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Examining Risk of COVID-19 Vaccine Distribution on Last-mile Delivery: a DEMATEL-based ANP Approach

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Abstract: The Indonesian government's decisive reaction to combat COVID-19, especially in vaccine distribution, is challenged by the system's complexity and various vaccine types. Cold chain management is essential for ensuring vaccines quality during last-mile delivery. This study employs the Decision-Making Evaluation and Laboratory (DEMATEL) based Analytical Network Process (ANP) to assess risk priorities in last-mile vaccine delivery by identifying three-dimensional risks: material handling, facilities, infrastructure, and coordination. Results indicate that material handling carries the most significant weight among these risks. Therefore, policymakers are advised to focus on mitigating risks associated with facilities and infrastructure to safeguard material handling.

Keywords: Vaccine last-mile delivery; Cold chain management; COVID-19; DEMATEL-based ANP; risk analysis

1. Introduction

COVID-19, or Coronavirus Disease, is defined as an infectious disease caused by a new coronavirus named SARS-CoV-2[1)]. One of the efforts to prevent infectious diseases caused by viral attacks is a vaccine. The advantage is that vaccines can actively stimulate the formation of a person's immunity and specifically help develop herd immunity. In line with these efforts, the Indonesian government has taken action based on Presidential Regulation No. 99 of 2020 concerning the Procurement of Vaccines and Implementation of Vaccinations in the Context of Coping with the COVID-19 pandemic[2)]. The regulation mentioned that the government will prepare for vaccine procurement, distribution, and implementation.

As a result, COVID-19 cases are already extremely low in 2023. This can be seen from the number of active COVID-19 cases of only 12,488 on June 1, 2023, or 0.2% of the total national COVID-19 positive cases[3)]. Along with efforts to reduce the number of active cases, the Indonesian government continues to vaccinate for boosters, with the number of 3rd vaccination recipients totaling 68,851,060 as of June 1, 2023, or 29.3% of the national vaccination target[3)]. COVID-19 booster vaccinations are necessary for restoring protection because of decreasing immunity and the appearance of novel SARS-CoV-2 variants[4)]. Therefore, vaccine distribution must continue to be carried out to prevent the worst-case scenario.

Handling vaccine distribution is crucial in maximizing the benefits of vaccination while mitigating other possible risks. This is because vaccines are very susceptible to damage and thermolabile. If not handled properly, it can result in vaccine damage, causing the potential of loss and irreparable[5)].

Handling of vaccine products commonly relies on cold chain management. A cold chain system is needed in the vaccine supply chain that requires control of the temperature and humidity of the vaccine from the production process to the vaccine to the patient. The vaccine cold chain is a temperature-controlled environment used to maintain and distribute vaccines under optimal conditions[6)].

In preparation for the vaccine cold chain, it is essential to map logistics requirements and identify potential bottlenecks along the supply chain, including at last-mile delivery[7)]. Last-mile delivery, in this case, is the distribution of vaccines to healthcare facilities such as health centers, clinics, and hospitals, as well as from hospitals/public health centers to subhealth centers, integrated healthcare centers, or local midwives (Fig. 1). The distribution of vaccines to health facilities and midwives typically involves the use of cold boxes or vaccine carriers. The mode of transportation varies depending on the geographical conditions and infrastructure of each region[8)].

	DESTINATION	TRANSPORTATION FACILITIES	STORAGE FACILITIES	INFORMATION
	Soekarno Hatta Airport	Enter **Envirotainer** transported by **airplane**	Refrigerated vehicle/aircraft	Vaccines arrive from the country of origin
	Biofarma	**Envirotainer** is transported by specially **refrigerated truck/airplane**	Cold room	Biopharma Center is located in Bandung
	Provincial Health Office	Enter the **cold box** transported by **special refrigerated vehicle / aircraft**	Cold room, vaccine refrigerator, freezer	Delivered from the Center/Biofarm
	District/City Health Office	Enter the **cold box/vaccine carrier** containing **cool packs** and transported by **special refrigerated vehicle, official car**	Cold room, vaccine refrigerator, freezer	The province delivers to the district/city or the district/city picks up from the province
	Primary Health Center / Government / Private Hospital	Enter the **cold box/vaccine carrier** containing the **cool pack** transported by **box car/ambulance/motorcycle/pioneer ship/helicopter**	Vaccine refrigerator, chiller, freezer	The Regency/City delivers to the Puskesmas or the Puskesmas picks up from the Regency/City
	Auxiliary Health Center / Midwife / Clinic / Posyandu	Enter the **cold box/vaccine carrier** containing the **cool pack** transported by **car or motorbike**	Chiller, freezer	The Puskesmas delivers to the posyandu or the posyandu picks up from the puskesmas

