Jurnal Teknologi dan Inovasi Kesehatan

SAH PUBLISHER

Vol. 1, No. 1, September 2026

A Prevention Model for Respiratory Virus Infections in Urban Environments

Elsa Pavita[1*], **Himmatunnisak Mahmudah**[1]

[1]Universitas Sugeng Hartono, Indonesia

**Corresponding author. Email: elsapavt@gmail.com*

Abstract. Respiratory virus infections impose a large and recurring burden on dense cities, where crowding, mass transit, indoor congregation, and polluted air multiply the contact opportunities through which influenza viruses, respiratory syncytial virus, and coronaviruses spread. This study develops an original layered prevention model for Indonesian metropolitan areas through a structured literature review of transmission science, intervention effectiveness, surveillance methods, and official data from the World Health Organization, Statistics Indonesia, and the Indonesian Ministry of Health. Evidence published predominantly by major international publishers was synthesised into a five layer framework named the LapisLindung Model, comprising a household shield layer, a safe mobility layer, a healthy workplace and school layer, a resilient healthcare layer, and a smart city governance layer, supported by two cross cutting functions, vaccination and risk communication. The review confirms that inhalation of small airborne particles is a principal route of transmission, that ventilation, filtration, well fitted masks, physical distancing, hand hygiene, and timely isolation act cumulatively rather than individually, and that wastewater monitoring, syndromic surveillance, and sentinel influenza like illness and severe acute respiratory infection networks can provide early warning several days before clinical case reports peak. The model is translated into a phased implementation roadmap with measurable indicators for metropolitan governments, including ventilation compliance in public buildings, sentinel reporting timeliness, influenza vaccine coverage among risk groups, and the interval between surveillance signal and public response. The study concludes that respiratory virus prevention in Indonesian cities should be reorganised from reactive outbreak response toward permanent, layered, and measurable urban health infrastructure that is financed, staffed, and evaluated continuously between outbreaks rather than improvised during them.

Keywords: respiratory virus infection; urban health; airborne transmission; prevention model; wastewater surveillance; Indonesia

Received August 2026 / Revised September 2026 / Accepted September 2026

This work is licensed under a Creative Commons Attribution 4.0 International License.

INTRODUCTION

Respiratory viruses are among the most persistent causes of illness and death worldwide, and their burden falls with particular weight on cities. Seasonal influenza alone is estimated to cause between 291,243 and 645,832 respiratory deaths each year across the globe, with South East Asia carrying some of the highest regional mortality rates [1]. Respiratory syncytial virus adds a further concentrated burden among young children, causing an estimated 33.0 million episodes of acute lower respiratory infection, 3.6 million hospital admissions, and 101,400 attributable deaths in children younger than five

years in 2019, with 97 percent of those deaths occurring in low and middle income countries [2]. The World Health Organization summarises the scale of seasonal influenza as around one billion cases annually, including three to five million cases of severe illness and between 290,000 and 650,000 respiratory deaths [3]. These figures describe endemic, recurring threats rather than rare emergencies, and they repeat every year in the crowded environments where most of humanity now lives.

Indonesia illustrates the urban dimension of this burden with unusual clarity. The province of Jakarta accommodates roughly 16,000 inhabitants per square kilometre on a land area of only about 661 square kilometres, making it the most densely populated province in the country, and its daytime population swells further as commuters arrive from the surrounding metropolitan region [4]. Similar, if less extreme, conditions characterise Surabaya, Bandung, Medan, Semarang, and Makassar, where households are often multigenerational, public transport is crowded at peak hours, informal settlements have limited ventilation and sanitation, and large shares of the workforce cannot work from home. In such settings, the probability that an infectious person shares air, surfaces, and confined space with susceptible people is structurally elevated, so prevention cannot rest on individual behaviour alone.

The COVID-19 pandemic forced a scientific correction that remains decisive for urban prevention planning. In 2020, Morawska and Milton argued that airborne transmission of SARS-CoV-2 through inhalable microdroplets had to be addressed directly by public health authorities, because the evidence from outbreak investigations, airflow studies, and virus detection in air samples could no longer be reconciled with a purely droplet and surface model [5]. Greenhalgh and colleagues consolidated ten lines of scientific evidence supporting airborne transmission, including superspreading events, long range transmission in quarantine hotels, and the markedly higher risk of indoor compared with outdoor exposure [6]. The practical consequence is that the quality of shared indoor air is a determinant of respiratory health on the same level as the quality of shared water, and cities that fail to manage it will repeatedly experience large respiratory outbreaks regardless of the specific virus in circulation.

