesia, 2021). To extend vaccination coverage to the broader general population, the government secured an increased supply of COVID-19 vaccines by incorporating multiple manufacturers, including Sinovac Biotech Ltd, AstraZeneca, Sinopharm, Moderna, Pfizer Inc., BioNTech, Novavax, as well as the locally produced PT Biofarma (Persero) (Ministry of Health, Republic of Indonesia, 2021a).

Approximately 50 million people in Indonesia have received partial vaccination against COVID-19, while only 12% of the population has been fully vaccinated. Although the vaccination rate has shown a steady upward trend over the months, there remain significant disparities in vaccination coverage across different regions of Indonesia (Ministry of Health, Republic of Indonesia, 2021b). One of the key strategies implemented to accelerate the nationwide vaccination rate is the deployment of mass vaccination campaigns, following the guidance of the World Health Organization (WHO).

Mass vaccination campaigns have been proven to be an effective approach for preventing or responding to outbreaks of vaccine-preventable diseases (World Health Organization, 2020).

Yogyakarta is one of the provinces with the highest COVID-19 vaccination coverage in Indonesia. The province has extensive experience in public health communication and vaccination mobilization, having served as a pilot region for the introduction of several new vaccines in recent years, including the Inactivated Polio Vaccine (IPV) and the Human Papillomavirus (HPV) vaccine. The total COVID-19 vaccination target in Yogyakarta is approximately 2.80 million individuals, distributed as follows: 16.00% elderly, 60.00% general and vulnerable populations, 12.00% civil servants, 1.00% healthcare workers, and 11.00% adolescents aged 12–17 as part of the newly targeted cohort.

The mandated COVID-19 vaccination program has shifted government priorities at the district level, particularly through the large-scale reallocation of health budgets to support COVID-19-related initiatives. One of the key strategies to accelerate vaccination coverage is the implementation of mass vaccination campaigns, which have become a focal point in budget reallocation discussions. However, there is currently no comprehensive reference on the cost of implementing mass vaccination service delivery for COVID-19 vaccines, which, in practice, involves multiple stakeholders. This information is crucial, as mass vaccination will remain a primary strategy to achieve the target of fully vaccinating 100% of the population in the upcoming year, 2022.

Mass vaccination is a proactive strategy for delivering vaccines to a large segment of the targeted population at one or more locations within a specific timeframe (Grabenstein & Nevin, 2006). In the context of COVID-19, this approach is essential for accelerating vaccination rates and ensuring coverage across diverse demographic groups. In addition, mass vaccination campaigns will play a crucial role in the introduction of new vaccines in the coming years. Given these factors, estimating the incremental cost of implementing mass vaccination is essential. The estimated unit cost will serve as critical information for advocating local government budget reallocations to ensure adequate funding for COVID-19 service delivery in future scale-up programs.

In the context of Indonesia, mass vaccination programs have been pivotal in the national effort to achieve widespread immunity and reduce the burden of the disease on the healthcare infrastructure and the broader economy. A crucial aspect of evaluating the effectiveness and sustainability of such programs lies in the comprehensive assessment of their economic implications, particularly the accurate estimation of the costs associated with vaccine delivery (Portnoy et al., 2020). This study aims to estimate the unit cost of delivering the COVID-19 Sinovac vaccine through a mass vaccination program, both per dose and per fully vaccinated individual (two doses), at a public health center in Ngampilan, Yogyakarta City. Conducting detailed costing studies, like the one performed at Ngampilan Health Center in Yogyakarta, provides valuable insights into the financial and economic resources required to implement mass vaccination campaigns, informing policy decisions related to resource allocation, program optimization, and long-term planning for public health preparedness.

MATERIAL AND METHODS

Study sites and program activities

Yogyakarta City has 18 public health centers, among which Ngampilan Health Center was selected for this study due to its significant role in serving 4.48% of the city's total population and having the highest population-weighted density, with 22,622 people per square kilometer (Yogyakarta Bureau of Statistics, 2020). High population density can potentially increase person-to-person transmission of COVID-19 (Baser, 2021). This study covered activities involving multiple stakeholders responsible for the success of the COVID-19 mass vaccination program in Yogyakarta City. These stakeholders include the Yogyakarta District Health Office, sub-district officials and leaders, and networks of private healthcare facilities. Effective mass vaccination requires adequate planning based on standardized guidelines (Center for Disease Control and Prevention, Ministry of Health, Republic of Indonesia, 2021). The mass vaccination program at Ngampilan Health Center is structured into four key phases: (1) training for healthcare workers, including vaccinators, (2) pre-mass vaccination activities, (3) mass vaccination activities, and (4) post-mass vaccination activities (Table I).

