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STRENGTHENING IMMUNIZATION SYSTEMS THROUGH EFFECTIVE SUPPLY CHAINS: INSIGHTS FROM GLOBAL EFFECTIVE VACCINE MANAGEMENT INITIATIVE

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ABSTRACT: The Expanded Programme on Immunization (EPI), launched in 1974, is the world's major vaccination program against vaccine preventable diseases. Despite progress, the program's success, measured through coverage rates, has recently stalled, especially in low-income countries where access to vaccines remains challenging. EPI's effectiveness relies heavily on the Immunization Supply Chain, but technological changes and new vaccine introductions have strained these systems, leading to stock-outs and risks due to outdated cold chain equipment. These challenges cause health disparities and undermine immunization coverage, particularly in contexts constrained by resource scarcity. Launched in 2010, Effective Vaccine Management (EVM) initiative addresses some of these concerns by improving and evaluating vaccine supply chain systems at large scale globally. This study, utilizing the EVM 2.0 to analyse data from 57 nations that are in the public domain between 2019 and 2023 using the EVM 2.0 assessment tool, offers an analysis of Immunization Supply Chain. The review shows the composite score of 73 which depicts an average performance overall with strengths in financial, human and managerial resources. However, information technology comes out as a weakness that exposes flaws in maintenance and repair mechanisms. The paper offers recommendations like more budgetary allocations towards IT, better infrastructure, personnel development and knowledge sharing. The limitations of the study include the absence of comprehensive subcategory scores and highlight the necessity of a more detailed analysis for more targeted suggestions for improvement.

INTRODUCTION: Inception of the EPI during 1974 by World Health Organization (WHO) was a milestone in global health that aimed to ensure vaccination for vaccine-preventable diseases such as tuberculosis, diphtheria, pertussis, tetanus, polio, and measles by ensuring widespread immunization estimate [1]. It is estimated that EPI has provided the single greatest contribution to improved infant survival over the past 50 years [2].

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The EPI intended to make immunization universally accessible and currently saving an estimated 3 million lives of children under five each year. While 85% of eligible children receive the three doses of the diphtheria-tetanus-pertussis vaccine (DTP3), coverage has stalled, leaving 19.5 million children still un or under-vaccinated and vulnerable to vaccine-preventable diseases [3].

Over the last two decades, Gavi-supported countries have increased their coverage by over 20% with strong government commitment, international cooperation and assistance. However, this upward trend has flattened in the past ten years creating a critical challenge that is worsened by simultaneous rise of population worldwide [4].

This means that there is a need to review approaches towards overcoming new challenges. Especially, the low-income countries find themselves battling with access issues and lack necessary vaccines in most cases [5]. Considering this, targeted interventions are required to strengthen the EPI to bring about equitable distribution of immunizations among all the population groups.

The success of the EPI has been associated with the adequate supply of vaccines. The efficiency of immunization supply chains determines directly the levels of coverage which is a crucial factor for a successful EPI program [6]. Regular supply of vaccines to targeted groups guarantees that goals set by EPI can be achieved in terms of prevention and control of VPDs worldwide. The backbone for EPI programs is Immunization Supply Chains (ISC) that facilitate vaccine storage, distribution and delivery to different healthcare facilities [7]. A study in one of the South Asian Country highlights that the maintenance of the vaccine cold chain is one of the major challenges in the implementation of the EPI [8]. The expansion of the program increased complexity of the landscape, and introduction of new vaccines have led to significant burden on Immunization Supply Chain systems. The National immunization programs are now aimed at protecting against more than two times as many diseases, using a complete lifecycle approach, administering each person three times as many doses, handling four times greater vaccine volume per fully immunized person, investing six fold on vaccines to fully immunize one person and serving a worldwide population size that has doubled [9].