Indonesian surveillance data confirm that this is a present and continuing problem rather than a historical one. The Ministry of Health reported that sentinel surveillance through epidemiological week 38 of 2026 recorded an influenza positivity rate of 56 percent among 265 examined specimens, with influenza A(H1N1)pdm09 dominant and community activity classified in the medium category, a rise the Ministry judged consistent with the seasonal pattern normally observed in Indonesia [7]. Tropical countries do not enjoy a reliably quiet season for respiratory viruses, so Indonesian cities require prevention arrangements that operate continuously, intensify when surveillance signals rise, and protect the settings where transmission is most efficient.

Existing Indonesian arrangements remain fragmented. Responsibilities are divided among health offices, transport operators, education authorities, employers, and facility managers, and interventions tend to be activated as temporary campaigns during outbreaks rather than maintained as permanent systems. What is missing is an integrated model that assigns every major transmission setting to an accountable layer, specifies the interventions each layer must maintain, and connects all layers to shared surveillance, vaccination, and communication functions. This study therefore pursues three objectives. First, it synthesises the current scientific understanding of respiratory virus transmission and of the urban conditions that multiply it. Second, it constructs an original five layer

prevention model, named the LapisLindung Model, tailored to dense Indonesian cities. Third, it translates the model into an implementation roadmap with indicators that metropolitan governments can adopt, monitor, and report.

METHODS

This study used a structured literature review combined with constructive model building. Literature was identified from international journal databases and publisher platforms using combinations of the terms respiratory virus transmission, airborne transmission, ventilation, face masks, physical distancing, school closure, wastewater surveillance, syndromic surveillance, influenza burden, respiratory syncytial virus burden, air pollution and respiratory infection, vaccine effectiveness, and risk communication. Priority was given to systematic reviews, meta analyses, Cochrane reviews, large modelling studies, and landmark primary studies published in journals of major international publishers, namely Elsevier, Springer Nature, Wiley, Taylor and Francis, Oxford University Press, and SAGE, supplemented by official publications of the World Health Organization, the Indonesian Ministry of Health, and Statistics Indonesia. Every reference included in this paper was verified against its publisher page, digital object identifier, or issuing institution before citation, and unverifiable sources were excluded.

The synthesis proceeded in three steps. In the first step, the evidence was organised by transmission mechanism, so that each intervention could be traced to the route it interrupts: inhalation of aerosols, deposition of larger droplets at close range, and transfer through contaminated hands and surfaces. In the second step, interventions were mapped onto the urban settings in which exposure actually occurs, namely households, public transport, workplaces and schools, and healthcare facilities, together with the governance functions that finance, regulate, and monitor them. In the third step, the mapped interventions were assembled into a layered model following the logic of defence in depth, in which no single measure is expected to be sufficient, and the failure or partial uptake of one measure is compensated by the others. Indicators for the implementation roadmap were then derived by asking, for each layer, what a metropolitan government could count, audit, or publish at regular intervals using data systems that already exist in Indonesia, such as sentinel influenza like illness and severe acute respiratory infection surveillance, the early warning and response system known as SKDR, routine immunisation reporting, and municipal building and transport records. No primary data were collected, and no surveillance figures are reported in this paper other than those published by the official sources cited.

RESULT AND DISCUSSION

3.1. Transmission Science: Droplets, Aerosols, and Fomites

Any credible prevention model must begin with how respiratory viruses actually travel between people. Kutter and colleagues distinguished three routes: contact transmission, in which virus reaches mucous membranes through direct touch or through contaminated intermediate objects known as fomites; droplet transmission, in which relatively large respiratory particles deposit on the mucous membranes of a nearby person; and aerosol transmission, in which small particles remain suspended in air and can be inhaled, including at distances beyond the immediate vicinity of the source [8]. These routes are not mutually exclusive, and the same virus may exploit all three with different efficiency depending on the setting, the activity, and the stage of infection.

