Vaccine Supply Chain Management: Implications for Reforming Supply Chain Policy and Practice in Pandemic Times

https://doi.org/10.36369/2616-9045/2022/v11si2a9
Online ISSN: 2616-9045.Print ISSN: 2218-5615

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Abstract

Vaccination is one of the most powerful weapons to prevent and control the outbreak of pandemics. The adoption of a supply chain, anchored on the proponents of the network theory and practice posits with a potential to deliver scale and speed in vaccination effort during pandemics but it's not holistically explored. Based on a literature review, this study proposes the adoption of a holistic approach that involves private actor partnerships and involvement to improve scale and speed of vaccination during pandemic times. The study has also revealed that social actors like religious and community leaders need to be involved in order to support communication that is necessary for reducing misinformation and development of trust for citizens to go ahead and vaccinate. The outcome of the study is important since it provides for an extended framework for vaccine supply chains while providing ways to manage misinformation that tends to fail immunization effort during pandemics.

Keywords: COVID-19, Vaccine, Supply Chain, Network Theory, Vaccine Hesitancy, Herd Immunity

Introduction

Vaccination is one of the most powerful weapons to prevent and control the outbreak of pandemics. The design of vaccine supply chain plays an important role to play in curbing the spread and fatality of infectious diseases (WHO,2019). To vaccinate requires diagnostics, treatment and vaccines as critical public health technologies for emergency preparedness and response (Olliaro & Torreele,2022). In the advent of COVID-19, ensuring the timely development, availability, delivery and use of the vaccines has resonated the need for governments to pay key attention to their supply chain management practices. This is because, overtime time, vaccine supply chain has proved to be as important as in vaccine itself. The COVID-19 outbreak brought shock to the world (Baxter & Casady, 2021) exposing humanity to a socio-economic mystery than ever before (World Health Organization WHO, 2019). Starting in Wuhan, China COVID-19 rapidly spread to the world causing economic, political and social frustration that emanated from the 1st wave of national lockdowns and border closure around March 2020 and the second wave of lockdown that is gaining momentum in the last half of November 2020 (Padiya, 2013; Rahi, Sharma, 2020; Rahi, Das & Sharma, 2020; Wang, Peng, Xu, Cui, & Williams, 2020). In the early phases of the COVID-19 epidemic, the focus was to prevent the spread of COVID 19 (WHO, 2019). The objective of

controlling the spread of COVID-19 was deemed to be achieved with lockdowns, boarder closures, use of sanitizers, isolation and masks was used as measures to prevent the control of the spread (WHO,2019). Like other epidemics, it is noted that the sustainable strategy, however was planned to prevent and control COVID-19 and its intensity was the discovery and ultimate delivery of the vaccine which was deemed as most sustainable solution to curtail the pandemic (WHO, 2019). To realize this effort, recent studies indicate that 105 are under trials, out of which (18) vaccines have been approved for emergency use (Ndwandwe & Wiysonge, 2021). In fact, this was a great development, however achieving herd immunity remains a challenge. From production, allocation, and distribution, constraints continue to manifest. Notwithstanding, existing studies indicate that significant effort has been allocated to discovery (Fauci, 2021; Connors, Graham, Lane & Fauci, 2021), production (Calina, Docea, Petrakis, Egorov, Ishmukhametov, Gabibov & Tsatsakis, 2020) and allocation (Hassan-Smith, Hanif, & Khunti, 2020) yet storage and distribution of vaccines have continued to remain deficient. This calls for the adoption of supply chain paradigm for the successful vaccination that delivers herd immunity.

Supply Chain Management and Vaccination

According to the Chartered Institute of Procurement and Supply (CIPS) (2021), supply chain management is defined as;

> *"Management of the flow of goods, services and suppliers from raw materials to the consumption by the consumer, requiring a network of suppliers that link the supply chain together." (CIPS, 2021).*
>
> *"Typically supply chains consist of stages, namely, upstream, midstream, downstream and reverse stream* " (Lysons & Farrington,2021).

A review of the works of Pamucar, Torkayesh & Biswas (2022), Tseng, Ha, Lim, Wu & Iranmanesh (2022) indicates that supply chain management is about activities that seek to identify customers' needs and managing flows of information, materials, finance, stakeholders aimed at satisfying needs of customers. This view is upheld by Lysons & Farrington (2020), that additionally indicate that supply chain activities must be integrated. As the definition of the supply evolves, today newer definitions advocate for sustainability (de Sousa Jabbour, Jabbour, Hingley, Vilalta-Perdomo, Ramsden & Twigg, 2020), resilience, a balance for just in time and just in case principles (Wei & Xiang, W. (2013), visibility, velocity- shrinking end to end supply chain activity time, flexibility (focusing on newness, options, convenience), stakeholder management, data and insights that define customer overt and silent voices), globalization. While such trends are captured, it is also notable that anchors of the future of supply chain

management will for some time be characterized by themes climate and environment and ICT enablement.