Immunization programs at all levels of supply chain are under a significant threat posed by pervasive vaccine stockouts. Stockouts arise when demand for vaccines exceeds availability leading to breaks in the immunization schedule. This not only undermines the credibility and effectiveness of immunization programmes but also compromises the health status of individuals by leaving them unguarded from vaccine preventable infections [10]. The incidence of vaccine stockouts is linked to reduced immunization coverage for children in low- and middle-income countries [11]. Vaccine stockouts impact negatively on low-income countries since they face resource constraints and logistical challenges which make it hard for them to sustain adequate stocks of vaccines hence recurrent interruptions occur [12, 13].

Another critical factor contributing to low immunization coverage and inequities is the unequal availability and distribution of vaccine cold chain equipment (CCE), which serves as the foundation of any effective immunization program [14]. The other challenge is that outdated cold chain equipment which poses grave danger to vaccine quality. Outdated technology may interfere with the ability to maintain required temperatures for the vaccines thereby resulting into lowered effectiveness or even spoilage. Since vaccines are highly perishable bio-products, preserving potency and effectiveness requires integrity in maintaining cold chain throughout their storage & transportation till use. Inadequate CCE across health facilities results in inequity in access to vaccines [15]. Having reliable and suitable cold chain equipment (CCE) is crucial to ensuring that the target population, especially those in inaccessible and difficult areas, can receive vaccinations, where coverage can often decline. Effective management of CCE to ensure high quality is equally important to enhance overall efforts [16]. Whereas some well-resourced institutions can properly store and distribute vaccines, others located far away or in underserved regions may lack appropriate infrastructure required for this purpose. By exacerbating disparities between different population segments regarding health disparities; these challenges such as non-functioning/obsolete cold chain equipment and vaccine stock outs further widen gaps in terms of vaccination coverage thereby exposing vulnerable individuals.

Launched in 2010, the EVM initiative [17] is a strategic program aimed at improving performance of immunization supply chains all over the world. The principal aim of this program was to address challenges associated with vaccine supply chain operations and enhance their efficiency in delivering vaccines to those who need them.

The EVM program also introduced an inclusive diagnostic tool used for evaluating immunization supply chain performance. EVM scores provide quantitative information about diverse aspects such

as vaccine storage conditions, distribution practices and overall management of supply chain among others. This is significant because these scores permit countries to identify weak areas that can be improved thereby enabling them effectively allocate resources. Apart from numerical scores, a major focus of the EVM initiative is to build the capacity of health workers involved in the vaccine management. These training programs are an integral part of this initiative, and they ensure that personnel have been equipped with up-to-date skills and knowledge on best practices. In doing so, it has not only contributed towards increasing EVM scores but also improved competence level within staff cadre in general. In 2015, a four-step EVM framework was introduced intending to offer a structured and systematic approach for the continuous improvement of supply chains as well. This four-step blueprint encompasses assessment, planning, implementation and review. The framework also helps the countries to continuously improve their vaccine management systems [18].

REVIEW METHODOLOGY: The methodology for review involved selection of countries based on specific criteria and the availability of EVM scores. The countries are mostly low and low- middle income countries where these assessments were conducted. The analysis sought to provide a comprehensive overview and consolidated scores of immunization supply chains, offering insights into the current state of 57 countries over the period between 2019 and 2023. These countries were selected based on their participation in the EVM program and the availability of the scores in the public domain. The inclusion of these countries allows us to provide a comprehensive overview of the current state of immunization supply chains in a diverse set of nations [19]. The heat map of 57 countries from different WHO Regions was analysed.