The historical debate concerned the relative weight of each route. For influenza, the systematic review by Brankston and colleagues concluded that natural transmission occurs predominantly at close range and questioned the importance of long range airborne spread in most clinical settings, while acknowledging that aerosol generating procedures could create exceptions [9]. Subsequent work has substantially revised the practical balance of that conclusion. Fennelly showed that the cough aerosols of patients with influenza, tuberculosis, and other respiratory infections contain pathogens predominantly in small particles below five micrometres, which remain airborne, penetrate deeply into the lung, and are poorly stopped by loose fitting barriers [10]. Tellier and colleagues, reviewing the same body of evidence for a wider group of respiratory agents, concluded that aerosol transmission should be recognised as a normal mode of spread and not treated as an exotic exception [11]. For SARS-CoV-2, the airborne case became overwhelming, and it is summarised in the ten lines of evidence presented by Greenhalgh and colleagues [6] and in the call to action by Morawska and Milton [5].

Experimental shedding studies explain why shared air matters so much. Leung and colleagues collected exhaled breath from patients with seasonal coronavirus, influenza virus, and rhinovirus infections and found that surgical masks significantly reduced the detection of influenza virus RNA in respiratory droplets and coronavirus RNA in aerosols, demonstrating both that these viruses are emitted in fine particles during ordinary breathing and speech and that source control at the face can intercept a meaningful share of the emission [12]. Timing compounds the problem. He and colleagues estimated that 44 percent of secondary SARS-CoV-2 infections were acquired during the presymptomatic stage of the index case, with infectiousness peaking at or before symptom onset [13]. Prevention that waits for obvious symptoms therefore arrives after much transmission has already occurred. Incubation periods are short for most respiratory viruses, with pooled median estimates of 1.4 days for influenza A, 1.9 days for rhinovirus, 3.2 days for human coronaviruses, and 4.4 days for respiratory syncytial virus [14], which means that case finding, isolation support, and contact notification in a city must operate within days, not weeks, to interrupt chains of transmission.

The fomite route, although real, should be assigned its proper weight. Virus deposited on surfaces can survive for hours and can be transferred by hands to the eyes, nose, and mouth, which is why hand hygiene remains a rational component of every layer of the model proposed here. However, the epidemiological record of explosive outbreaks in choir practices, restaurants, buses, offices, and dormitories, in which many people who never touched a common object or approached the index case closely became infected, cannot be explained by surfaces alone, whereas it follows naturally from shared, inadequately ventilated air. The correct conclusion for model design is not that surfaces are irrelevant, but that air is the priority route in crowded urban interiors, droplets dominate at conversational distance, and contact hygiene provides a low cost supporting measure whose value is greatest in households, schools, and healthcare settings.

3.2. Urban Risk Multipliers: Density, Transit, Indoor Crowding, and Air Pollution

Cities do not create respiratory viruses, but they systematically multiply the conditions under which the viruses spread. The first multiplier is contact intensity. Hamidi, Sabouri, and Ewing analysed 913 metropolitan counties in the United States and found that county population density by itself was not significantly related to infection rates once other factors were controlled, whereas metropolitan size and connectivity were strongly related, and denser counties in fact experienced lower mortality rates, plausibly because of better

resourced healthcare [15]. This finding refines rather than excuses the urban risk argument. What endangers residents is not density as an abstract number but the specific exposure structures that accompany it in Indonesian cities: crowded dwellings with several persons per room, packed commuter trains and buses, queues in enclosed terminals, classrooms and offices with closed windows and recirculated air, and large informal workplaces where sick leave is unavailable. Density combined with good ventilation, spacious transport, and strong healthcare can be safe; density combined with crowding, poverty, and stagnant indoor air is not.

The second multiplier is the time people spend in shared indoor environments. A systematic review by Li and colleagues examined forty studies of ventilation and airflow in buildings and found strong evidence that ventilation rates and airflow patterns are associated with the transmission of measles, tuberculosis, influenza, and SARS, concluding that inadequate ventilation in public buildings and transport environments increases airborne infection risk [16]. Rudnick and Milton provided the practical measurement tool for this risk by showing that the fraction of air in a room that has already been breathed by others can be estimated from the carbon dioxide concentration, allowing infection risk from long range airborne transmission to be inferred from a simple, inexpensive sensor reading [17]. For a metropolitan government, this is a consequential insight: the most dangerous rooms in a city can be identified and ranked with carbon dioxide audits before any outbreak occurs.