Fig. 1: COVID-19 Vaccine Distribution Flow (Adopted from[9)]).

The Decree of the Director General of Disease Prevention and Control HK.02.02/4/1/2021 from the Ministry of Health of the Republic of Indonesia, regarding technical guidelines for the implementation of vaccinations in the context of combating COVID-19, mentioned that Indonesia, as an archipelagic country has many small islands with minimal access caused complexion on the distribution network. In addition, the diversity of types of COVID-19 vaccines with different temperature requirements, massive distribution in a fast period, and the number of 180 million targets are new challenges for the Government of Indonesia[9)]. Therefore, more than just a guide is needed to manage the COVID-19 vaccine cold chain.

Several studies have examined the risks in the last mile of vaccine distribution. Several works have discussed problems in cold chain management in Indonesia[5,10)]. Meanwhile, experts were able to understand the risk factors for COVID-19 vaccine distribution based on conditions in the field[11)]. However, discussions on identifying and prioritizing COVID-19 vaccine distribution risks on last-mile delivery are still limited. Still, this analysis is essential to avoid decision-making mistakes that could affect the number of COVID-19 cases in Indonesia. The resulting decision will also help the Indonesian government to be better prepared in the event of a pandemic with a high risk of vaccine distribution. This study aims to identify and prioritize risks to determine which ones require the most attention so policymakers can formulate prevention and response strategies, especially in last-mile delivery. DEMATEL-based ANP (DANP), the MCDM tool that can be utilized to prioritize risks and gain a better understanding of their interrelationships, will be used in this study.

2. Theoretical review

COVID-19 vaccine management has been regulated, starting with vaccine storage, temperature monitoring, and management at vaccination facilities. Vaccine storage must comply with Standard Operating Procedures to ensure the quality of the vaccine is maintained until the recipients receive it. The distributed COVID-19 vaccines in Indonesia had a storage temperature of 2-8°C (Sinovac, AstraZeneca, and Sinopharm). Implementing the COVID-19 vaccination also requires other logistics, such as safety boxes and good governance. In addition, temperature monitoring is carried out to maintain the temperature following the temperature storage recommendations for each vaccine to maintain vaccine quality[8)]. Then, the vaccine will be carried using a vaccine carrier or for vaccines with ultra-cold chain storage procedures. Vaccines that will be used must be monitored for quality by paying attention to the expiration date, stored at 2-8°C, labeling still exists, and not submerged in water[9)].

For the vaccine's distribution, the government is responsible for distributing logistics at the provincial level. Subsequent distribution is the responsibility of the regional government in stages, with the mechanism being delivered by a higher level or taken by a lower level, depending on the policies of each region[8)]. Distribution from the District/City Health Office to public health centers, clinics, and Hospitals is carried out using a box car or mobile health center car, where the vaccine is placed in a cold box/vaccine carrier or other means of transporting vaccines according to the type of COVID-19 vaccine. Then, the vaccine is stored in the vaccine refrigerator or storage area according to the kind of COVID-19 vaccine. Vaccine distribution must pay attention to Vaccine Vial Monitor (VVM) conditions, expiration date (FEFO), and vaccine entry order (FIFO). If the vaccine is distributed in small quantities, where the freeze-sensitive vaccine is mixed with heat sensitive, a cold box is used, which contains a cold liquid (cool pack) box[12)].

