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Optimising Drugs and Vaccines Management Utilizing 5 M Method: The Case of Riau Islands, Indonesia

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ABSTRACT

A resilient health system should include the ability to access essential drugs and vaccines in all locations. This study aims to perform root cause analysis and develop recommendations to optimize drugs and vaccines management for Riau Islands Province, Indonesia. This study used qualitative approaches which included interviews and group discussions with key stakeholders (n=6) as well as an expert panel (n=4). Data on the underlying causes of problems and recommendations were structured into 5M (Man, Money, Machine, Method, Material). Problems related to Man (limited human resources) were identified for most management stages. Other problems reported: Planning – Money (inefficient budget management), Material (inaccurate data on local needs); Receival (unqualified delivery couriers); Storage - Machine (lack of infrastructure and cold chain assurance); Distribution – Material (urgent supply requests), Money (high cost of transportation), Machine (unqualified (cold chain) delivery couriers); Disposal – Machine (limited capacity); Documentation – Machine (unintegrated information system), and Material (mismatched data). Recommendations included improving human resources and budget management; improving infrastructure, especially to enhance cold chain assurance; scheduled distribution; and integrating the internal information system into the national system to provide real-time stock data. Findings from this study should provide a model for optimising pharmaceutical management in low-resource settings.

INTRODUCTION

The COVID-19 crisis has highlighted the vulnerability of health systems across the world.[1] As the largest archipelagic nation and one of the world's most disaster-prone countries, Indonesia needs to build a resilient health system.[2-4] In 2022, the Ministry of Health, Republic of Indonesia (MoH-RI) established resilient health systems as one of six pillars of health transformation in Indonesia.[2] Optimal management of drugs and vaccines was among the key indicators to ensure access to quality medicines and vaccines in all locations.[2]

Based on a government regulation, drugs and vaccines management has now been included within pharmacy services, and involves a process of planning, procurement (and receival), storage, distribution, disposal/ recall, and monitoring/documentation.[5] Under the decentralisation policy, Indonesia has provided autonomy to regional governments to execute a wide range of responsibilities. Regional health offices – a technical unit of regional governments – are responsible for the health sector at the regional level (in coordination with MoH-RI).[6] While each regional health office might have different structures and policies, the management of drugs and vaccines has usually been carried out by different sub-sections, i.e., a Pharmacy Unit, and Surveillance and Immunisation Section, respectively.[7]

Previous Indonesian studies have reported issues related to the management of drugs and vaccines in various regional health offices. These occur within the planning stage with drugs purchased not meeting the actual needs, or drugs that are needed not being included in the national formulary.[8,9] Within the distribution stage, untimely distribution occurs to public health facilities,[10] while within the storage stage, cold chain facilities for vaccines has not yet matched the requirements.[11] The COVID-19 crisis has further raised the urgency to optimise the management of drugs and vaccines within regional health offices, as this had much greater impact on the access to medicines and vaccines at local public health facilities. A review by Yusiana et al. (2022) reported that the management of drugs and vaccines in several *Puskesmas* (Public Health Centres, PHC) across Indonesia during the COVID-19 pandemic did not conform to the standards.[12]

Riau Islands Province is an archipelago consisting of 2,408 islands.[13] The geographically widespread nature of the islands in this region has made the management of drugs and vaccines a challenge. Riau Islands Provincial Health Office previously had separate divisions to handle drug and vaccine where systemic inefficiencies had been reported, particularly during COVID-19 crisis. Inaccuracy in planning and procurement, issues with availability and quality of drugs or vaccines in the region had been reported.[14] To improve efficiency, in 2024, the Pharmacy Unit has been upgraded into the Regional Technical Service Unit – Pharmacy Unit (*Unit Pelayanan Teknis Daerah – Instalasi Farmasi*, UPTD-IF) to manage both drugs and vaccines 'under the same roof' ('One Gate Policy');[14] UPTD-IF is responsible for supplying drugs and vaccines to the municipal/city health offices which would continue the supply to the local public health facilities.[6,12] While the UPTD-IF is still in its infancy, consistent evaluation on the logistic processes would be required to optimize its performance in supplying drug/vaccine.