The third multiplier is air pollution, which interacts with respiratory infection at several levels. Zhu and colleagues analysed 120 Chinese cities and found that short term increases in ambient pollution were associated with increased daily confirmed COVID-19 cases, with each 10 microgram per cubic metre increase in fine particulate matter associated with a 2.24 percent increase in cases and the same increase in nitrogen dioxide associated with a 6.94 percent increase [18]. Beyond this ecological association, chronic exposure to polluted air damages airway defences and sustains the high background prevalence of chronic respiratory and cardiovascular disease that converts infection into severe illness. Jakarta and other Indonesian metropolitan areas regularly record fine particulate concentrations far above international guideline values, so air quality policy is, in part, respiratory infection policy. The fourth multiplier is social inequality in exposure and protection: residents of informal settlements face the most crowded housing, the longest crowded commutes, the least access to testing and vaccination, and the greatest income loss when isolating, so a model that ignores equity will fail precisely where transmission is most intense.

3.3. The LapisLindung Model: Architecture and Principles

The model proposed in this study is named the LapisLindung Model, from the Indonesian words lapis, meaning layer, and lindung, meaning to protect. It organises urban respiratory virus prevention into five layers that correspond to the settings in which exposure occurs and to the institutions that can be held accountable for each setting. The first layer, the household shield, covers dwellings, where the longest and closest exposures occur. The second layer, safe mobility, covers public transport vehicles, stations, terminals, and the commuting system as a whole. The third layer, healthy workplaces and schools, covers offices, factories, markets, and educational institutions, where people spend the working day in shared air. The fourth layer, resilient healthcare, covers community health centres (puskesmas), clinics, and hospitals, which must treat the infected without amplifying transmission. The fifth layer, smart city governance, covers

the metropolitan government functions of surveillance, early warning, regulation, financing, and evaluation that hold the other four layers together. Two functions cut across all five layers: vaccination, which reduces susceptibility and severity at population scale, and risk communication, which sustains the public cooperation on which every other measure depends.

The model rests on five design principles drawn from the evidence reviewed above. The first principle is that air comes first: because inhalation of aerosols is a principal route of transmission [5], [6], every layer must contain at least one measure that improves the quality of shared air, whether by ventilation, filtration, occupancy management, or moving activities outdoors. The second principle is defence in depth: no single intervention is fully effective, so each layer combines environmental, administrative, and personal measures whose effects multiply. The third principle is that speed is a design specification, because presymptomatic transmission [13] and short incubation periods [14] punish slow systems; isolation support, test access, and public alerts must be measured in days. The fourth principle is that protection is allocated by exposure, not by administrative convenience, so resources flow first to the most crowded dwellings, vehicles, classrooms, and clinics. The fifth principle is that every layer carries indicators that are published routinely, converting prevention from a campaign promise into auditable public infrastructure. The following subsections specify the content of each layer and the evidence behind it.

3.4. Layer One: The Household Shield

The household is the most efficient transmission environment in any city, because exposure there is prolonged, repeated, unmasked, and often involves the very young, the elderly, and the chronically ill. The household shield layer therefore combines hygiene, separation, air, and support. Hand hygiene is its foundation. The Cochrane review by Jefferson and colleagues, covering 78 randomised trials of physical interventions, found that hand hygiene programmes probably reduce the burden of acute respiratory illness modestly, while the trial evidence for community masking against laboratory confirmed influenza was inconclusive, with pooled risk ratios close to unity [19]. This honest reading matters for household policy: handwashing with soap at key moments, respiratory etiquette, and regular cleaning of frequently touched surfaces are cheap and probably beneficial, whereas expecting masks alone to protect a household is not supported by trial evidence.