While Min, Zacharia & Smith (2019) contribute to defining supply chain management by identifying factors that shape the design of supply chains. For instance, they argue that channel power has overtime shifted from the organisation to the customers. By implication, customers have a greater edge in determining how they need to be served, channels in which they will be served. Infact, it is asserted that while customers demand for price cuts, they are increasingly demanding for improvements in products and services they consume. This largely influenced by what is termed as the customer journey (Richardson,2010). Lemon & Verhoef (2016:3) opines that a customer service map provides "visual depiction of sequential events through which customers interact in their purchase process". By mapping the customer service journey, managers in this case policy makers can design and deploy touchpoints that deliver customer satisfaction. This notion is emphasized by Rosenbaum, Otalora & Ramírez (2017), Lemon & Verhoest (2016) that opine that touch points create customer experiences, that have now become a key management objective. The success of supply chain and the objective of delivering customer experiences has been attributed to several factors, but quite popular is how data is captured, analyzed data and making optimal decisions, is changing. The definitions and trends associated with supply chain management as an enabler of vaccination that achieves herd immunity (Min, Zacharia & Smith, 2019) provide implications for the vaccine supply chain, namely how to exploit networks, manage and make sense of data and delivery of experiences for citizens in order to improve success of vaccination programs by governments. There has been significant effort dedicated to the study and understanding of practice of health supply chain management in normal and crisis times. Existing literature on vaccine supply chain management has focused on the need for cold storage constraints (Purssell 2015; Ashok, Brison and LeTallec (2017), Lin, Zhao & Lev, 2020), medical staffing constraints (Haidari, Brown, Ferguson, Bancroft, Spiker, Wilcox, Ambikapathy, Sampath, Connor & Lee,2016; Bhatt, Pourmand & Sikka,2018; Bhreasail, Sarkis, Galaitsi, Linkov, Pritcherd, Carluccio & Keisler, Krey & Seiler, 2020), infrastructure such as patient bed scarcity (Baxter & Cassady,2021). Additionally, studies on health supply chain management in normal and crisis times have limited their scope on need to financial and non-financial resources, constraints, diagnostics, treatment and development of vaccines (Forni & Mantovani, 2021;Olliaro *et al.*,2022), constraints to achieving herd immunity (Yamey, Schäferhoff, Hatchett, Pate, Zhao & McDade, 2020), vaccine efficacy, inadequate supplies (Olutuase, Iwu-Jaja, Akuoko, Adewuyi & Khanal ,2022), public private partnerships (Nduhura *et al*,2021; Settumba, *et al.,*2022). What is deficiently researched in the role of the private and social actors like religious and community leaders when managing pandemics for supporting governments efforts to achieve herd immunity targets as soon as possible.

The paper provides a contribution in the context of vaccination using the lens of supply chain management. While studies on vaccine supply chains in vaccination environments they have limitations on aspects such as private actor involvement and management of information flows, yet earlier studies in the outbreak of the pandemic indicate that existing public health infrastructure was overstretched (Baxter *et al*., 2021) and with misinformation delaying vaccination and herd immunity targets (Yamey, Schäferhoff, Hatchett, Pate, Zhao & McDade, 2020). In this paper we focus on how private actors can be involved in vaccination supply chains and how data can be managed to influence improved uptake of vaccines to achieve herd immunity levels in times of pandemics. The study was guided by two research questions, namely;

RQ 1: How can supply chain for vaccination be improved with private actor involvement?

RQ 2: What approaches can be used to improve misinformation?

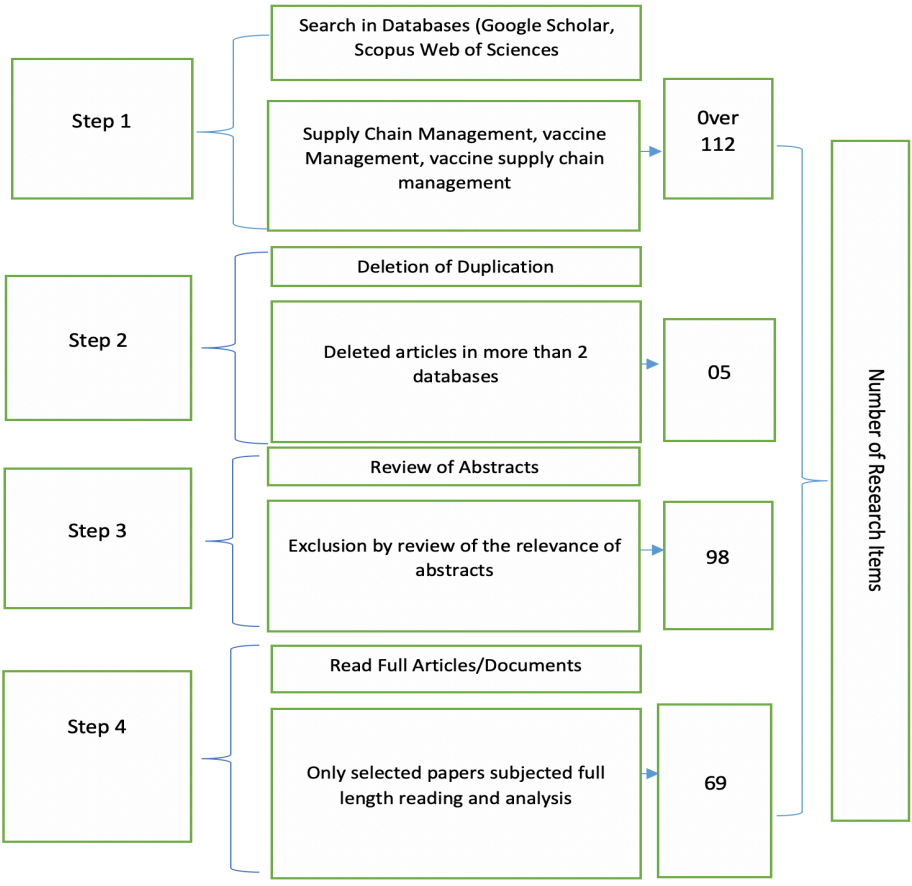
In the next session, we for the methods and methodology that was adopted in this study.