One useful tool for process optimization is the 5M methodology; it is structured around Man, Material, Machine, Method, Money which are designated as the main elements of possible causes of a system failure.[15,16] By examining 5M, one will be able to recognise if a process is not working, analyse the causes, and taking actions for improvements.[16] While the concept of 5M may be well applied for optimising drug or vaccine logistics, no published research is available. This study aimed to perform root-cause analysis (using 5M methodology) and to develop recommendations to optimise drug and vaccine management in the newly developed UPTD-IF, Riau Islands Provincial Health Office. This preliminary study would inform the potential use of 5M methodology to solve logistic problems in other areas in Indonesia as well as international low-resource settings.

MATERIAL AND METHOD

This qualitative research was conducted in Riau Islands Province, Indonesia. The logistic management of public drugs in this area was previously performed by a Pharmacy Unit within Riau Islands Provincial Health Office. Since 2024, the unit has been upgraded to UPTD–IF by adding staff and a pharmacist as Head of the unit (appointed in 2023). This new

unit is intended to include both drugs and vaccines management.[14] This study has received approval from the Research Ethics Committee of Universitas Surabaya (Number 421/KE/VIII/2024), and permission from Riau Islands Provincial Health Office (May 24, 2024).

Data Resources and Collection

Stage 1: Root Cause Analysis of Problems on The Management of Drugs and Vaccines

Interviews with key stakeholders was conducted to understand the current practice of drugs/vaccines management at UPTD-IF Riau Islands. A purposive sampling was conducted by the Head of Riau Islands Provincial Health Office to include key stakeholders responsible for management of drugs/vaccines. Six key stakeholders was selected, including: 1 pharmacist as the Head of UPTD-IF; 1 Head of Distribution and Section; 4 technical staff for drug/vaccine management; and 1 staff responsible for the information system. Face-to-face in-depth interviews were conducted in August, 2024. Before conducting the interviews, a short questionnaire was administered to collect data on their characteristics. The interviews were assisted with a semi-structured guide to allow detailed descriptions of each stage of the management of drugs or vaccines, which included: 1) input, 2) process, and 3) output (Table 1). The input was informed with 5M methodology i.e., Man, Material, Machine (equipment), Method (procedure), Money).[17] When necessary, observations and/or documents were obtained as field notes to complement data from the interviews.[18] A follow-up focus group discussion (1st FGD) with the same key stakeholders (n=6) was conducted at August 16, 2024. 5M methodology was used to provide a structured approach to allow the identification of possible causes.[17]

Stage 2: Developing Recommendations to Optimise Drugs and Vaccines Management

A subsequent FGD (2nd FGD) was conducted at August 29, 2024, with the same key stakeholders (n=6) to discuss the solutions for problems identified in the 1st FGD. This was followed with a hybrid expert panel at September 10, 2024. The panel included: 1 UPTD-IF representative, 1 expert in pharmacy practice, 1 expert in health policy, and 1 expert in public health. The panel process included: 1) primary investigator (ES) presented the problems, underlying causes along with the proposed recommendations; 2) each expert member provided their opinions on the recommendations – i.e., agree or disagree or suggest changes, and discussed to reach group agreements. The Interviews and FGDs were performed at Riau Islands Provincial Health Office using Bahasa Indonesia and were audio-recorded.

Data Analysis

The data analysis first involved preparation and organisation of the data conducted by the primary investigator (ES), which initially involved transcribing the audio tapes followed by familiarisation of the data. Data from the interviews were arranged in chronological order to describe the sequence steps of current drugs/vaccines management (i.e., planning, procurement and receival, storage, distribution, disposal, to documentation). Deductive thematic analysis was used to structure each of the steps into input (based on 5M),[17] process, and output.[18,19] The initial coding was performed manually using 'cut and paste' technique by ES, and was validated by discussion with the research team members (AP, YIW).

Data from the FGDs was analysed thematically. A deductive approach using 5M framework was used to identify possible causes of problems in the drug/vaccine management,[17] while an inductive approach was used to discuss the recommendations. The initial coding was performed manually using 'cut and paste' technique by ES, and was validated by discussion with the research team members (AP, YIW). The recommendations were then confirmed with the expert panel where each expert member provided their opinions on the recommendations – i.e., agree or disagree or suggest changes. Summary of the findings were presented to the participants (i.e., the six key stakeholders) at Riau Islands Provincial Health Office at September 19, 2024 as a means of 'member-checking', thus increasing for the credibility of the data.[19] Characteristics of the respondents were summarised using descriptive statistics.