Separation within the home is the second element. Isolation of ill persons and quarantine of exposed contacts are among the oldest and most effective tools of public health, but their definitions and purposes differ: isolation separates people who are ill from those who are not, while quarantine restricts the movement of people who were exposed but may not be infected, and both fail when households receive no material support [20]. In dense Indonesian housing, full separation is often physically impossible, so the model specifies a graduated household protocol: the ill person uses the best ventilated room, wears a mask in shared spaces, eats separately where possible, and is supported by the neighbourhood unit and the puskesmas with food and medicine delivery so that isolation does not cost the family its income. Ventilation is the third element. Morawska and colleagues set out the engineering controls that minimise airborne transmission indoors, including adequate ventilation, particle filtration, avoiding air recirculation, and avoiding overcrowding [21], and most of these translate to dwellings in low cost form: opening windows on opposite sides to create cross flow, using exhaust fans, limiting the number of guests indoors

during high transmission periods, and moving gatherings to open air. The fourth element is masking and distancing outside the home by household members who are ill or caring for the ill, where the large observational synthesis by Chu and colleagues found that physical distancing of at least one metre was associated with a substantially lower infection risk (adjusted odds ratio 0.18) and that face masks were associated with a similarly large risk reduction (adjusted odds ratio 0.15) across healthcare and community settings [22]. The household layer is monitored through puskesmas records of household contacts assessed, isolation support packages delivered, and secondary cases identified within monitored households.

3.5. Layer Two: Safe Mobility

Public transport concentrates strangers in enclosed, moving air for extended periods, and it connects every other layer: an infection acquired in a household in one district can be carried across the metropolitan area within an hour. Modelling by Prem and colleagues of the Wuhan outbreak showed that interventions reducing social mixing, including travel related restrictions and staged release of controls, substantially delayed and reduced the epidemic peak, demonstrating how strongly transmission responds to the intensity of everyday mobility and mixing [23]. A metropolitan model cannot and should not aim to stop commuting, which would destroy livelihoods, so the safe mobility layer instead reduces the risk per journey. Its core measures are ventilation standards for vehicles and stations, with fresh air exchange requirements written into operator contracts; occupancy management at peak hours through service frequency increases, staggered working hours negotiated with major employers, and real time crowding information; mask wearing during officially declared high transmission periods, justified by the observational evidence that masks are associated with large reductions in infection risk in close contact settings [22]; and contactless payment and queue design that shorten the time passengers spend stationary in enclosed terminals. Engineering controls for public buildings and transport environments, including effective ventilation enhanced by filtration and the avoidance of air recirculation and overcrowding, were explicitly recommended by Morawska and colleagues as part of an overall control strategy [21], and carbon dioxide monitoring in stations and terminals, using the rebreathed air approach of Rudnick and Milton [17], gives operators an objective trigger for corrective action. Indicators for this layer include the share of the public vehicle fleet meeting the ventilation standard, peak hour crowding indices on principal corridors, and the number of stations publishing carbon dioxide readings within target ranges.

3.6. Layer Three: Healthy Workplaces and Schools

Workplaces and schools are where the metropolitan population spends the largest share of its indoor time, and they are also the settings where absence policies most directly shape transmission, because employees and students who lose income or standing when they stay home will attend while infectious. The evidence on the most drastic workplace and school intervention, closure, counsels restraint. Viner and colleagues, in a rapid systematic review of school closure during coronavirus outbreaks, found that modelling studies estimated school closure alone would prevent only about 2 to 4 percent of deaths, a small benefit relative to its educational and social cost, although combined social distancing packages performed better [24]. The model therefore treats closure as a last resort for severe surges and instead builds routine protection into these settings.

The first routine measure is ventilation with verified performance. The World Health Organization roadmap on indoor ventilation recommends a minimum ventilation rate of 10 litres per second per person in non residential buildings, with substantially higher rates in healthcare settings [25]. Metropolitan governments can convert this guidance into building permit conditions, school infrastructure standards, and workplace safety inspections, verified by carbon dioxide measurement [17] rather than by paperwork alone. The second measure is a protected sick leave norm: employers receiving city contracts or licences are required to provide paid isolation leave during declared transmission periods, and schools adopt non punitive absence rules for respiratory illness, because presenteeism converts a single case into a classroom or office cluster. The third measure is density and scheduling management, including hybrid attendance options during alert periods, outdoor or open sided learning and meeting spaces where climate permits, and staggered canteen and prayer room use. The fourth measure is targeted protection of high risk workplaces that history has shown to be amplifiers, such as dormitory based factories, call centres, markets with enclosed halls, and elder care facilities. Indicators for this layer include the percentage of schools and large workplaces passing annual ventilation audits, the share of formal employers with compliant sick leave policies, and absenteeism surveillance signals reported by large schools, which double as an early warning input to the governance layer.