Methodology

The study adopted a systematic review of existing literature on supply chain management and management of pandemics. According to David and Han (2004) a systematic review of existing evidence of secondary data can be a powerful approach in conducting new studies. In the discipline of public health (Smith, 2006; Togun, Kampmann, Stoker &Lipman, 2020; and Hargreaves, Davey, Auerbach, Blancherd, Bond, Bonell, Burgess, Busza, Colboum, Cowan & Doyle, 2020) recommend the need to manage pandemics based on lessons learnt from previous pandemics. Such learning has been made available through publications. Applied to this study, we systematically reviewed existing scholarly literature related to managing pandemic situations, supply chains and COVID-19 to derive a design and functionality of a potential supply chain framework for delivering COVID-19 vaccine to the most vulnerable people across the world. Using this approach, we searched existing databases; Google Scholar, Web of Science and Scopus for articles using catch words supply chain management, then supply chain management in pandemics and vaccines and vaccine supply chain supply chain management. Figure 1 illustrates the proccess we undertook to undertake the review process. This was done using an approach inclusion and elimination criteria adopted by Newbert (2007) that seeks ingredient replicability, transparency and scientific principals into process of identifying, selection and review and synthesis of secondary data reviewed while reducing bias in the study. We used search words

“supply chain management’’, ‘’vaccine management’’, ‘” vaccine supply chain management” then network and knowledge theory. We used the search words since they relate with sought to identify studies done and had similarity with the theme and objective of the study. In stage 3, we then reviewed abstracts to check alignment with the aim of the study. Lastly, and in stage 4, papers and articles that were selected based on their relevance from the review of abstracts for full reads. From the readings, results and discussion are presented. The seventy-eight remaining articles were read in their entirety. We designed data extraction sheets as a template for the full readings of the articles and application of inclusion criteria. They include: details of the publication, aims of the research, research design, definitions of key terms, relevance, whether the article was theoretical or empirical, country of analysis, and results and conclusions. The review consisted of 4 steps, that are described in the figure1 below;

Figure 1: Process for systematic review



The data extraction sheets aided reading, analysis, and synthesis, and also provided an additional quality control stage. The final number of research articles included in the systematic review was sixty-nine (69).

Findings

Context and constraints of vaccine supply chains in developing world

The problem addressed in this paper considers that the government vaccine supply chains are usually constrained during pandemics and require engagement of private actors in vaccine supply chain that is often rare despite the value that the involvement of private actors provide to achieve herd immunity in the shortest time possible in developing countries (Lia,2012; WHO,2019).The study seeks to focus on developing countries, since most studies recognize that developed countries have robust health systems and better vaccine supply chains (Georgiadis & Georgiadis, 2021). Existing studies have indicated that health supply chains in most developing countries have been hardest hit by COVID-19 pandemic (Trump, Golan, Keisler, Cegan, & Linkov; 2022). This fact adds onto existing status, where it is believed that in the context of epidemics and vaccines, developing countries have always lagged (Adepoju, 2021). Coupled with the lack of information on vaccines, their distribution and administration in 2021 (Tavana, Govindan, Nasr, Heidary & Mina ,2021) makes efforts to manage pandemics in developing countries problematic and challenging (Yarlagadda, Patel, Gupta, Bansal, Upadhyay, Shaheen & Jain, (2022). Adepoju (2021) also recognizes budgetary constraints that are somewhat being addressed by the COVAX facility that sought to provide low developing countries in Africa with free vaccines. Earlier studies had also indicated that supply chain systems that should constitute of storage systems have been rated as poor (Lydon, Raubenheimer, Arnot-Krüger & Zaffran, 2015). Consistently, Purssell (2015), Ashok, Brison and LeTallec (2017) argue that developing countries are confronted with severe lack of cold storage facilities required for vaccine logistics. Earlier studied by WHO and UNICEF in sixty-five (65) middle and low income countries found that many countries in the sampled category operated below standard in terms of storage, handling, distribution and management of stocks of vaccines. The challenge is exacerbated with unreliable electricity, resulting into significant obsolescence costs for governments.

The findings indicate last mile herd immunity requires both storage and logistical capabilities in order to achieve herd immunity in the fastest time possible but such capabilities are usually in deficiency (Ameny,2022). For instance, Murhekar, Dutta, Kapoor, Bitragunta, Dodum, Ghosh and Takum (2013) affirms that despite their importance, vaccine supply chains have constantly been constrained by storage facilities, handling and distribution (Lydon et al., 2015). Such and more have made and

continue to cause trouble in the vaccine policy making processes as COVID-19 continued to cause adverse effects on the Africa's economy and lives on the African continent (Nachega, Sam-Agudu, Masekela, van der Zalm, Nsanzimana, Condo & Suleman,2021).

The findings confirm that the vaccine supply chain usually tends to be misaligned with objectives of scale and speed. This is because of several reasons but largely the none use of network thinking and limited collaborative capacity in managing pandemics (Lai 2021) like COVID-19. For instance, vaccine hesitancy not only by health workers but citizens (Dubé, Laberge, Guay, Bramadat, Roy & Bettinger,2013; Paris, Bénézit, Geslin, Polard, Baldeyrou, Turmel & Tattevin,2021). Vaccine hesitancy has been defined as "an indecision around accepting a vaccination" (Jarrett, Wilson, O'Leary, Eckersberger & Larson (2015:4180). In other words, vaccine hesitancy can be construed to imply the unwillingness to vaccinate by individuals.