Table 1. Summary of The Interview Guide

Key Topics	Sub-Questions
Planning	1. Input: identify sources required for planning using 5M – Man, Material, Machine (equipment), Method (procedure), Money 2. Process: explain steps of planning with incorporating 5M 3. Output: performance indicators of planning
Receival	1. Input: identify sources required for reception using 5M – Man, Material, Machine (equipment), Method (procedure), Money 2. Process: explain steps of reception with incorporating 5M 3. Output: performance indicators of reception
Storage	1. Input: identify sources required for storage using 5M – Man, Material, Machine (equipment), Method (procedure), Money 2. Process: explain steps of storage with incorporating 5M 3. Output: performance indicators of storage
Distribution	1. Input: identify sources required for distribution using 5M – Man, Material, Machine (equipment), Method (procedure), Money 2. Process: explain steps of distribution with incorporating 5M 3. Output: performance indicators of distribution
Disposal	1. Input: identify sources required for disposal using 5M – Man, Material, Machine (equipment), Method (procedure), Money 2. Process: explain steps of disposal with incorporating 5M 3. Output: performance indicators of disposal
Documentation	1. Input: identify sources required for documentation using 5M – Man, Material, Machine (equipment), Method (procedure), Money 2. Process: explain steps of documentation with incorporating 5M 3. Output: performance indicators of documentation

Source: Primary Data, 2024

RESULTS

Stage 1: Root Cause Analysis of Problems on The Management of Drugs and Vaccines

Detailed characteristics of the six key stake-holders involved in the interviews and FGDs are presented in Table 2. The current management of drugs and vaccines in UPTD-IF Riau Islands are summarised in Figures 1.

The identified themes on the problems in the management of drugs and vaccines in UPTD-IF Riau Islands covered several stages.

At the planning stage, two main problems were identified by some of the participants (n=4) were: The first problem was that planning was not completed on time and not according to the timeline in Standard Operating Procedure (SOP), as AP02 mentioned:

> "*We need to manage our time to do a range of tasks, so we often can't catch up with the timeline for planning*". The second problem was inaccurate planning for provincial needs, as stated by AP02: "*Some of the drugs planned and received turned out not being used too much – such as 50% remained in the stock. This indicated problem with the planning.*"

During the procurement and receival stage, the main problem indicated by some participants (n=2) was the risk of vaccines being received not in a good condition. As AP04 stated:

> "*We have experienced problems with receiving vaccines which were exposed at the incorrect temperature.*"

Problems related to storage were identified by some participants (n=4), particularly the risk of drugs/vaccine being stored not according to the requirements. AP01 explained:

> "*The storage capacity is quite limited – we have inadequate shelves and pallets, and no electric forklift to help in arranging the pharmaceutical items.*"

In the distribution process, two problems were identified by some participants (n=4). The first problem was that drug/vaccine distribution to municipal or city health offices was not conducted according to the designated time, as stated by KL01:

> *"Limited transportation to some of the islands could be a problem – the transportation to Anambas and Natuna Islands for example is only available on specific days."*

The second problem concerned the risk of damaged vaccines during distribution due to interrupted cold chain, as AP02 mentioned:

"In some cases, the delivery couriers used pickup trucks instead of refrigerated trucks for vaccines, thus risking them exposed to the incorrect temperature."

With regard to disposal, the problem identified by some participants (n=4) was that drugs/vaccines disposal was not completed on schedule. This was reported by AP03:

"It took a longer time to prepare for the disposal (e.g., remove the drug from the original container) as we have inadequate staff… also we use the incinerator at the regional public hospital, so it depends on the available time slot."

For documentation, the problem indicated by some of the participants (n=2) was mismatch between documentation and the real stock of drugs/vaccines at UPTD-IF at the provincial level. As mentioned by AP01:

"The problem is… the data in the national information system or the documents often do not conform with the real stock."

Further, the first FGD explored the underlying causes of the problems using 5M methodology, in which those causes can be categorised into Man, Money, Machine (equipment), and Material. Method was not considered as a cause since SOP have been available for all of the stages, from planning to documentation. Themes related to the problems and the underlying causes (5M) are presented at Table 3.