Several studies have focused on the risks involved in vaccine distribution. Bell et al.[13)] found that the main risk factors associated with vaccine storage outside the recommended temperature range were lack of thermometers in the freezer, lack of thermometers in the refrigerator, and failure to maintain freezer temperature. Then, another study conducted a risk analysis and identified 32 risks with five dimensions: supply and suppliers, operational, financial, government & market demand, and logistics[14)]. Research on cold chains in vaccine management has also been conducted in several regions in Indonesia. Afriani et al.[10)] found that vaccine storage at a public health center in Depok, Indonesia, was not equipped with a generator to maintain vaccine quality during a power outage. The distribution of vaccines also only uses public vehicles, making them vulnerable to vaccine damage. In Manado City, Indonesia, Lumentut et al.[5)] found that several public health centers have not complied with cold chain management guidelines in terms of vaccine storage and distribution, which can be seen from the absence of temperature measuring devices, freeze tags, not having generators, not having freezer indicators and limited liquid cold boxes in cold boxes during distribution. In another study, Pangalo et al.[15] found that high knowledge improved positive attitudes toward implementing cold chain management, although, in Gorontalo City, this was statistically not significant. Aminah and Slamet[16] also mention that some locations (ex. South Sumatra and North Sumatra) lacked an appropriate cold chain, including the delayed vaccination distribution caused by geographical limitations on the institutional capacity dimension. Then, Jailani[13] found that the cold chain management of vaccines in the basic immunization program at several public health centers in Jambi province, Indonesia, did not meet the requirements of the vaccine cold chain. This study shows Indonesia's vaccine cold chain management system is not yet evenly distributed.

3. Research methodology

We reviewed the literature to gather risk factors in COVID-19 vaccine distribution activities at last-mile delivery. It was based on the most critical points found in the occurrence of risks in previous studies. Based on the literature review from[17–19], our work concludes that the critical points of operational risk in the distribution are contained in the three dimensions: Risks related to material handling[18]; Risks related to facilities and infrastructure needs[19]; and Risks related to coordination mechanisms[17].

The risk factors collected from various literature reviews were validated using the content validity index (CVI) method based on these three dimensions. This method involves selected experts determining these factors' relevance to the field's conditions. This method is done by conducting interviews and filling out questionnaires using a 4-point ordinal scale[20]. In this study, validation was conducted by six experts with different backgrounds: academia, vaccine supply chain/distributors/logistics, pharmaceutical companies, and cold supply chain experts. In addition, experts can also provide additional suggestions/opinions if there are risks that have not been written in the questionnaire but are deemed necessary by the expert.

This study validated the 35 gathered risk factors using the item level (I-CVI) and scale level (S-CVI) validity index. Those factors with an I-CVI value more than or equal to 0.78, and an S-CVI value greater than or equal to 0.80 are considered valid[20]. In this study, 11 risk factors were found invalid, while the other 24 factors were considered valid with detail in Table 1.

The selected factors were then assessed by five experts from the health and pharmaceutical fields with different experience backgrounds, with details in Table 2. The rating results will then be analyzed to determine the relationship between factors using the DANP method. DANP is a combination of the stages already carried out with DEMATEL, which is then continued by using ANP to give weight to the criteria. This method is deemed suitable for determining which criteria from the options are the most important criteria. The combination with DEMATEL gives the initial stages a greater significance since it allows for a better understanding of the influences through the examination of elements in cause-and-effect interactions[21].

Table 1. Selected COVID-19 Vaccine Last-Mile Delivery Risk Factors.

Item	Dimension	Risks	Source
A1	Risks related to material handling (D1)	Vaccine storage at inappropriate/variable temperatures	13)
A2		Vaccine storage is not supported by temperature monitoring devices (thermometer, freeze tag/temperature logger)	13)
A3		Failure of temperature monitoring in storage facilities (temperature checking and recording)	13)
A4		Risk of physical loss/damage during shipping and transportation (transit)	22)
A5		Dry ice/ice gel validation error	23)
A6		Improper transport and storage methods	23)
A7		Vaccine storage is not following standard operating procedures	22)
A8		There is no preconditioning of the equipment before the vaccine is packed for shipping	Expert Inputs
B1	Risks related to the facilities and infrastruc-ture needs (D2)	Damage to temperature monitoring equipment, storage facilities, cold storage, and other supporting facilities	19)
B2		Lack of electrical backup equipment and cold storage in the event of a power outage / running out of fuel / damaged vaccine refrigerator	13)
Item	**Dimension**	**Risks**	**Source**
B3	Risks	Inadequate access to	5)