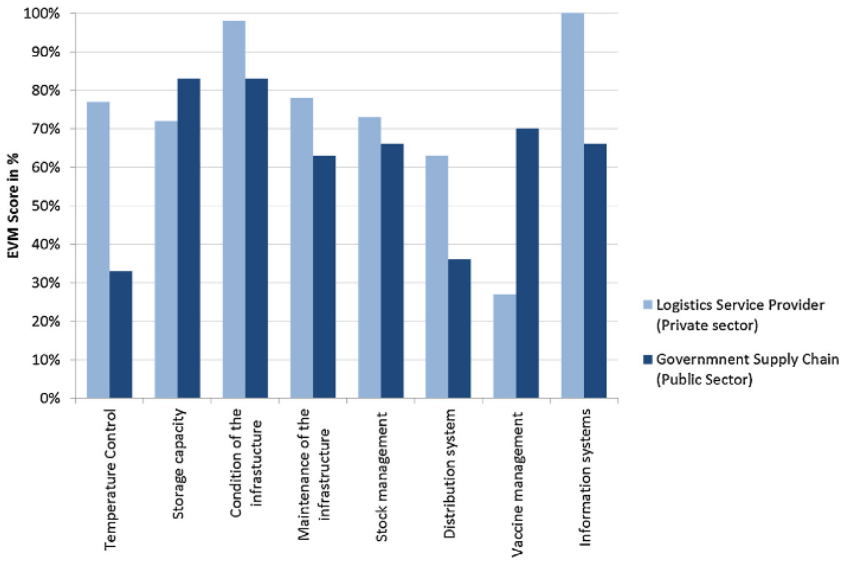
Earlier studies by Dubé et al., (2013), Jarrett et al (2015) consistently assert with recent studies on vaccine hesitancy (Paris *et al.,*2021). Recent studies on vaccine hesitancy indicate that like in previous studies, COVID-19 vaccines are perceived as unsafe and unnecessary by a growing number of health workers and individuals (Paris, *et al.,* 2021). Generally, negative perceptions about vaccines tend to fail efforts to build immunity by governments. This confirms that vaccine hesitancy It is opined that health workers have an important role to play as change agents in vaccine supply chains. For example, in France, it is noted that 63% of nurses while 33% physicians had vaccinated (Jarret *et al.,*2021). The reasons attributed to several reasons, namely; failure to directly target under vaccinated and under vaccinated populations, lack of vaccination knowledge and awareness, inconvenience and lack of access to vaccination (Jarret *et al.,*2015). Other reasons advanced for vaccine hesitancy have been the failure to engage influential leaders (Kodji,2006), for example religious leaders in creating awareness for vaccination (Kondji, 2006)., and lack of tailored effort to meet specific needs of a population that should be vaccinated (Weaver, Smith, LaVela, Wallace, Evans, Hammond & Goldstein,2007). In another study misinformation has been attributed to vaccine hesitancy especially in Africa (Mutombo, Fallah, Munodawafa, Kabel, Houeto, Goronga, & Akanmori,2022). False beliefs that vaccines provide no extra protection cover (Cooper, van Rooyen, & Wiysonge,2021) and make individuals impotent. A study undertaken by Aborode, Fajemisin, Ekwebelem, Tsagkaris, Taiwo, Uwishema & Yunusa (2021) with respondents from 15 countries in Africa, namely, Uganda, Gabon, Cote d'Ivoire, Burkina Faso, Kenya, the Democratic Republic of Congo, Morocco, Ethiopia, Kenya, Malawi, Morocco, Nigeria, Niger, Senegal, South Africa, Sudan, and Tunisia presents interesting findings. In this study (Aborade *et al.,*2021) it reveals that most people have and continue to resist to vaccinate against COVID-19 due to a belief that

Western countries are seek to use vaccines and results in Africa as a means for experimenting the efficacy of COVID-19 vaccines. In another study in South Africa, Acheampong, Akorsikumah, Osae-Kwapong, Khalid, Appiah & Amuasi (2021) reveal that most South Africans were unwilling to vaccinate due to firstly religious beliefs and feeling that calls to vaccinate were associated with tracking and surveillance of persons while in Zimbabwe, participants were unsure on why they would need to take the COVID-19 vaccine. Yet a randomized study by Ssanyu, Kiguba, Olum, Kiguli & Kitutu (2022) in Uganda, validates misinformation as a major contributor of vaccine hesitancy. Another study in Uganda indicates that the lack of trust in public health systems and post vaccination effects were responsible for up to 40% vaccinate hesitancy rate in a randomized study in Northern Uganda (Oloya, Baguma, Okot, Alema, Acullu, Ochula & Kitara,2022). It was also revealed that religious beliefs and use of religious leaders for promoting vaccination effort is an important acts of reducing vaccination effort. For instance, in the study by Oloya *et al* (2022) findings indicate that when the Archbishop in a Catholic dominated region communicated the need to vaccinate most Catholics that vaccinated yet government messages had not yielded much. It was also revealed that Muslims did not belief in vaccination as their belief was the vaccine was manufactured and did not evolve naturally. Therefore, based on these findings the paper recommends that governments engage religious and influential leaders of society, as critical actors of vaccine supply chain to champion vaccination efforts. Customized messages in local languages and communication channels like radios, television, personal selling of the need to vaccinate is also important to persons that do not believe that COVID-19 emerged as part of natural evolution. In addition, findings from South Africa have revealed that vaccination may be construed as a means a track and surveillance mechanism, therefore there is need communicate the purpose of the vaccination campaign and perhaps use vaccination as a part of amnesty campaigns to forgive criminals in hiding that come up to vaccinate. By use of a tradeoff vaccinate for amnesty, perhaps citizens in hiding can be convinced that vaccination programs seek to target the purpose of having a safe and health population rather than an act of tracking and surveillance.