TABLE 1: NUMBER OF COUNTRIES WITH EVM SCORES AVAILABLE (2019-2023) [20]

Sr. no.	WHO Region	Number of countries
1	African Region	27
2	Eastern Mediterranean Region	10
3	European Region	4
4	South – East Asia Region	6
5	Western Pacific Region	10
	Total	57

Methodology employed the EVM 2.0 assessment tool, which incorporates thirteen evaluation criteria distributed across six categories. These criteria cover various aspects of vaccine supply chain management, including infrastructure, storage capacity, distribution systems, and overall performance [21]. The thirteen criteria and six categories are as follows [22]:

TABLE 2: THE CRITERIA AND SUB- CRITERIA OF THE EVM 2.0 ASSESSMENT

Code	Criteria	Sub-Criteria
	Facility operations criteria (E1-E9)	
E1	Vaccine arrivals	E1.1 Inspection of shipments, E1.2 Custom clearance & transition facilities, E1.3 Transport from port of entry to primary store
E2	Temperature management	E2.1 Temperature management in storage, E2.2 Temperature management during transportation
E3	Storage and transport capacity	E3.1 Capacity of infrastructure and equipment, E3.2 Utilisation of available capacity
E4	Facility infrastructure and equipment	E4.1 Quality of infrastructure, E4.2 Quality of equipment
E5	Maintenance	E5.1 Maintenance & repair of buildings, E5.2 Maintenance & repair of cold chain equipment, E5.3 Maintenance & repair of vehicles
E6	Stock management	E6.1 Replenishment, E6.2 Receipt and put-away, E6.3 Inventory management, E6.4 Release and dispatch, E6.5 Managing returns, damaged & expired stock
E7	Distribution of vaccines and dry goods	E7.1 Distribution planning, E7.2 Transportation of vaccines
E8	Vaccine management	E8.1 The shake test, E8.2 Use of freeze-dried vaccines, E8.3 Multi-dose vial policy
E9	Waste management	E9.1 Handling of syringes after use, E9.2 Storage of immunisation waste, E9.3 Disposal of immunisation waste
	Facility management criteria (M1-M4)	
M1	Annual needs forecasting	M1.1 Forecasting vaccine needs, M1.2 Forecasting dry goods needs
M2	Annual work planning	M2.1 Preparing an annual work plan, M2.2 Budgeting activities of the plan,

		M2.3 Recording income and expenditure, M2.4 Monitoring the implementation of the annual work plan
M3	Supportive supervision	M3.1 Planning supervision visits, M3.2 Recording supervision visits, M3.3 Providing supportive feedback
M4	ISC performance monitoring	M4.1 Monitoring ISC key performance indicators, M4.2 Reporting ISC performance data, M4.3 Monitoring reporting rates, M4.4 Reviewing ISC performance

TABLE 3: THE CATEGORIES AND SUB- CATEGORIES OF THE EVM 2.0 ASSESSMENT

Code	Category	Sub-categories
C1	Infrastructure	C1.1 Utilities & services, C1.2 Buildings & amenities
C2	Equipment	C2.1 Storage equipment (cold & other storage equipment), C2.2 Transportation equipment (vehicles & Insulated containers), C2.3 Waste management equipment
C3	Information technology	C3.1 General IT equipment (telephone, computers, printers), C3.2 Data management technology (standard data collection forms, software, reporting forms)
C4	Human resources	C4.1 Staffing (availability and quality), C4.2 Training, C4.3 Knowledge & understanding
C5	Policies & procedures	C5.1 Evidence generation (studies, reviews, and assessments), C5.2 Policies/Strategies, C5.3 SOPs/ guidance, C5.4 Contracts
C6	Financial resources	C6.1 Salaries, C6.2 Funds for operations, C6.3 Funds for new equipment, C6.4 Funds for training

Heat map was extracted from the EVM 2.0 assessment website **Fig. 1** and the detailed data analysis was done. The goal here is to provide holistic view regarding immunization supply chains in the chosen context. Vaccine storage facility and distribution systems were assessed together with other components associated with overall supply chain management. This focused on understanding what the strengths or weaknesses are within its immunization infrastructure as well as suggestions for improvement. This composite score which is one major outcome measures how all individual scores assigned by each criterion taken together available from heat map were arrived at by using them. This approach quantitatively measures how well the immunization supply chain works in terms of strengths and weaknesses.