	related to the facilities and infrastructure needs (D2)	distribution/infrastructure	
B4		Unsupported transportation/storage/cold storage facilities	24)
B5		There is no freezing indicator on the cold box or vaccine carrier, or VVM on the vaccine	25)
B6		No alarm for temperature monitoring in case of deviation	Expert Inputs
C1	Risks related to coordination mechanisms (D3)	Lack of training for vaccine delivery and receiving personnel	13)
C2		No coordination in vaccine temperature monitoring	13)
C3		Lack of understanding of officers on Good Storage and Distribution Practices (GSDP) and cold chain management	23)
C4		There is no coordination regarding humidity and temperature regulation in transportation vehicles	5)
C5		Risks of handling vaccines at freezing temperatures	7)
C6		Ensures consistent temperature management on last-mile delivery	7)
C7		Not checked against the expiration date of the vaccine	25)
C8		Not implementing FEFO (First Expired First Out) or FIFO (First in First Out)	25)
C9		Filling out the Certificate of Outgoing Goods & Vaccine Arrival Report forms is not accurate or not filled in	Expert Inputs
C10		There is no coordination of vaccine needs planning from health facilities to regional offices related to storage capacity	Expert Inputs

The DANP process begins with processing the DEMATEL stages to obtain the value of the total influence matrix. Then, the matrix will proceed to the ANP stage to obtain local weights and global weights for each factor[26]. All DANP method calculation steps were based on Hsu et al.[26], as follows:

a. Calculating the average matrix (A) built from the scoring experts' results.
b. Normalize the initial influence matrix (X) with normalize the average matrix A with diagonal elements equal to zero.
c. Calculating the total influence matrix (T) using equation (1).
d. $T = X + X1 + X2 + X3 + \ldots + Xh = X\,(I - X)^{-1}$ (1)
e. Develop Unweighted Supermatrix (W) with normalized supermatrix Tc for ANP dimension weights (clusters) using influence matrix T. The final result will show a matrix which is based on the process of transposing the normalized total influence matrix by dimension (cluster) W = $(T_c^{\alpha})'$.
f. Calculating Weighted Supermatrix (W^{α}) by summing up each column to be normalized to obtain the matrix T_D^{α}.
g. Limiting Weighted Supermatrix by multiplying Wα by its own matrix several times until it converges and becomes a stable matrix to create a global priority vector.

Table 2. Selected COVID-19 Vaccine Last-Mile Delivery Risk Factors.

Experts	Background	Experience
Expert 1	National Key Account Manager Pharma & Healthcare	15 - 20 years
Expert 2	Head of Pharmacy Installation at State University Hospital (Type B)	> 20 years
Expert 3	Junior Researcher in Organization of International Public Health Coordinator	5 - 10 years
Expert 4	Preclinical/Clinical Test Evaluator for Drugs in Government Agency A	> 10 years
Expert 5	Executive Assistant to the Government Agency B	5 - 10 years

4. Results and discussion

Based on the results of data processing that has been carried out, a summary of the weights and values (R + S) for the dimensions, along with their ranking, can be seen in Table 3. The weighting results of the DANP show that the Material Handling dimension (D1) has the highest priority in the distribution of COVID-19 vaccine on last-mile delivery, followed by the Coordination Mechanism dimension (D3) and the Facility and Infrastructure Needs dimension (D2) in third place.

The results of the calculation of the Network Relationship Map (NRM) rating show that the Material Handling dimension (D1) has the highest value (R + S), followed by the Coordination Mechanism dimension (D3) and the Facility and Infrastructure Needs dimension (D2). The results of the calculation of weights and values (R + S) show that both resulted in the same rank.