Table 2. Characteristics of The Participants

Characteristics	n = 6
Gender	
Male	1
Female	5
Age (Range, in Years)	27-46 Years
Education	
Master Degree in Pharmacy and Pharmacist	1
Bachelor Degree in Environmental Health	1
Pharmacist	3
Senior High School	1
Position/Role	
Head of UPTD-IF	1
Technical Staff for Drug/Vaccine Management	4
Staff Responsible for The Information System	1
Working Experience (Range, in Years)	0.5 – 18 Years
Frequency of Prior Training in the Last 12 Months (Range, n)	0 – 12 Times

Source: Primary Data, 2024

Stage 2: Developing Recommendations to Optimise Drug and Vaccine Management

Based on the underlying causes identified at Stage 1, the key stakeholders discussed the proposed solutions during the second FGD, which was followed up with an expert panel (n=4) to reach group consensus. The recommendation concensus is presented in Table 3.

DISCUSSION

This study has provided insights into the use of a structured root cause analysis (5M methodology) to identify and potentially solve problems in the pharmaceutical supply management area. This study indicated the underlying causes of problems in the management of drugs/vaccines in Riau Islands Province, Indonesia, which can be categorised into Man (lack of human resources), Money (inefficient budget management), Machine (lack of infrastructure for storage and cold chain systems; and unintegrated information systems), and Material (mismatched between documentation and the real stock/availability). This structured approach was used to provide directions for developing recommendations, which included improving human resources and budget management, improving infrastructures for storage and cold chain assurance, scheduled distribution, and integrating the internal information system with the national system to improve real-time stock data at the provincial level. Advocating the implementation of these recommendations (followed by evaluation and continuous improvement) would be necessary to ensure quality public drugs/vaccines are available in Riau Islands, thus strengthening the country's health resilience.

Since 2010, the Indonesian government has gradually implemented a 'One Gate Policy' – i.e., a merger between drugs and vaccines units – to facilitate coordination in ensuring accessibility of quality products to the public.[20] While this present study reported a problem with limited staff for most stages in the drug/vaccine management, the recent establishment of UPTD-IF in Riau Islands Province (as a merged pharmacy unit to manage drugs and vaccines) should provide an opportunity for human-resources optimisation; it is recommended that a full work analysis should be done to rationally determine the quantity and quality of human resources required to perform the tasks.

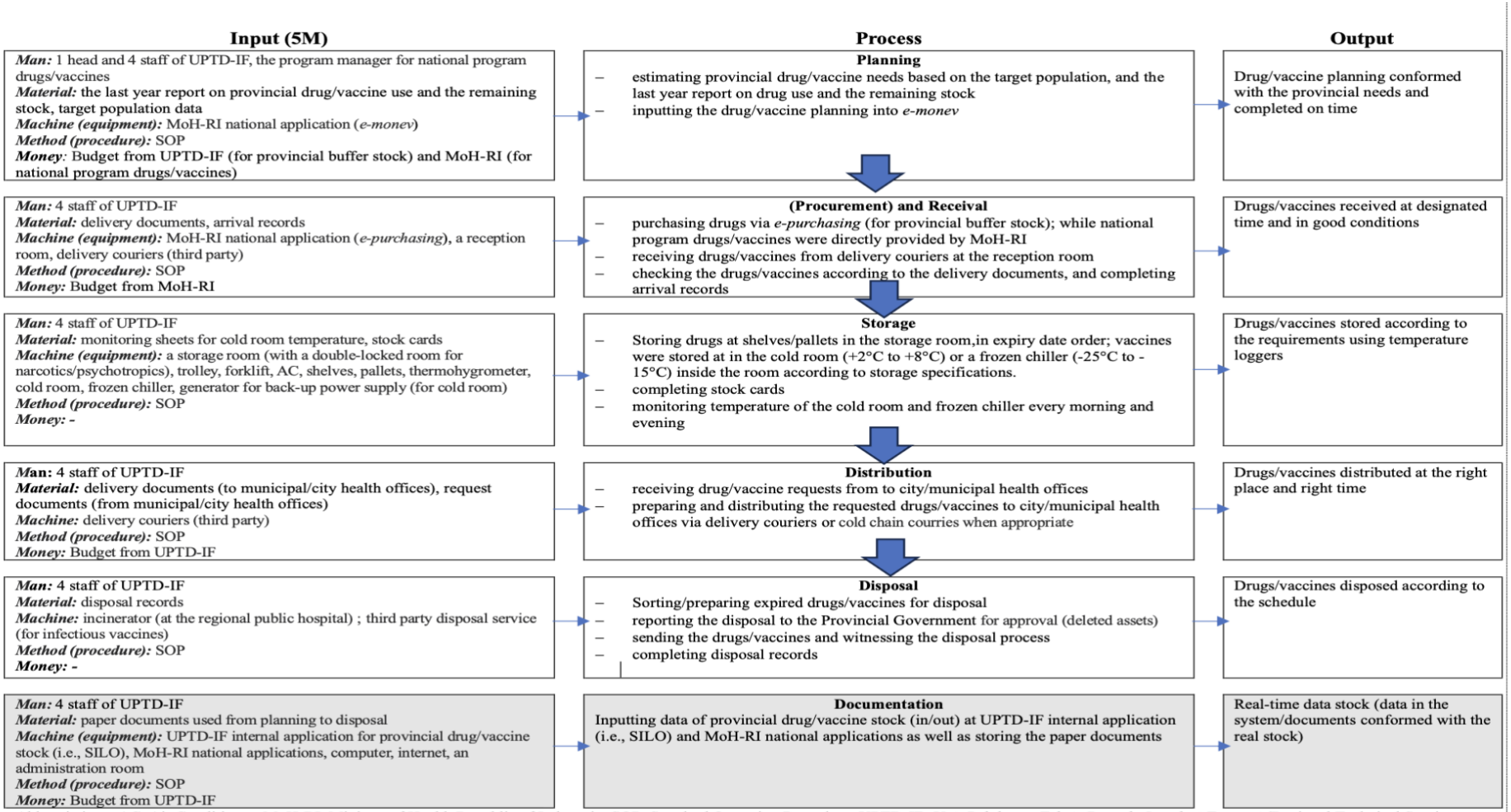
Table 3. Root Cause Analysis (5M Methodology) and Consensus Recommendations to Optimise Drug/Vaccine Management at UPTD-IF Riau Island Provincial Health Office