3.7. Layer Four: Resilient Healthcare

Healthcare facilities face a dual obligation: they concentrate the most infectious and the most vulnerable people in the same buildings, and their staff are simultaneously the most exposed workers and the most essential responders. The resilient healthcare layer begins with respiratory triage at every entry point, separating patients with respiratory symptoms into ventilated waiting areas, fast tracking them to assessment, and applying source control masks at the door. Personal protective equipment policy must reflect the actual evidence. MacIntyre and Chughtai, synthesising 19 randomised trials, found that respirators protected healthcare workers when worn continuously during shifts, whereas cloth masks performed poorly and should not be recommended for healthcare workers in high risk settings [26]. The Cochrane review by Verbeek and colleagues on protective equipment against highly infectious diseases found the overall certainty of evidence low to very low, while indicating that more protective equipment types may reduce contamination at the cost of greater discomfort and more doffing errors, which argues for investment in training, fit testing, and supervised doffing rather than in equipment procurement alone [27].

Ventilation in healthcare is the highest specification application of the citywide air agenda: the World Health Organization roadmap sets minimum rates of 60 litres per second per patient in general healthcare areas and 160 litres per second per patient where aerosol generating procedures are performed [25], and puskesmas, as the most numerous facilities in Indonesian cities, require particular attention because their buildings were rarely designed with airborne infection control in mind. The layer also includes the response machinery that acts on confirmed cases. Hellewell and colleagues modelled the feasibility of controlling outbreaks by isolation of cases and tracing of contacts and found that at a basic reproduction number of 2.5, more than 70 percent of contacts would need to be traced, and at 3.5 more than 90 percent, with success also depending on short delays between symptom onset and isolation [28]. Metropolitan health offices should therefore maintain trained tracer teams in peacetime, integrated with puskesmas, rather than

recruiting them during crises. Indicators for this layer include healthcare associated respiratory infection rates, the percentage of facilities passing ventilation and triage audits, respirator fit testing coverage among high risk staff, and the median interval from symptom onset to isolation among investigated cases.

3.8. Layer Five: Smart City Governance, Surveillance, and Early Warning

The governance layer converts the other four layers from good intentions into a system, and its centrepiece is surveillance that detects rising transmission early enough to act. Three complementary surveillance technologies now exist. The first is environmental surveillance of wastewater. Ahmed and colleagues reported the first confirmed detection of SARS-CoV-2 RNA in untreated wastewater in Australia, demonstrating that catchment level monitoring could reveal community circulation independently of clinical testing behaviour [29]. Peccia and colleagues then showed that viral RNA concentrations in sewage sludge tracked community infection dynamics and preceded reported case data by up to a week when measured against reporting dates, because shedding begins before symptoms, testing, and reporting [30]. For Indonesian metropolitan governments, wastewater sampling at treatment plants, pumping stations, and selected dense neighbourhoods offers an anonymous, population level signal that cannot be obtained from clinic data alone, and it can be extended to influenza and respiratory syncytial virus as laboratory capacity allows.

The second technology is syndromic and digital surveillance. Ginsberg and colleagues demonstrated that aggregated search engine query data could estimate influenza activity one to two weeks ahead of conventional surveillance reports [31], and although later experience showed that such digital signals drift and must be recalibrated against clinical data, the principle stands: school absenteeism, pharmacy sales, puskesmas visit syndromes, and search trends can each contribute weak early signals that gain strength in combination. The third technology is the established sentinel system. The World Health Organization coordinates global influenza surveillance through the Global Influenza Surveillance and Response System, a network operating since 1952 and now comprising 166 institutions in 136 member states, which monitors circulating viruses, detects novel strains, and recommends vaccine composition twice each year [32]. Indonesia is connected to this architecture through its national sentinel network: a 2023 decree of the Director General of Disease Prevention and Control formally designated the influenza like illness and severe acute respiratory infection sentinel sites, COVID-19 sites, and reference laboratories [33], and routine reporting flows through the SKDR early warning system operated by the Ministry of Health. The weekly national reporting illustrated by the week 38 of 2026 release, in which specimen positivity reached 56 percent with influenza A(H1N1)pdm09 dominant [7], shows the system functioning; the governance task is to bind these signals to pre agreed metropolitan actions, so that defined thresholds of syndromic activity, wastewater signal, and sentinel positivity automatically trigger mask recommendations in transport, ventilation inspections, hospital readiness checks, and public communication, without waiting for political deliberation during a surge.