Table I. Activities and Involved Stakeholders

Activities	District Health Office	Ngampilan Health Center	Sub-District Office	Private Health Facilities Network (i.e., Clinics)
Training Healthcare workers	√	√		
Pre-Mass Vaccination	√	√	√	√
Planning and Coordination Meeting for COVID-19 Vaccination				
Mapping targeted cohort for COVID-19 vaccination in Ngampilan Health Center's area of services				
Vaccine distribution and storage				
Socialization and Mobilization on COVID-19 Vaccine Service Delivery				
Vaccination Day		√	√	√
Mass vaccination service delivery				
Post-Mass Vaccination		√	√	
Evaluation Meeting Post Vaccination Service Delivery				

Study design

This study conducted an incremental cost analysis of the COVID-19 mass vaccination service delivery program at the healthcare center level from the government's perspective, specifically that of the District Health Office and health centers (*Puskesmas*). The analysis employed an activity-based costing approach to estimate both the incremental financial cost and the full economic cost of the mass vaccination program within the context of COVID-19. Incremental financial cost refers to the additional expenditures on new resources that were not previously utilized in existing health programs and were incurred by the government to facilitate mass vaccination sessions. In contrast, the full economic cost encompasses both financial and opportunity costs, quantifying all associated resources, including labor (e.g., salaries of healthcare workers), materials, and capital investments (e.g., additional cold chain equipment). Both recurrent costs and investment costs necessary to support vaccination activities were taken into account in this analysis.

Study program: COVID-19 mass vaccination service delivery

At least six types of COVID-19 vaccines from different manufacturers have been approved for use in Indonesia, including Sinovac, Sinopharm, AstraZeneca, Novavax, Moderna, and Pfizer (Center for Disease Control and Prevention, Ministry of Health, Republic of Indonesia, 2021). Each of these vaccines has a distinct dosage regimen and recommended administration schedule. The COVID-19 vaccination program in Indonesia targeted adults aged 18 years and older. The mass vaccination activities at Ngampilan Health Center took place between June 9 and October 14, 2021, utilizing both the Sinovac and AstraZeneca vaccines. This study specifically focuses on the Sinovac vaccine, which was widely distributed during the initial phase of the mass vaccination program.

The study conducted at Ngampilan Health Center employed an activity-based costing approach, a methodology recognized for its precision in allocating costs to specific activities within a program (Riewpaiboon et al., 2015). This approach involves a meticulous examination of all resources consumed during the vaccination process, including personnel time, supplies, equipment, and overhead expenses (Bani et al., 2022). The researchers gathered data through a combination of financial records, in-depth interviews with healthcare providers and administrative staff, and direct observations of the vaccination workflow. This multifaceted data collection strategy ensured a comprehensive understanding of the resources utilized at each stage of the vaccination process, from vaccine storage and preparation to administration and post-vaccination monitoring. By meticulously tracking the resources involved in each activity, the researchers were able to assign costs more

accurately, providing a more realistic estimate of the true cost of delivering the Sinovac vaccine. The determination of both incremental financial and full economic costs is essential for a comprehensive cost analysis (Bilinski et al., 2017). The incremental financial cost reflects the direct expenditures incurred by the healthcare provider, encompassing expenses such as vaccine procurement, personnel salaries, and consumable supplies.