		Infrastructure	Equipment	Information technology	Human resources	Policies & procedures	Financial resources			ALL CATEGORIES
		C1	C2	C3	C4	C5	C6	OUTPUTS	PERFORMANCE	
Vaccine arrivals	E1			78	87	60	93	81		76
Temperature management	E2			70	83	66		60	84	73
Storage and transportation capacity	E3	92	65		93	70	88	78	97	76
Facility infrastructure and equipment	E4	72	77	81			82	78		75
Maintenance and repair	E5			42	83	63	79	62	85	71
Stock management	E6			83	83	74		66	51	72
Distribution of vaccines and dry goods	E7		91	62	70	52	79	76	89	71
Vaccine management	E8				84	72		66		80
Waste management	E9		69		77	61	84	65	89	76
Annual needs forecasting	M1				80	68		82	54	73
Annual work planning	M2				73	58	84	62	58	69
Supportive supervision	M3	98	99	72	81	70	77	63		72
iSC performance monitoring	M4			82	74	66		46		59
ALL CRITERIA		75	74	76	80	65	82	66	77	73

FIG. 1: HEAT MAP DETAILING THE AGGREGATED EVM SCORES OF THE 57 COUNTRIES

Key Findings: The heat map gives an overview on the EVM 2.0 assessment scores out of 57 countries, grouped based on criteria and performance levels. A score of 80 or more points indicates satisfactory

performance while a score ranging between 50-79 is average. Scores below 50 are considered weak.

From the heat map, it is evident that an average composite score of 73 was the result for all the fifty-seven assessed nations regarding their immunization supply chains. Differences in criteria scores across categories indicate strengths and weaknesses throughout the global immunization supply chain. There were no major differences as far as vaccine management is concerned because it has been rated at a standard for instance; its score stood at 80. Besides that, human resources category receives a mark of 80 whereas financial resources section has an assessment value equal to 82. The rest categories and criteria were found average with no signs of poor performance observed in vaccination supplies.

Weakness could be noticed which concerns information technology with respect to maintenance & repair plus output for Immunization Supply Chain performance monitoring.

The following were identified as the strengths:

- Well established systems for cold chain and supportive supervision.
- Sufficient devices for cold chain and supportive supervisions.
- The availability of functional facility infrastructure, equipment inventory management and performance monitoring system across all levels of care.
- Overall strength in human resources across multiple criteria.
- Allocation of adequate financial resources for vaccine arrivals, storage, transportation, infrastructure, equipment, distribution, waste management, and annual work planning.
- Remarkable performance on temperature control; storage capacity; transport; maintenance & repair; distribution; waste disposal.

Average ratings were obtained by the performance in several domains that indicated some areas that need improvement like facility and equipment infrastructure. The need to improve was pointed out with regards to storage, transportation and waste management equipment. Information technology had space for growth particularly in relation to vaccine arrivals, temperature control as well as transportations or vaccines and dry goods under supply chain supervision. Improvements are needed in human resources in terms of vaccine distribution, waste management as well as annual work planning and performance monitoring. There is a need to enhance policies and procedures on all criteria. There is potentiality of improving resource allocation especially on maintenance & repair costs along with vaccine distribution costs.

Recommendations:

Investment in Information Technology (IT): This will involve making use of sophisticated tools for better monitoring and evaluation of immunization supply chain. Countries may choose to invest in existing real time Cold Chain and vaccine stock management inventory systems like:

Cold Chain Equipment Inventory and Gap Analysis Tool (CCEIGAT) [23]: A tool used to prepare an equipment inventory having preloaded vaccine data, PQS equipment data.

Equipment Inventory Gap Analysis Web-Based Tool (IGA) [24]: It is a web-based software for cold chain equipment inventory implementation and maintenance for monitoring capacity gaps at national level as well. This can also be applied to other class of health equipment.

National Cold Chain Management Information System (NCCMIS) [25]: System consists multiple sections; Health Facility which has comprehensive and updatable information, Cold Chain Equipment that provides details on the equipment specifics, and Cold Chain Equipment Breakdown Details with insights into breakdowns, notifications, and repair times developed by MoHFW India UNICEF supported internet application. The system enables timely updates ensuring real time national dashboard as well as allowing for break down analysis & reporting.