Stages	Problems	Underlying Causes (5M)	Consensus Recommendation
Planning	Provincial drugs/vaccines planning not completed on time (not according to SOP)	Man: lack of human resources to handle drugs/vaccines management (currently 4 persons while workload analysis suggested 6 persons)*	Conducting work analysis to ensure adequate staff in terms of quantity and quality (i.e., the qualification required to perform a task, such as handling vaccine and cold chain system)*
	Inaccurate planning for provincial drug/vaccine needs	Material: inaccuracy data of drugs/vaccines needs from municipal/city health offices	Working with municipal/city health offices to improve their staff capability in estimating local targets, thus providing accurate input for provincial planning
		Money: limited budget for drugs/vaccines	Improving budget management with making prioritisation in planning (involving planning beneficiaries from local levels), such as using ABC-VEN analysis
Procurement and Receival	Risk of vaccines received not in a good condition (interuppted cold chain)	Machine (equipment): delivery couriers delivering drugs/vaccine not on working hours (e.g. at night)	(refer to **)
Storage	Risk of drugs/vaccine stored not according to the requirements	Man:*	(refer to *)
		Machine (equipment): limited power supplies and risk of power outages; limited shelves/pallets and forklift capacities	Improving infrastructure to increase storage capacity (e.g. additional shelves/pallets, electric forklift), and to enhance cold chain assurance (e.g. backup power supply systems)
Distribution	Costly drugs/vaccine distribution to municipal/city health offices in order to keep with the designated time	Man:*	(refer to *)
		Material: urgent requests from municipal/city health offices (as no buffer stock left), causing problem with *Money:* high distribution costs to municipal/city health offices (islands area). This required cost-sharing with municipal/city health offices, making the distribution process longer	Working with municipal/city health offices for scheduled distribution (e.g., at three-monthly basis). This requires municipal/city health offices to improve their planning, check their stock and submit their supply requests on regular basis. A regular distribution should allow efficiency in the budget for distribution.
		Machine (equipment): limited delivery couriers to some islands (e.g., Natuna dan Anambas Municipalities)	Using qualified delivery couriers to ensure timely distribution
	Risk of damaged vaccines during distribution (interrupted cold chain)	Machine (equipment): lack of qualified cold chain delivery couriers	Enhancing cold chain assurance, including: using qualified cold chain delivery couriers (mandatory) with clear delivery contract**, and improving cold chain temperature monitoring (e.g., using electronic temperature monitoring which is connected to a mobile application/national information system)
Disposal	Drugs/vaccines disposal not completed according to the schedule	Man:*	(refer to *)
		Machine (equipment): limited incenerator capacity, thus the disposal has been carried out bit by bit depending on the available time slot.	Develop regular schedule for disposal (based on the incinerator capacity), and improve system management to reduce requirements for disposal
Documentation	Mismatched between documentation and the real stocks of drugs/vaccines at UPTD-IF (provincial level)	Man:*	(refer to *)
		Machine (equipment): unintegrated information systems between UPTD-IF provincial application (i.e., SILO) and MoH-RI national applications (there are various MoH-RI applications for specific national programs, which are also not integrated to each other)	Integrating the provincial information system to the national system to provide provincial real-time stock data that can be accessed at national level (and discussing with MoH-RI to integrate the various national applications)
		Material: late data entry (i.e., supply requests) by municipal/city health offices in the national applications (requests often informally sent to UPTD-IF via *Whatsapp*); late return of distribution documents/papers from municipal/city health offices to UPTD-IF	Working with municipal/city health offices to improve systems for facilitating timely data entry in the national applications, and returns of distribution documents (e.g., using electronic documents), thus allowing conformity between data in the system, documents, and the real stock in UPTD-IF