Cost component and valuation of resources used

This study analyzes two types of costs: financial costs and economic costs. The unit costs of the COVID-19 vaccination program were calculated by identifying labor costs, capital costs, and material costs. The total quantity of resources used was divided by the corresponding outputs to determine the monetary value of these resources. Capital costs were estimated using the equivalent annual cost (EAC) method. Each piece of equipment used for vaccination activities was assessed based on its useful lifespan. The EAC was calculated by dividing the cost of equipment by 365 days to obtain the equivalent daily cost, then further dividing by 24 hours to determine the equivalent hourly cost, which was subsequently multiplied by the number of hours the equipment was used for mass vaccination. Training costs were classified under capital costs and assumed to have a useful life of three years. Vaccine refrigerators and vehicles were considered to have a useful lifespan of ten years, while other equipment such as vaccine carriers, cool boxes, and cool packs were assumed to last for five years. A 3.00% discount rate was applied in the EAC calculation. Labor costs were determined by adjusting salaries to a daily rate, dividing by 24 working days per month and eight working hours per day, resulting in an hourly wage. This hourly wage was then multiplied by the duration of each activity to estimate labor costs for each component of the vaccination program. Material costs were calculated based on direct observations of the materials used in each activity, including expenditures on snacks and meals for meetings, meeting supplies, vaccination cards, personal protective equipment (PPE), sanitation supplies, and rented equipment. The price per dose of the Sinovac vaccine used in this study was USD 9.52 (BPS-Statistics of Yogyakarta Municipality, 2020; Setyawan, 2022).

All costs were then classified into fixed and variable costs. Fixed costs refer to expenditures that remain unchanged regardless of the number of vaccine doses administered, such as planning and coordination expenses. In contrast, variable costs fluctuate based on the number of vaccine doses delivered. To determine the unit cost per dose, the total cost of each activity within the mass vaccination program was divided by the number of individuals vaccinated. This value was then multiplied by two to calculate the cost per fully vaccinated person (two doses). All costs were initially recorded in the local currency (Indonesian Rupiah, IDR) and subsequently converted to U.S. dollars at an exchange rate of USD 1.00 = IDR 14,229.50 (Bank Indonesia, 2021).

Data collection and data management

Data collection for this study involved measuring the quantity of resources used and the corresponding outputs during the period from September to October 2021. Resource utilization was assessed for each activity, including the frequency of activities throughout the entire vaccination program. Data were obtained from activity and financial reports provided by Ngampilan Health Center. In addition, interviews and direct observations were conducted to estimate labor costs by calculating the time required for officers to carry out mass vaccination activities. Outputs were defined as the number of vaccine doses administered and the number of individuals who received two doses of the Sinovac vaccine through the mass vaccination program at Ngampilan Health Center. Data extracted from forms and financial reports were systematically recorded and analyzed using MS Excel.

Analysis and presentation

All costs in this study are presented in 2021 USD values, using an exchange rate of USD 1.00 = IDR 14,229.50 (Bank Indonesia, 2021). The cost analysis includes the following components: Total cost of the mass vaccination program, covering both financial and economic costs; Total cost classified by type of activity; Cost per vaccine dose (Sinovac); Unit cost per fully vaccinated individual.

The sensitivity analysis was conducted based on variations in the COVID-19 vaccine price and the number of vaccinated individuals. This cost analysis specifically utilized the Sinovac vaccine for price calculations, as it was the most widely available vaccine in Indonesia during the first quarter of the national mass vaccination program. The supply of Sinovac vaccines in Indonesia was facilitated through bilateral cooperation between the Indonesian government, represented by the

domestic pharmaceutical industry Biofarma, and the Chinese manufacturer Sinovac Biotech Ltd. The vaccine price used in this analysis was based on the projected price range per dose for lower-middle-income countries. Since the number of vaccinated individuals influences the unit cost of fixed costs, a sensitivity analysis was also conducted based on the capacity of healthcare workers to administer vaccinations during mass vaccination sessions. The analysis considered a range of 40 to 70 individuals per healthcare worker (Center for Disease Control and Prevention, Ministry of Health, Republic of Indonesia, 2021). This analysis assessed the impact of increasing and decreasing healthcare worker capacity on the unit cost of vaccination. The findings provide valuable insights for future planning and budgeting, supporting more efficient resource allocation for upcoming mass vaccination programs.

Ethical Consideration

This study received ethical clearance from the Medical and Health Research Ethics Committee, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Indonesia, under approval number KE/0969/09/2021. In addition, formal permission was obtained from the Yogyakarta Health Department, as documented in letter number 070/6010.