On matters of trust, the study has revealed that most citizens in have overtime lost trust in their governments. Therefore, the development of partnerships with private for profit and nonprofit actors in the vaccine supply chain is recommended. The engagement of private actors is recommended on several fronts. Firstly, Baxter *et al* (2021) reveals that government infrastructure was overstretched. Secondly the network theory posits that actors in networks must work together to complement each other's efforts into to achieve independent objectives together in such case herd immunity. Thirdly, in some cases private actors have outperformed public sector entities in delivering of public services. The involvement of the private sector actors

in service delivery has been critiqued on grounds that co-delivered projects are rarely successful (Leigland,2020). Despite the critique, recent studies acknowledge the successes and value that private sector actors provide in service delivery and thus champion the need to engage the private sector actor in service delivery (Nduhura *et al.,*2020). In the education sector a privately owned university Harvard has continued to be number 1 best university in the world beating the state owned universities across the world. In the health sector too, while it has been traditionally known in some countries that public health care facilities perform better, evidence also reveals that in some cases private sector facilities have outperformed public health care facilities. Based on an empirical study in Western Cape in South Africa. Lydon, Raubenheimer, Arnot-Krüger & Zaffran, 2015) opine that by engaging the private sector actors in the vaccine supply chain, the public sector can benefit from various aspects of effective vaccine management as laid out in the World Health Organisation framework for standardizing vaccine management.

Figure 2: Comparative analysis of private and public sector on effective vaccine management



Key: EVM= Effective vaccine management evaluation
Source: Lydon, Raubenheimer, Arnot-Krüger & Zaffran (2015)

In Figure 2, it is revealed that by engaging supply chain network players such as private sector actors in the vaccine supply chain, the public sector can benefit from better temperature controls as the private sector players may possess better and well-maintained cold chain infrastructure (Lin, Zhao & Lev, 2020). It is also revealed that

on a larger scale, the public sector would benefit from better and robust information systems among other benefits such as stock management, better distribution systems. While the private sector can do well on other aspects, the study by (Lydon et al, 2015) suggest that usually, the private sector may not do well on aspects such as storage capacity and generally vaccine management than the public sector. The analysis points to areas where the private sector can do best, for instance infrastructure, information management, distribution systems, temperature control and generally quality infrastructure. However, workflows must be transparent to avoid. To ensure that this is achieved, the route flows of the vaccine with the engagement of private actors is important (Reiter, 2017; and Roberts, 2020). Therefore, a framework for engaging private actors in the vaccine supply chain processes is important.

Frameworks for engaging private actors in vaccine supply chains

Experience from COVID-19 outbreaks has revealed that government alone cannot manage pandemics not even in 1st World economies like Singapore (Kim, Goh, & Kang (2022. According to Kim, *et al.,* (2022) the reliance on government organisations in Singapore seemed insufficient as spikes when up for transmissions and as hospitalization cases surged. The collaboration with private actors under the whole of society approach, governments engaged private clinics and hospitals to provide both material and financial support, for example in areas such as helping patients with swab test, medications, vaccines and developing capacity of health works through the provision of professional training health workers. Additionally, experience from Singapore indicates that the scope of engagement of private actors could include the transfer of medically stable COVID-19 patients to private hospitals for continued recovery. Notably private actors have a potential to more patients and provide enhanced medical support within a short time as demand for health care services sores up (Bown & Bollyky ,2022). Olliaro & Torreele (2022) also notes that access to vaccines in the developing world, was hindered by transport, storage and geographical constraints. Infact it is argued that the cited constraints were made severe by the lack of transport vessels and storage facilities. Additionally, it is asserted that existing facilities lacked sufficient temperature and refrigeration as reach in some location is becomes characterized by unstable areas and high altitudes (Yarlagadda *et al*.,2022). There is evidence that private actors have been involved in supporting governments to enhance their capabilities across several areas in the vaccine supply chains (Lydon *et al.,*2015). Infact, Bown et al., (2022) assert that private sector actors have a potential to be involved in the vaccine supply chains. Citing the initial four (4) vaccines; Pfizer. Moderna. AstraZeneca. Johnson & Johnson, (Bown *et al* (2022) recognize the effort of public and private actor firms to produce the much needed vaccines.