Training for Human Resources: Although supply chain managers are present in most nations, they are typically not highly skilled in the field. They also frequently lack the financial control and

authority accountability needed to enhance supply chain performance [26]. Vaccinators play a key role in managing the EPI by ensuring proper vaccine storage, overseeing cold chain management [27].

It is suggested that there should be specific training programmes targeted towards staff involved in annual work planning, waste management, vaccine distribution and performance monitoring. Continual education should focus on meeting skills gaps so that staff can adapt easily with changes in the immunization supply chain [28]. Healthcare workers' knowledge can also be improved by regular supportive supervision which also monitors their practices [29].

Refinement of Facility and Equipment Infrastructure: Improve facilities and equipment infrastructure by concentrating on improvements in storage, transportation, waste management among others. Comprehensive strategies should be put in place to enhance overall facility infrastructure including utility and services, buildings and other facilities.

These can either be in house or outsourced for example the Gambia Ministry of Health outsources fleet management through which it has increased its health program visits by three times, reaching more villages and escalating vaccination coverage by nearly twenty percent [30]. It is also recommended to allocate sufficient funding for non-vaccine costs, such as transportation and fuel as these are critical to minimizing delivery delays and preventing stockouts within the in-country supply chain [31].

Strengthening Policies and Procedures: A complete review and updating of policies and procedures that aligns them with world best practices across all criteria is necessary. Additionally, there is a need to introduce evidence-based studies, reviews, and assessments to inform the development of robust policies and strategies.

Optimization of Financial Resource Allocation: The introduction of newer and expensive vaccines put great burden on already fragile systems. This results in high costs and low performance [32]. Additional financial resources are allocated for maintenance & repair of infrastructure, vaccine distributions, supportive supervisions etc. This also emphasizes priority funding for continuous training initiatives with investments into technology that will strengthen further finance tracking systems.

Collaborative Partnerships and Knowledge Sharing: Encourage Partner Country collaboration on best practices, resource sharing, knowledge dissemination. Establish a focused platform for global collaboration allowing the exchange of common challenges faced as well as successful strategies. Utilizing current global health platforms such as Technet-21 [33] which serves as a hub among the Immunization Supply Chain Experts. Leveraging the support given by International Association of Public Health Logisticians (IAPHL) [34] for knowledge transfer among managers in global health logistics and the People that Deliver [35] network for human resources in health supply chain and logistics can further strengthen these initiatives. There is a need to promote utilization of these platforms.

Limitations:

- The scores accessible on the open forum were limited to criteria and category scores. The detailed information on subcategory/criteria scores was lacking.
- Only aggregated information for the 57 countries was accessible. Individual country-specific details were not provided on the open forum.

CONCLUSION: The EPI, started in 1974, has significantly contributed to combating vaccine-preventable diseases. However, despite commendable progress over the years, the last few years have seen a plateauing effect compounded by COVID-19 related challenges. The EVM 2.0 assessed the immunization supply chain of 57 countries and depicts their nuanced scenario with an overall average performance suggesting identified strengths and disparities. Opportunities for improvement indicate strategic interventions are required here. This implies that information technology will require a significant input from governments to upgrade it whereas this is also important to include some other advancements such as upgrading the training system infrastructural facilities that support IT platforms. Other recommendations include operationalization of policies; optimization of financial resource

allocation; partnership for teamwork and performance needs with a comprehensive approach. However, these recommendations must not be seen as stand-alone initiatives but should instead be seen as part of the overhaul that is needed for effective immunization supply chain management in a holistic way. To achieve safety, adequacy and effectiveness, stakeholders must focus on improving upon these initial difficulties and addressing the immediate deficiencies within national immunizations systems to strengthen the Immunization Supply Chain thus contribution to overall health systems strengthening.

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