RESULTS AND DISCUSSION

COVID-19 mass vaccination program activities and resources used

Ngampilan Health Center is one of the 18 public health centers in Yogyakarta City, serving a total population of 18,550 (BPS-Statistics of Yogyakarta Municipality, 2020). As of October 10, 2021, approximately 36.60% of the population in Ngampilan Sub-District had received at least one dose of the COVID-19 vaccine. Between June 9 and October 14, 2021, Ngampilan Health Center conducted 10 mass vaccination sessions, targeting 5,331 individuals. However, 16.10% of the targeted population did not attend the vaccination sessions. Among the 4,471 individuals who arrived at the vaccination site, 4,218 successfully passed the health screening and received the vaccine. For this study, we specifically observed and calculated the resources utilized during one mass vaccination event held on October 14, 2021. This session targeted 531 individuals, of whom 490 were successfully vaccinated. The average monthly salaries for key personnel involved in the mass vaccination program were as follows (Table II): General Physician (GP): USD 281.11; Vaccinator: USD 158.12; Administration and Logistics Staff: USD 145.44; Pharmacist: USD 189.75; Sub-District Office Staff: USD 145.44.

Each vaccinator and supporting staff working on a mass vaccination day received a daily subsistence allowance (per diem incentive) of approximately USD 6.67. On average, a single vaccinator was capable of administering vaccinations to 40 to 70 individuals per session.

Before and after conducting a mass vaccination, a series of activities must be completed (Table I), requiring multi-sectoral coordination with the District Health Office, Sub-District Office, private clinic networks, Ngampilan Health Center, and volunteers. Pre-mass vaccination activities include planning and coordination meetings to identify and map the targeted cohorts for COVID-19 vaccination within Ngampilan Health Center's service area, as well as socialization and advocacy meetings to engage stakeholders and inform the public about the vaccination program. Post-mass vaccination activities involve evaluation meetings to assess implementation, identify challenges, and improve future vaccination sessions. On average, each of these activities lasted 1–2 hours and involved 25 participants.

Based on our observations during the mass vaccination day at Ngampilan Health Center, a single vaccinator was able to administer vaccines to an average of 61 individuals, with each vaccination process taking approximately 18 min (Table III). This time includes registration, health screening, blood pressure check, vaccine administration, data entry, and side-effect monitoring. The total labor time required for a single mass vaccination session was approximately 7 hours. Before the nationwide rollout of the COVID-19 vaccination program, the central government provided training for vaccinators at the healthcare center level to ensure proper vaccine administration. At Ngampilan Health Center, six vaccinators underwent training on COVID-19 vaccine service delivery. In this analysis, training costs are categorized as capital costs and are also considered economic/ opportunity costs. Since mass vaccination for the general population began in June, two types of COVID-19 vaccines were used at Ngampilan Health Center: Sinovac and AstraZeneca. Neither of these vaccines required special cold chain equipment; thus, no additional capital costs were incurred for COVID-19 mass vaccination, except for the acquisition of 20 additional Cool Pax units.

Table II. The unit cost of resources used

Payment	USD	Unit
Average Salary GP HC	281.11	Per month
Average Salary Vaccinator HC	158.12	Per month
Average Salary Admin Staff HC	145.44	Per month
Average Salary Logistic Staff HC	145.44	Per month
Average Salary Pharmacist HC	189.75	Per month
Average Salary SDO	145.44	Per month
Compensation for vaccinators and other staff on Mass Vaccination Day	6.67	Per day
Travelling; motorcycle	0.103	Per km

Note: GP= General Practitioner; HC=Health Center; DO=Sub-District Office; USD 1.00= IDR 14,229.50

Table III. The activity of the mass vaccination

Activity	Average time	Unit
1. Pre-mass vaccination		
Meeting and planning	1.00	hour
Vaccine pick-up	1.00	hour
Vaccine storage	1.00	hour
Advocacy	2.00	hour
2. Vaccination Day		
Registration	0.50	minute
Screening	1.80	minute
Blood pressure check	1.10	minute
Vaccine injection	1.10	minute
Side effect monitoring	12.50	minute
Entry data	1.08	minute
Total time	18.10	minute
3. Post-mass vaccination		
Evaluation	1.00	hour

Table IV. The total cost of the mass vaccination program (financial and economic cost)

Activity	Financial Costs		Economic Costs	
	USD	%	USD	%
1. Training for health care workers	-	-	100.66	5.80
2. Pre-Mass Vaccination	22.46	1.80	77.72	4.40
- Planning and Coordination Meeting for COVID-19 Vaccination	15.81	1.20	38.47	2.20
- Vaccine distribution and storage	1.05	0.10	8.93	0.50
- Advocacy, Socialization, and Mobilization on COVID-19 Vaccine Service Delivery	5.60	0.50	30.32	1.70
3. Vaccination Day	1255.76	97.00	1533.76	87.60
4. Post-Mass Vaccination				
- Evaluation Meeting Post Vaccination Service Delivery	15.81	1.20	38.10	2.20
Total Costs	1294.04	100.00	1750.70	100.00
Cost per vaccinated person	2.64		3.57	
Cost per fully vaccinated person	5.28		7.15	