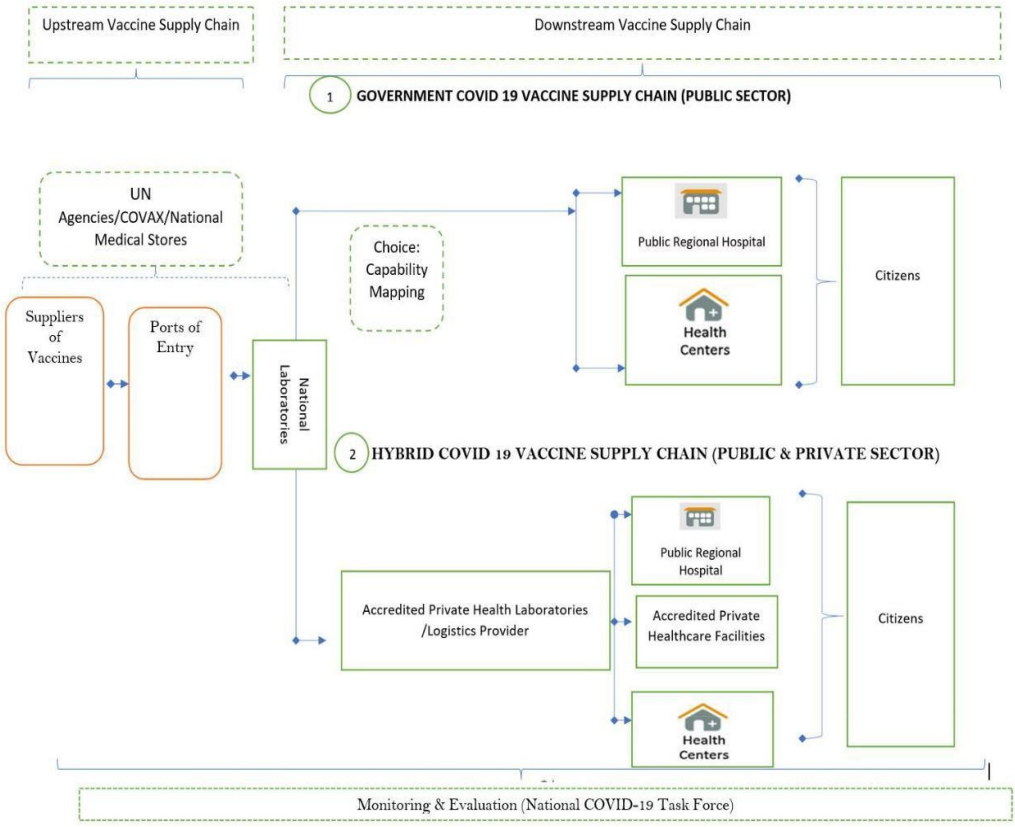
Similarly, DHL (a private logistics firm) is also acknowledged to have played a major role in supporting the logistics part of delivery of vaccines across the world (Sinha, Noor & Kumar, 2022). Infact DHL is recognized for investing in additional capabilities to track and trace products including vaccines. By providing such capabilities, governments are able to know where their vaccines have reached, when they reach and where they are at any one time. This enables governments to plan for their ultimate deliveries to their stores and ultimately to their citizens.

Consistently and based on experience in managing the supply chain in pandemic times, (Kaufmann *et al.,*2011) recommends for the need for governments to engage private actors in the vaccine supply chain. By involving private actors, the governments are opined to then be in position enhance public sector capacity. To illustrate this, Kaufman *et al* (2011) uses the adage of Coke Cola that presupposes that you will always find coke in every village but not necessarily drugs or equipment (Kaufmann et al.,2011). The adage recognizes that recognize private actors possess capacity that can be tapped to improve distribution and infrastructure across the entire vaccine supply chain. Other recommendations for effective vaccine supply chain management have included retraining of healthcare staff for dynamic health care approaches implemented during times of pandemics.

There is need to the private sector both private for-profit actors such as DHL, UPS and private not for profit such as faith-based organizations and hospitals and other actors to complement the existing capabilities of the public sector in delivering the vaccines, citizen engagement and undertaking immunization in the country. Experience has shown that when the private actors are involved access and time compression (Kauffman *et al,*2011) for vaccination efforts are achieved.

While traditional supply chain flow frameworks have been adopted to manage pandemics, we add to the literature of managing pandemics by providing an extension to a framework proposed by Rahi, Das &Sharma ,2020). The rationale of the extensions is based on the limited infrastructural capacity of the government. In the framework, we advocate for increased private sector participation in the supply chain journey that aims at delivering COVID-19 vaccines at speed.

Figure 3: Proposed supply chain framework for delivering COVID-19 vaccine



Source: Rahi, Das &Sharma (2020) with modifications by author.

In Figure 3, the analysis indicates that managing pandemics requires building on existing wisdom. Based on the proposition, we extend the framework to include the need for capacity mapping of potential partners in managing the pandemic. We acknowledge that vaccine supply chains constitute two tiers as earlier proposed by Rahi, *et al* (2020). In tier 1, also highlighted as the "Government COVID-19 vaccine supply chain -Public Sector)" that we refer to as the upstream vaccine supply chain. This involves activities, flows of finance, people, vaccines, information, and vaccines from the point of manufacture of vaccines to ports of entry and at times may extend to national medical stores or laboratories. The vaccines would then be distributed to public hospitals and health centres to ultimately vaccinate citizens respectively.

In Tier 2 (Hybrid COVID-19 vaccine supply chain- involves both private and public sector health facilities), we refer to the vaccine supply chain as the downstream vaccine supply chain that involves activities and activities associated with the delivery of vaccines from either port of entry such as airports, seaports. In this tier, once the vaccines arrive, they will be stored in both private/public accredited laboratories. From the laboratories, the vaccines will be distributed through route to beneficiary channels such as public hospitals and health centres that would then deliver vaccines to citizens as beneficiaries.

Rahi *et al* (2020) recommend a seemingly linear downstream that does not advocate for private sector participation. While this traditional supply chain approach was ideal for earlier pandemics, the approach may not manage the COVID-19 pandemic that has overstretched existing healthcare infrastructure and capacity. Added pressure on public health facilities thus creating a rationale for engagement of private sector actors in the delivery of COVID-19 interventions. While Rahi *et al* (2020) do not recognize the role of private sector participation, the outcome of their study suggests that the COVID-19 vaccination window may be short. This situation, therefore, justifies the need for additional capacity to save lives. Capacity can be enhanced by increasing the role of private sector engagement beyond testing and production of vaccines to include; intensive care unit, outpatient reach services, management of mortuaries alongside traditional engagement routes.

While the vaccine requires cold chain requirements such as temperature-controlled environments as cold as -8 degrees, technology solutions such as drone technology for delivery of vaccines, blood and boosting capacities where medical workers have been slim on the ground (Haidari, Brown, Ferguson, Bancroft, Spiker, Wilcox, Ambikapathy, Sampath, Connor & Lee,2016;Bhatt, Pourmand & Sikka,2018;Bhreasail, Sarkis, Galaitsi, Linkov, Pritcherd, Carluccio & Keisler, Krey & Seiler, 2020).Despite the character of this uniqueness, custom made rather than off-shelf solutions should be developed and procured to serve the unique requirements for the delivery of COVID-19 vaccines across the world.