Source: Primary Data, 2024

*refer to the same problem/recommendation, **refer to the same recommendation

Abbreviations: MoH-RI, Ministry of Health Republic of Indonesia; SOP, Standard Operating Procedure; UPTD-IF, *Unit Pelaksana Teknis Daerah–Instalasi Farmasi* (Regional Technical Service Unit-Pharmacy Unit)



Abbreviations: AC, Air Conditioner; MoH-RI, Ministry of Health Republic of Indonesia; SOP, Standard Operating Procedure; UPTD-IF, *Unit Pelaksana Teknis Daerah–Instalasi Farmasi* (Regional Technical Service Unit-Pharmacy Unit)

Source: Primary Data, 2024

Figure 1. The Current Practice of Drug/Vaccine Management at UPTD-IF Riau Island Provincial Health Office

Among management elements, Man is the most dynamic and active element, and they are an important asset in an organisation. Work analysis is part of human resources management aiming to "put the right people in the right jobs at the right time".[21] Human resources management includes a series of processes, such as recruitment, training, assessment, motivation, and adjustment of staff (based on review of current staffing, their roles and workload), to bring into play their potential and to ensure the achievement of the organisation's goals.[21,22] The World Health Organization (WHO) states that the quality and efficiency of health services depend on the availability, accessibility, acceptability, and quality of health staff.[22]

Money as a budget is a key lever in organisational planning and management, including in the health sector. Budgeting is the process of resource allocation to produce the best outputs according to the revenue levels involved.[23] While this study reported a problem with limited budgeting, Indonesia's decentralisation policy provides UPTD-IF as a regional pharmacy unit a greater authority in the process of planning and budgeting in the health sector. To ensure budgeting is in line with local health priorities or needs, planners, enactors and executors of budget must be strategically involved in the process.[24,25] Their participation in the budgeting process can enhance their commitment to budget execution.[26,27] Budget performance feedback should be provided to unit managers periodically so that they can timely identify budget variance and modify their settings. It was evidenced that budget participation (followed by budget control and feedback) had the greatest impact on budget performance.[26]

In addition, this present study proposed the integration of the internal UPTD-IF information system into the national MoH-RI national system in order to provide real-time data on the stock or availability of drugs and vaccines in Riau Islands Province. A reliable information system is required in planning and budgeting process to reduce unintentional cognitive bias due to information asymmetry and limited information.[25] Adequate stock information is also essential as this study proposed to implement a scheduled distribution system (i.e., distribution on a regular basis) to the municipal/city health offices; the system should be started with good planning and allow modifications along the way according to the available stocks in the local facilities. The scheduled distribution should minimise the transportation cost to the local facilities, which is particularly important for island areas, such as Riau Islands. Literature data have suggested that Indonesia was in the 46th rank for logistics performance in the world, and maritime transportation remains a difficult challenge in Indonesia as an archipelagic country.[28]