For vaccine storage, Ngampilan Health Center utilized one vaccine refrigerator (TCW 2000), one cold box (RCW 8), and five vaccine carriers (RCW 4). Before each mass vaccination day, the vaccine logistics officer at Ngampilan Health Center was responsible for collecting vaccines from the Vaccine Warehouse at the District Health Office (DHO). The travel cost for vaccine distribution was estimated at USD 0.103 per kilometer. To quantify the unit economic cost of vaccine storage equipment, the analysis applied a fixed-based consumer price index, using the 2018 index as a reference (Index 2018 = 100), adjusted based on data from the Indonesia Central Bureau of Statistics (2021).

Unlike mass vaccination for routine immunization programs conducted before the pandemic, COVID-19 mass vaccination requires adherence to strict guidelines to ensure safety and efficiency. These guidelines include specific criteria for vaccination sites, such as outdoor settings or indoor locations with proper air circulation and handwashing stations. Additionally, mandatory Personal Protective Equipment (PPE) must be provided for healthcare workers, including gowns, nurse caps, surgical masks, KN-95 masks, gloves, hand sanitizers, and alcohol sprays. In this analysis, both vaccination site equipment and PPE are categorized as fixed costs, as they are essential requirements regardless of the number of individuals vaccinated.

Another cost factor considered in calculating the incremental cost of COVID-19 mass vaccination is the cost of biomedical waste treatment. It is assumed that each vaccinated individual generates approximately 150 grams of biomedical waste, including PPE, syringes, vaccine vials, alcohol swabs, and other disposable materials. The cost per additional kilogram for treating biomedical waste is estimated at USD 1.40, while the additional disposal cost for waste management is approximately USD 103.00.

Mass Vaccination Program Cost

For COVID-19 mass vaccination service delivery, the total annualized financial cost per fully vaccinated individual (two doses) was USD 5.28, while the total annualized economic cost was USD 7.15 (Table IV). The financial cost per vaccine dose was USD 2.64, whereas the economic cost per dose was USD 3.57. When comparing the proportion of costs by activity type, mass vaccination service delivery accounted for the largest share of both financial (93.20%) and economic (89.70%) costs. Pre-mass vaccination and post-mass vaccination activities contributed approximately 6.80% of the total financial costs and 9.50% of the economic costs. Meanwhile, training for vaccinators constituted about 0.90% of the total economic costs.

The unit cost per vaccinated individual and fully vaccinated individual, classified by program activities in the COVID-19 mass vaccination program (Table V). The incremental financial cost per dose was estimated at USD 2.64, covering activities from pre-mass vaccination, mass vaccination service delivery, and post-mass vaccination activities. Meanwhile, the economic cost per dose was calculated at USD 3.43. The difference between financial and economic costs arises from variations in cost categorization. When incorporating the vaccine price per dose into the calculation, the financial cost per fully vaccinated individual (two doses) amounted to USD 24.30, while the economic cost per fully vaccinated individual was USD 25.90. These results indicate that the vaccine price is the dominant cost component, accounting for more than 90% of the total expenditure. In contrast, operational costs constituted only 8–9% of the overall cost.

Sensitivity Analysis

The financial operational cost per dose supplied and per fully vaccinated individual (two doses), as presented in Table VI, is higher than the estimates reported by GAVI, WHO, and UNICEF in 2021 (Griffiths et al., 2021). Our analysis calculated a financial cost of USD 2.64 per dose supplied and USD 5.27 per fully vaccinated individual. In contrast, the GAVI, WHO, and UNICEF report estimated total financial costs, including country, regional, and global-level costs, at USD 1.66 per dose supplied and USD 3.70 per fully vaccinated individual, after adjusting for vaccine wastage. The discrepancy in results arises from differences in cost components and calculation assumptions. In this study, vaccine wastage was estimated at 15.00%, following WHO and the COVID-19 vaccination program guidelines (Center for Disease Control and Prevention, Ministry of Health, Republic of Indonesia, 2021). In addition, this study excluded innovation costs, such as smart vaccination certificates, traceability solutions, and other digital health technologies, which may have influenced the cost variations.