Misinformation, COVID-19 Vaccination and Herd Immunity

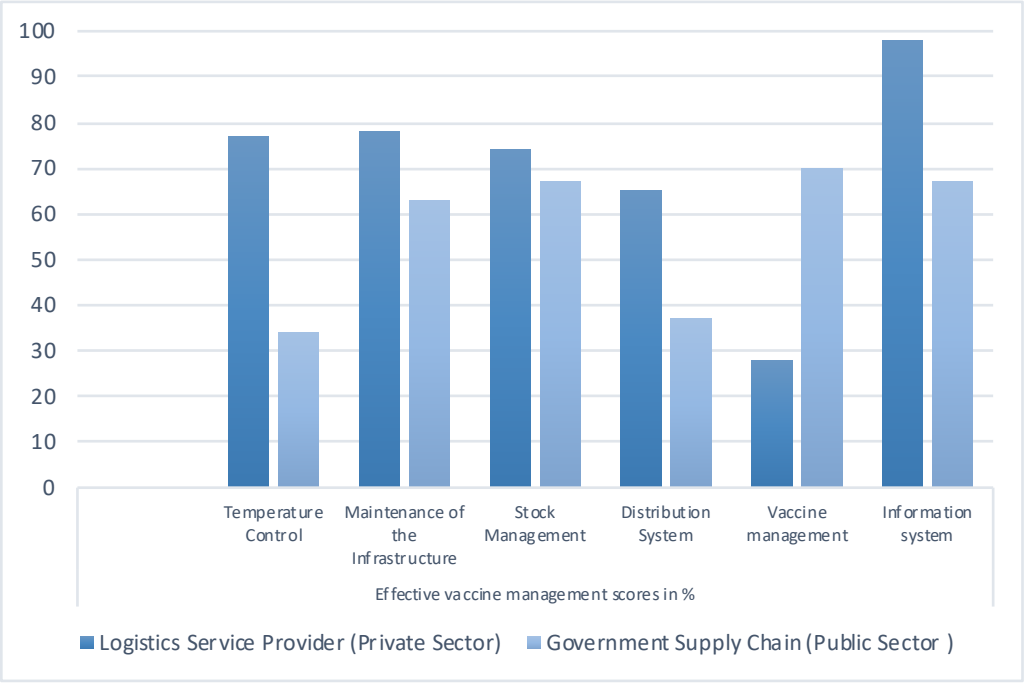
The findings confirm that the vaccine supply chain usually tends to be misaligned with objectives of scale and speed. This is because of several reasons but largely the none use of network thinking. For instance, vaccine hesitancy not only by health workers but citizens (Dubé, Laberge, Guay, Bramadat, Roy & Bettinger,2013; Paris, et al.,2021). Vaccine hesitancy has been defined as “an indecision around accepting a vaccination” (Jarrett et al., (2015:4180). In other words, vaccine hesitancy can be construed to imply the unwillingness to vaccinate by individuals.

The review indicates that earlier studies by Dubé, Laberge, Guay, Bramadat, Roy & Bettinger (2013), Jarrett, et al.,(2015) consistently assert with recent studies on vaccine hesitancy (Paris *et al.,*2021). Recent studies on vaccine hesitancy indicate that like in previous studies, COVID-19 vaccines are perceived as unsafe and unnecessary by a growing number of health workers and individuals (Paris, *et al.,* 2021). Generally, negative perceptions about vaccines tend to fail efforts to build immunity by governments. This confirms that vaccine hesitancy It is opined that health workers have an important role to play as change agents in vaccine supply chains. For example, in France, it is noted that 63% of nurses while 33% physicians had vaccinated (Jarret *et al.,*2021). The reasons attributed to several reasons, namely; failure to directly target under vaccinated and under vaccinated populations, lack of vaccination knowledge and awareness, inconvenience and lack of access to vaccination (Jarret *et al.,*2015). Other reasons advanced for vaccine hesitancy have been the failure to engage influential leaders (Kodji,2006), for example religious leaders in creating awareness for vaccination (Kondji, 2006)., and lack of tailored effort to meet specific needs of a population that should be vaccinated (Weaver, et al.,2007). In another study misinformation has been attributed to vaccine hesitancy especially in Africa (Mutombo, et al.,,2022). False beliefs that vaccines provide no extra protection cover (Cooper et al.,2021) and make individuals impotent. A study undertaken by Aborode, Fajemisin, E Ekwebelem, Tsagkaris, Taiwo, Uwishema & Yunusa (2021) with respondents from 15countries in Africa, namely, Uganda, Gabon, Cote d'Ivoire, Burkina Faso, Kenya, the Democratic Republic of Congo, Morocco, Ethiopia, Kenya, Malawi, Morocco, Nigeria, Niger, Senegal, South Africa, Sudan, and Tunisia presents interesting findings. In this study (Aborade *et al.,*2021) it reveals that most people have and continue to resist to vaccinate against COVID-19 due to a belief that Western countries are seek to use vaccines and results in Africa as a means for experimenting the efficacy of COVID-19 vaccines. In another study in South Africa, Acheampong et al (2021) reveal that most South Africans were unwilling to vaccinate due to firstly religious beliefs and feeling that calls to vaccinate were associated with tracking and surveillance of persons while in Zimbabwe, participants were unsure on why they would need to take the COVID-19 vaccine. Yet a randomized study by Ssanyu, Kiguba, Olum, Kiguli & Kitutu (2022) in Uganda, validates misinformation as a major contributor of vaccine hesitancy. Another study in Uganda indicates that the lack of trust in public health systems and post vaccination effects were responsible for up to 40% vaccinate hesitancy rate in a randomized study in Northern Uganda (Oloya et al.,2022). It was also revealed that religious beliefs and use of religious leaders for promoting vaccination effort is an important acts of reducing vaccination effort. For instance, in the study by Oloya *et al* (2022) findings indicate that when the Archbishop in a Catholic dominated region communicated the need to vaccinate most Catholics that vaccinated yet government messages had not yielded much. It was also