Fig. 2 shows NRM between dimensions where the horizontal axis shows the value of (R+S) and (R-S) is shown on the vertical axis. It can be seen that the

Dimension related to Facilities and Infrastructure Needs (D2) is in the top position, and the Dimension related to Material Handling (D1) is in the lowest position. The higher the position, the more the dimension will influence the others, and the lower the position in the graph, the easier the dimension will be influenced by other dimensions. Therefore, the Facility and Infrastructure Needs dimension (D2) has the most significant influence, and the Material Handling dimension (D1) is the dimension most influenced by other dimensions and has the highest priority.

Table 3. Dimension Priority Rank.

Dimension	Weight	Rank	R + S	Rank
Risks related to material handling (D1)	0.457	1	0.253	1
Risks related to the need for facilities and infrastructure (D2)	0.165	3	0.199	3
Risks related to coordination mechanisms (D3)	0.378	2	0.252	2

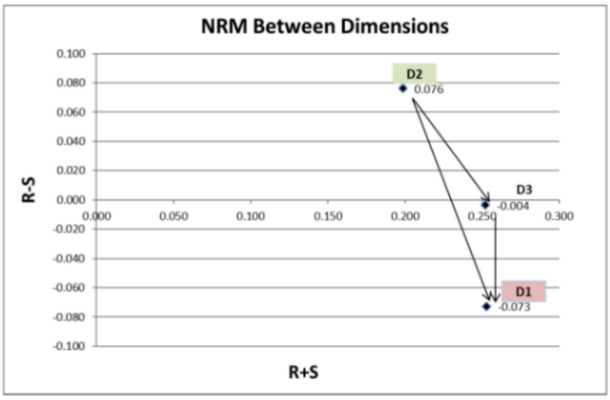


Fig. 2: NRM between Dimensions.

From these results, in distributing the COVID-19 vaccine on last-mile delivery, the government needs to focus on mitigating risks related to the need for facilities and infrastructure to prevent impacts on risks related to material handling. Furthermore, the government's efforts in developing this distribution strategy should prioritize establishing resilient and adaptive infrastructure that meets the different demands of each island. This method takes into consideration variable population densities, geographical obstacles, and accessibility concerns to arrange strategically located distribution sites[27]. By taking a targeted approach to infrastructure construction, the government may guarantee that the vaccination distribution process remains efficient and fair regardless of the region.

The results of the weighting of DANP and the value (R + S) on the NRM indicate that the risk of vaccine storage not following procedures (A7) has the highest priority and importance in the Material Handling dimension (D1). The results of the NRM between risk factors in the dimensions of material handling can be seen in Fig. 3(a). It shows that the risk of no preconditioning of the equipment before the vaccine is packed for shipping (A8) is the most significant influence on the risk of vaccine storage not following the procedures (A7). In contrast, the risk of vaccine storage at inappropriate/variable temperatures (A1) was the most significant influence of the risk of vaccine storage not being under applicable procedures (A7).

From these results, the government needs to ensure that officers carry out all vaccine distribution procedures properly, including preconditioning of equipment before vaccines are packaged and sent to hospitals and health centers[28]. To accomplish this, training programs should be customized to provide officers with the skills and knowledge they need to carry out distribution operations flawlessly[29]. Before packing, special attention must be paid to the critical step of equipment preconditioning. Furthermore, considering the importance of temperature stability, special attention should be provided to storage conditions[30]The government should also consider using technology solutions to improve monitoring and reporting. This would allow the government to reduce risks and contribute to the quality of vaccinations.

The results of the DANP in the Facility and Infrastructure Needs dimension (D2) show that the risk of no alarm for temperature monitoring in case of deviation (B6) has the highest priority, while the risk with the highest value (R + S) is the risk of unsupported transportation/storage/cold storage facilities (B4). The results of the NRM between risk factors in the dimensions of the need for facilities and infrastructure can be seen in Fig. 3(b) explains that the risk of no freezing indicator on the cold box or vaccine carrier or VVM on the vaccine (B3) gives the most significant influence on the risk of unsupported transportation/storage/cold storage facilities (B4) and the risk of no alarm for temperature monitoring in case of deviation (B6) got the most influence on the risk of unsupported transportation/storage/cold storage facilities (B4).