Table V. Unit Cost of COVID-19 Mass Vaccination Service Delivery.

Activity	Unit Cost Per Dose		Unit Cost Per Fully Vaccinated (2-Dose)	
	Incremental Financial Cost (USD)	Full Economic Costs (USD)	Incremental Financial Cost (USD)	Full Economic Costs (USD)
1. Training for health care workers	-	0.08	-	0.15
2. Pre-Mass Vaccination	0.04	0.15	0.08	0.31
- Planning and Coordination Meeting for COVID-19 Vaccination	0.03	0.08	0.06	0.16
- Vaccine distribution and storage	0.00	0.00	0.00	0.04
- Advocacy, Socialization, and Mobilization on COVID-19 Vaccine Service Delivery	0.01	0.07	0.02	0.11
3. Mass Vaccination (D-day)	2.56	3.13	5.12	6.25
4. Post-Mass Vaccination	0.03	0.08	0.06	0.16
- Evaluation Meeting Post Vaccination Service Delivery	0.03	0.08	0.06	0.16
Total Costs	2.64	3.43	5.27	6.86
Total Costs + Vaccine Price	12.20	12.90	24.30	25.90

Table VI. Sensitivity Analysis of the unit cost by price of the vaccine and output of the program (dose injected/fully vaccinated)

Activity	Unit Cost Per Dose		Unit Cost Per Fully Vaccinated (2-Dose)	
	Incremental Financial Cost (USD)	Full Economic Costs (USD)	Incremental Financial Cost (USD)	Full Economic Costs (USD)
Unit Cost of the Program (excluding Vaccine Price)	2.64	3.43	5.27	6.86
Based on Vaccine Price per dose				
- USD 3.17	5.81	6.60	11.62	13.20
- USD 6.35	8.98	9.78	17.97	19.55
- USD 9.52	12.16	12.95	24.31	25.90
Based on Vaccinators' Capacity (number of vaccinated people/vaccinator), including vaccine price (USD9.52 per dose)				
- 40 people (min. capacity)	13.56	14.99	27.13	29.98
- 61-62 people (actual obs.)	12.16	13.09	24.32	26.19
- 70 people (max. capacity)	11.83	12.65	23.66	25.29

Indonesia employs unique approaches to vaccine procurement, which significantly influence vaccine pricing. The negotiated price of the Sinovac vaccine per dose is largely shaped by a bilateral industrial agreement between Biofarma Indonesia and Sinovac Biotech Ltd, China. Under this agreement, Sinovac Biotech Ltd committed to supplying bulk vaccines and granting technology licensing to Biofarma for local production of the vaccine. This study refers to the actual 2021 price of the Biofarma-Sinovac vaccine, which was USD 9.52 per dose. This price is lower than the 2020 procurement price, which was USD 14.85 (Setyawan, 2022). To assess the impact of vaccine price fluctuations, sensitivity analysis was conducted by incorporating two additional scenarios, estimating vaccine prices at USD 13.70 (33.33% increase) and USD 6.35 (50.00% decrease). The analysis highlights the significant role of vaccine price in determining the overall cost of the vaccination program. Negotiating favorable vaccine prices through bulk purchasing or

international collaborations can substantially reduce the overall cost of the vaccination program. Additionally, maximizing the number of individuals vaccinated per session through efficient scheduling, streamlined procedures, and community outreach efforts can improve the utilization of resources and lower the unit cost per vaccinated individual (Banerjee et al., 2010).

The capacity of vaccinators, as outlined in the technical guidelines issued by the Ministry of Health, ranges from 40 to 70 individuals per vaccinator. The cost analysis was conducted using 40 vaccinated individuals as the minimum base and 70 vaccinated individuals per vaccinator as the maximum base. The results indicate that vaccination costs decrease as the number of vaccinated individuals increases. This finding suggests that achieving a lower unit cost requires increasing the vaccination output.

Accelerating the achievement of herd immunity in Indonesia, the fourth most populous country in the world, requires a strategic and collaborative effort across multiple sectors. The country aims to vaccinate over 200 million people by 2022 while adhering to strict physical distancing measures. One distinctive aspect of Indonesia's strategy to increase vaccine uptake is the implementation of mass vaccination programs, which facilitate high coverage at a lower cost, particularly at the health center level. Health centers play a crucial role in ensuring that the targeted population at the sub-district level receives vaccination efficiently. This analysis is designed to assist planning and budgeting units at the health center level and the District Health Office in more accurately estimating the actual costs required for COVID-19 mass vaccination service delivery, using empirical data and direct observations.