This study also indicated the importance to ensure cold chain in storage and distribution of vaccines from national to local levels. A prior Indonesian study across PHCs (n=517) reported inadequate cold chain systems, particularly related with storage rooms for vaccines (31.5%), temperature control during distribution (thermometer: 54.9%; and freeze-tag and log-tag: 35.4% and 29.5%, respectively).[29] While limited information related to cold chain assurance available on the local levels, this present study indicated problems in finding qualified cold chain delivery couriers to send vaccines to and from UPTD-IF (provincial level), thus increasing the risk of interrupting cold chain system during distribution. In addition to insufficient cold chain infrastructures and delivery couriers, staff's lack of knowledge and professionalism have been reported among the causes of interrupted cold chain systems.[29,30]

Hence, sufficient training and supervision of staff in UPTD-IF in handling vaccine warrants considerations. Poor vaccine and cold-chain management may only be identified when there is an outbreak of an infectious disease, only to find many in the community were vaccinated using sub-standard vaccines. These recommendations can be structured into short, medium, and long-term actions as follows (Table 4).

Table 4. Proposed Short, Medium, and Long-Term Actions

Short-Term Actions	Medium-Term Actions	Long-Term Actions
All stages:		
1. Conduct work analysis to ensure adequate staff in terms of quantity and quality	Training and/or recruiting based on the analysis	Continuing evaluation for the staff's quality and quantity
Planning:		
1. Improve municipality/city health offices' staff capability in estimating local targets to assist with accurate provincial planning 2. Develop prioritization system for budgeting	1. Develop information system to otbain accurate needs at the national level 2. Implementing prioritization system for budgeting	Continuing evaluation of accurate planning and budgeting
Distribution:		
1. Initiate collaboration with potential standardized couriers, especially to enhance cold-chain assurance 2. Develop regular schedule for distribution	Establish network with standarised courier to ensure timely and quality distribution	Continuing evaluation for timely and quality distribution
Storage:		
Improve infrastructure to increase storage capacity and ensure cold chain assurance gradually	Improve infrastructure to increase storage capacity and ensure cold chain assurance gradually	Continuing evaluation to ensure storage according to the standard
Disposal:		
Develop regular schedule for disposal	Monitoring timely disposal	Monitoring timely disposal
Documentation:		
Develop strategies with municipality/city health offices to improve stock data accuracy in the system dan documentation	Develop accurate information system for accurate stock data. at the provincial level	Establish reliable information system at provincial level which can be integrated to the national level

Source: Primary Data, 2024

This study has some limitations. As qualitative data are a product of views, experiences and perceptions of respondents, it can be biased if respondents do not reflect their true responses.[19] However, this research has an exploratory nature (i.e., no right or wrong answers), thus response bias was expected to be minimal. In addition, the use of multiple data sources from observations and or documents (i.e., triangulation) should improve the credibility of the findings.[18] Further, the use of a structured approach (5M methodology) might limit the flexibility to capture the real phenomena, however, all of the themes obtained in this study can be classified into 5M, thus indicating 5M has adequately pictured the phenomenon being studied. Lastly, this study included a small sample size which might limit the generalisability of the findings, however all of the key persons, i.e. staff in UPTD-IF responsible for pharmaceutical management in Riau Islands Provincial Health Office, have been included, and the thick description obtained should present adequate insights on public drugs and vaccines management in some other provinces in Indonesia.

CONCLUSION AND RECOMMENDATION

This study highlighted the underlying causes of problems in the management of drugs or vaccines in Riau Islands Provincial Health Office, Indonesia, which can be categorised into Man, Money, Machine, and Material. This structured approach has guided the development of strategies. The strategies can be structured into short, medium, and long-term actions to achieve optimal quantity and quality human resources, and accurate data for planning/budgeting; to gradually improve infrastructure for storage and distribution, (especially cold chain assurance); and to develop an integrated information system to provide real-time stock data. This can be a model for other areas in Indonesia as well as international low-resource settings to strengthen

health system resilience. Further studies are required to evaluate the adoption of the recommendations and their impacts, thus establishing a continuous cycle in improving the management of public drugs or vaccines.

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AUTHOR CONTRIBUTIONS

Conceived and designed the experiments by APS and BS; ES and IAN performed the experiments; ES and YIW analyzed the data; ES and YIW wrote the manuscript. All authors read and approved the final manuscript. APS = Adji Prayitno Setiadi; BS = Bruce Sunderland; ES = Erwin Sutejo; IAN = Indri Ayu Ningsih; YIW = Yosi Irawati Wibowo.

CONFLICTS OF INTEREST

The authors declare no conflict of interests. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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