These findings point out the need for the government to provide facilities and infrastructure to facilitate the seamless and successful distribution of the COVID-19 vaccine on the last-mile delivery. In light of this, an in-depth assessment of the region's current healthcare and distribution capabilities is critical[31]. Furthermore, the government must work closely with technology experts to establish cutting-edge solutions that improve infrastructure performance[32]. Smart integrated monitoring systems can give real-time data on temperature, storage conditions, and equipment operation[33]. This data-driven strategy allows preventive actions and promotes a more streamlined and accountable distribution process. For example, providing dependable temperature monitoring alerts helps protect the vaccine's potency and quality[34].

The results of the weighting of DANP in the Coordination Mechanism dimension (D3) and the value (R + S) on the NRM indicate that the risk of handling vaccines at freezing temperatures (C5) has the highest priority and importance. The results of the NRM between risk factors in the dimensions of the coordination in Fig. 3(c) describe that the risk of lack of training for vaccine delivery and receiving personnel (C1) has the most significant influence on the risk of handling vaccines at very freezing temperatures (C5). The risk of ensuring consistent temperature management on last-mile delivery (C6) was the most influenced by the lack of understanding of officers on Good Storage and Distribution Practices (GSDP) and cold chain management (C3).

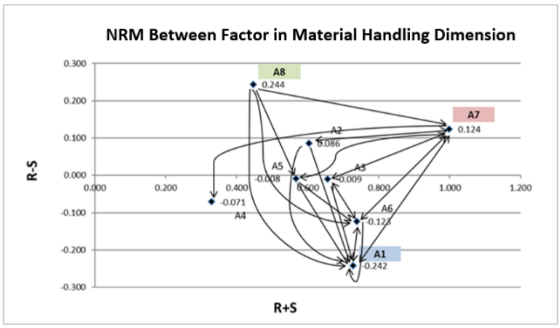
From these results, in ensuring consistent temperature management on last-mile delivery as well as handling vaccines at freezing temperatures, the intervention that the government needs to do is the same as an intervention on global risks, namely focusing on training and understanding for officers sending or receiving COVID-19 vaccines[28]. The government's role evolves to the position of an educator and enabler, preparing officers to handle the complexities of temperature management and the cold chain in last-mile delivery[35]. Officers should be well-versed in GSDP and cold chain management principles, especially when working with vaccines that need extremely low temperatures. Furthermore, establishing a strong awareness of the relevance of officers' duties in the distribution chain is critical. Officers are more likely to adhere to protocols and follow best practices with thoroughness when they understand the vital role they play[36].

The findings of this study have implications for the development of human resources, facilities and infrastructure, and technology. Some previous studies strengthen these findings. According to Ashok et al.[22], Three primary challenges restrict cold chain performance, and nine therapies have been proposed. Some solutions provided, such as effective monitoring throughout implementation, in-country piloting new equipment, and using tools to understand equipment trade-offs better, align with the study's research findings.

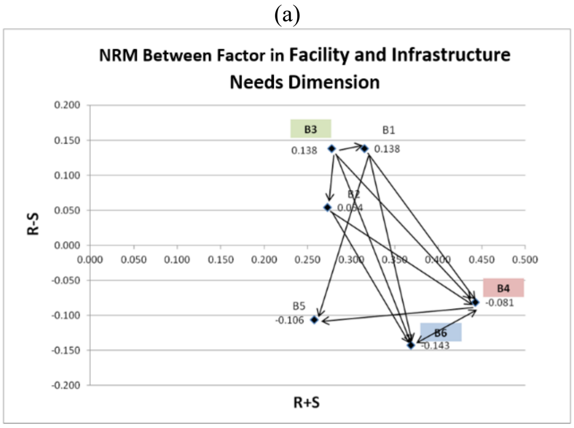
Manupati et al.[37] built a cold chain model for managing vaccine distribution to give decision assistance on how to deliver the vaccine to a complete population in their research. The selection is based on priority, determined by doing predictive analysis and then developing a mixed-integer linear programming model for finding and assigning cold storage facilities for bulk vaccine manufacturing. Although it has included a variety of aspects in its approach, what is critical in all of this is motivated and adequate healthcare staff.