This study identified four key cost drivers for mass vaccination service delivery in the context of COVID-19. First, additional Personal Protective Equipment (PPE) and Infection Prevention and Control (IPC) measures were required for each mass vaccination session to ensure the safety of healthcare workers and vaccine recipients. Second, increased staffing at vaccination sites, including both healthcare and non-healthcare personnel, was necessary to support critical functions such as registration, health screening, data recording, and reporting. Third, to ensure compliance with physical distancing measures, two options were available: either increasing the frequency of vaccination sessions, which resulted in additional compensation costs for healthcare workers and staff, or holding vaccination sessions in larger indoor or outdoor venues, requiring more vaccinators and support staff. Fourth, other additional costs included public communication and mobilization efforts, extra training for vaccinators, and vaccine distribution logistics.

This study found that the incremental financial cost for each fully vaccinated individual at the healthcare center level was approximately USD 5.27. When compared to a similar study on the incremental cost of routine immunization amid COVID-19, operational service delivery costs per dose in campaign-based vaccination programs were estimated to increase by 5.00–20.00% due to the addition of PPE and IPC measures, by 10.00–26.00% to support physical distancing and health screening, by 8.00–32.00% due to additional per diems resulting from changes in delivery strategies, and by 10.00–40.00% when expanding transport and social mobilization efforts (Moi, Banks, & Boonstoppel, 2020).

The role of community health workers is pivotal in increasing vaccination coverage. A qualitative study by Akbar et al. (2021) explored the role of community health workers during the COVID-19 pandemic by conducting interviews with cadres and nurses (Akbar MA, Juniarti N, & Yamin A, 2021). The study emphasized that, beyond the role of community health workers, optimizing the involvement of all stakeholders at the community level is crucial. Collaborative efforts between cadres, community health workers, and the local COVID-19 task force can enhance health screening processes, allowing for a better prediction of eligible vaccine recipients. Our findings indicate that not all invited individuals ultimately received the vaccine. The concept of altruism can significantly influence vaccination decisions, as individuals may choose to get vaccinated not only for their own protection but also to protect others in their community (Shim et al., 2012, Cucciniello et al., 2022; Hierro et al., 2023). In this report, out of 561 invited individuals, only 490 were successfully vaccinated. Furthermore, the study's findings can inform the development of targeted interventions to address specific barriers to vaccination, such as misinformation, hesitancy, and logistical challenges, thereby increasing vaccination coverage and reducing the overall cost per fully vaccinated individual. The secondary reason for this discrepancy was failure to pass the health screening test, which was a prerequisite for vaccination. Enhancing the role of community

health cadres in the pre-screening process has the potential to increase the number of eligible vaccine recipients.

Despite the potential usefulness of these findings, this study has several limitations. Due to time constraints in conducting field observations and gathering resources, this study was limited to observing one mass vaccination session at a single healthcare center in Yogyakarta City. Consequently, there may be variations in per diem allowances, salaries, and staff incentives across different regions, particularly those with varying fiscal capacities. Another limitation is the lack of sufficient reference materials on COVID-19 mass vaccination service delivery and costing at the health center level.

CONCLUSION

The incremental financial cost and economic cost per dose were estimated at USD 12.20 and USD 12.90, respectively, while the cost per fully vaccinated individual (two doses) using the Sinovac vaccine was USD 24.30 and USD 25.90, respectively. Sensitivity analysis indicated that the unit cost per fully vaccinated individual is significantly influenced by vaccine price and the number of vaccinated individuals per mass vaccination session. To reduce the cost of mass vaccination at both health facility and district levels, this study suggests that the government take several measures, including minimizing vaccine hesitancy at the community level through enhanced health promotion and social mobilization via multiple media platforms; ensuring that invited individuals are eligible for vaccination and attend vaccination sites by empowering local health volunteers, such as community health cadres; and optimizing vaccination coverage and resource utilization by improving planning and organization of mass vaccination sessions and ensuring synchronization of the targeted population database with the Universal Health Coverage (UHC) system information. We hope that this costing analysis will assist local governments in developing accurate budget estimates for conducting future COVID-19 mass vaccination sessions at the health center level and responding effectively to other unprecedented outbreak situations.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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