revealed that Muslims did not belief in vaccination as their belief was the vaccine was manufactured and did not evolve naturally. Therefore, based on these findings the paper recommends that governments engage religious and influential leaders of society, as critical actors of vaccine supply chain to champion vaccination efforts. Customized messages in local languages and communication channels like radios, television, personal selling of the need to vaccinate is also important to persons that do not believe that COVID-19 emerged as part of natural evolution. In addition, findings from South Africa have revealed that vaccination may be construed as a means a track and surveillance mechanism, therefore there is need communicate the purpose of the vaccination campaign and perhaps use vaccination as a part of amnesty campaigns to forgive criminals in hiding that come up to vaccinate. By use of a tradeoff vaccinate for amnesty, perhaps citizens in hiding can be convinced that vaccination programs seek to target the purpose of having a safe and health population rather than an act of tracking and surveillance.

On matters of trust, the study has revealed that most citizens in have overtime lost trust in their governments. Therefore, the development of partnerships with private for profit and nonprofit actors in the vaccine supply chain is recommended. The engagement of private actors is recommended on several fronts. Firstly, Baxter et al (2021) reveals that government infrastructure was overstretched. Secondly the network theory posits that actors in networks must work together to complement each other's efforts into to achieve independent objectives together in such case herd immunity. Thirdly, in some cases private actors have outperformed public sector entities in delivering of public services. The involvement of the private sector actors in service delivery has been critiqued on grounds that co-delivered projects are rarely successful (Leigland,2020). Despite the critique, recent studies acknowledge the successes and value that private sector actors provide in service delivery and thus champion the need to engage the private sector actor in service delivery (Nduhura et al.,2020). In the education sector a privately owned university Harvard has continued to be number 1 best university in the world beating the state owned universities across the world. In the health sector too, while it has been traditionally known in some countries that public health care facilities perform better, evidence also reveals that in some cases private sector facilities have outperformed public health care facilities. Based on an empirical study in Western Cape in South Africa. Lydon, et al., 2015) opine that by engaging the private sector actors in the vaccine supply chain, the public sector can benefit from various aspects of effective vaccine management as laid out in the World Health Organisation framework for standardizing vaccine management.

Figure 4: Comparative analysis of private and public sector on effective vaccine management



Source: (Lydon, Raubenheimer, Arnot-Krüger & Zaffran, 2015)

In Figure 4, it is revealed that by engaging supply chain network players such as private sector actors in the vaccine supply chain, the public sector can benefit from better temperature controls as the private sector players may possess better and well-maintained cold chain infrastructure. It is also revealed that on a larger scale, the public sector would benefit from better and robust information systems among other benefits such as stock management, better distribution systems. While the private sector can do well on other aspects, the study by (Lydon et al, 2015) suggest that usually, the private sector may not do well on aspects such as storage capacity and generally vaccine management than the public sector. The analysis points to areas where the private sector can do best, for instance infrastructure, information management, distribution systems, temperature control and generally quality infrastructure. However, workflows must be transparent to avoid. To ensure that this is achieved, the route flows of the vaccine with the engagement of private actors is important (Reiter, 2017; and Roberts, 2020). Therefore, a framework for engaging private actors in the vaccine supply chain processes is important.

Conclusion and Recommendations

The study has revealed learning from experience lays a foundation to build new interventions in times of crisis shifting focus from resilience by design to resilience by adaptation. The study has shown that networked stakeholders such as private and social sector are important. Private actors can help to enhance capabilities in terms of infrastructure and services provided to the public. Additionally, it is noted that the panic that came along with the COVID-19 pandemic and vaccination effort and the pace for achieving herd immunity was and remains slow. Underlying the rapid efforts to discover COVID-19 and vaccinate citizens was confronted by lack of trust that had either existed or been escalated by a speedy nature of the requirement for citizens to be vaccinated causing deeper mistrust of governments among their citizens. This gave to anti COVID-19 vaccination saboteurs, that designed and spread only bad news on the effects, yet it is widely known that immunization comes up with temporarily effects that disappear gradually after immunization. Escalating fear, negative communication of effects of immunization resulted into such mistrust created tension resulting into public both overt and opaque revolts from global health statistics (WHO,2022). When social actors like religious and community leaders where involved their witnessed increase and willing to immunize with COVID-19 vaccines.

Therefore, this study concludes firstly that engagement of private actors, social actors like religious and community leaders. Secondly government communication is considered to be very critical but requires partnerships with social actors like religious and community to develop trust that is necessary for uptake of vaccination. Additionally, there is need to use communication strategy that helps people get the message quicker and impact. For example, the use of skits, audio visual messages. Customization of messages including the use of role play is recommended. Additionally, the use of peer based communication strategy is important. Lastly building on lessons learnt will help to continuously improve vaccine supply chains and reduce vaccine hesitancy in future where it is predicted that the next pandemic will be more daunting.

Building on lessons learnt will help o continuously improve vaccine supply chains and reduce vaccine hesitancy in future where it is predicted that the next pandemic will be more daunting.

Declaration of Conflicts of Interest

The author(s) declare that there are no conflicts of interest that relate to the research, authorship or publication of this article.

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