Rosyidi et al.[38] mentioned blockchain technology can help government programs that utilize vaccination to prevent pandemics by enhancing the oversight of vaccine delivery. By offering reliable information, it addresses the challenge of tracking and evaluating occurrences and provides cutting-edge technology for distributed data security. Also, it increases mutual trust among the participants. In other research, Sudari et al.[39] explained that for distributing COVID-19 vaccinations in Indonesia's rural areas, combining Internet of Things technology with bio-detection and bio-tracking can be the most successful method, considering their advanced features. Furthermore, healthcare practitioners are needed to raise community awareness about the need for vaccination. A pharmacist plays an essential role in verifying the quality of the vaccine.

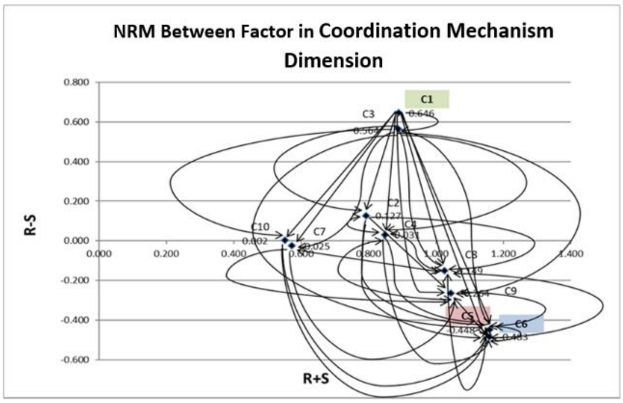
Lusiantoro et al.[40] proposed a mathematical model to maximize the coverage of the COVID-19 vaccine distribution based on a maximum covering location problem (MCLP). A mathematical model is suggested and presented using a real-life study of healthcare facilities and the physical coordinates of communities in Yogyakarta, Indonesia. The results indicate that the proposed model provides adequate vaccination coverage by reducing the distances the target group carries. Another study used simulation-based analysis to examine the successful dissemination of COVID-19 vaccinations in a case study in Norway[41]. The findings show that fleet size, composition, vehicle type, and route optimization may substantially impact a cold chain vaccine logistics system's service quality, cost-effectiveness, environmental performance, and equity. Furthermore, this work offers suggestions for testing new technologies in COVID-19 vaccine delivery in a risk-free simulation setting. As a result, the findings of Sun et al.[41] is in line with this study.



(a)



(b)



(c)

Fig. 3: Results of NRM between:
(a) Risk Factors in the Dimensions of Material Handling; (b) Risk Factors in the Dimensions of Facilities and Infrastructure Needs; (c) Risk Factors in the Dimensions of the Coordination Mechanism.

5. Conclusion

Risk identification in the distribution of COVID-19 vaccines at last-mile delivery resulted in 24 risk factors with three dimensions: material handling, facilities and infrastructure needs, and coordination mechanisms. Priority analysis was carried out using the MCDM method, namely DEMATEL-based ANP. The study found that the Facility and Infrastructure Needs dimension (D2) has the most significant influence with a weight of 0.457 and (R + S) 0.253.

The strategies proposed to policymakers include focusing on the mitigation of risks related to the need for facilities and infrastructure to prevent impacts on risks related to material handling; focus on training and understanding for vaccine delivery or receiving officers to understand GSDP and cold chain management in last-mile delivery truly ensure that officers carry out all vaccine distribution procedures properly, including equipment preconditioning before vaccines are packaged and sent to hospitals and health centers[31)]; mobilize all teams related to the provision of facilities and infrastructure to ensure that all facilities and infrastructure are correctly available and support the distribution of COVID-19 vaccines[34)].

These strategies show the importance of human resources in using facilities and infrastructure. Thus, along with the development of suitable facilities and infrastructure, improving the skills of human resources involved in the vaccine distribution process is needed to maintain the quality of vaccines distributed throughout Indonesia. The government can minimize the risks during vaccine distribution by implementing the proposed strategies focusing on the facilities and infrastructure needs and the relevant human resources using them. The quality of vaccines can be appropriately maintained. The strategy above also explains the critical role of human resources in running facilities and infrastructure throughout Indonesia. Thus, there is a need for research related to strategies to develop human resource capabilities evenly in vaccine management in Indonesia, which is full of challenges in the future.

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