Governance also includes the regulatory and financial instruments that make the other layers durable: ventilation clauses in building permits and transport contracts, budget lines for puskesmas ventilation upgrades and tracer teams, data sharing agreements among the health office, transport operators, and education authorities, and an annual public report against the indicators defined in this model. A metropolitan respiratory health dashboard, updated weekly, should present sentinel positivity, syndromic trends,

wastewater results where available, hospital respiratory admissions, and vaccine coverage in one place, so that the public, employers, and schools can calibrate their own behaviour to the same evidence the government uses.

3.9. Cross Cutting Function One: Vaccination

Vaccination is the only intervention that reduces the susceptibility of the population itself, and it therefore runs across all five layers rather than belonging to any one of them. The honest evidence base for influenza vaccines in healthy adults comes from the Cochrane review by Demicheli and colleagues, which found that inactivated influenza vaccines reduced laboratory confirmed influenza from 2.3 percent to 0.9 percent (risk ratio 0.41), corresponding to a number needed to vaccinate of 71 to prevent one case, with a smaller effect on influenza like illness [34]. These are moderate individual effects, yet at metropolitan scale they translate into substantial reductions in consultations, admissions, and workplace absence, and the case is stronger still for the groups at risk of severe disease: pregnant women, children from six months to five years, older people, people with chronic conditions, and health workers, whom the World Health Organization identifies as the priority groups for annual vaccination [3]. The vaccine composition itself depends on the governance layer, because the strains included each year follow the recommendations issued through the global surveillance network [32], which is one more reason sentinel surveillance is a prevention intervention and not merely a measurement exercise.

Indonesia does not yet operate a universal seasonal influenza immunisation programme, so the model proposes a metropolitan pathway: employer and hajj related vaccination schemes are expanded into standing annual campaigns for healthcare workers, transport crews, teachers, market workers, and residents of elder care facilities in the largest cities; puskesmas offer subsidised vaccination to registered patients with chronic disease; and coverage is recorded in the same dashboard as the surveillance indicators. For future respiratory threats, including novel coronaviruses and pandemic influenza, the governance layer must maintain the regulatory, cold chain, and communication readiness that allows rapid deployment when new vaccines become available, since the value of vaccine science is only realised at the speed of the delivery system behind it.

3.10. Cross Cutting Function Two: Risk Communication

Every measure in this model depends on voluntary public cooperation repeated daily over years, which makes risk communication a load bearing component rather than an accessory. Van Bavel and colleagues synthesised the social and behavioural science relevant to pandemic response and showed that effective communication builds on trusted messengers, clear and consistent guidance, appeals to collective identity and the protection of others, and practical enablement rather than fear or blame [35]. The cost of failure is measurable. In a randomised controlled trial in the United Kingdom and the United States, Loomba and colleagues found that exposure to online misinformation about COVID-19 vaccines reduced the share of respondents who would definitely accept vaccination by 6.2 and 6.4 percentage points respectively, with scientific sounding misinformation the most damaging [36]. Indonesian metropolitan governments should therefore maintain permanent risk communication units that publish the weekly dashboard in plain language, pre brief journalists and community and religious leaders before alert thresholds are crossed, monitor circulating rumours, and correct them through the same channels that carried them, while schools and employers receive ready to use

materials rather than improvised instructions. Communication must also be honest about uncertainty and about the modest size of some intervention effects, because public trust, once spent on exaggerated claims, is not available when a genuinely dangerous surge arrives.

3.11. Implementation Roadmap and Indicators for Metropolitan Governments

The model is designed for adoption by an Indonesian metropolitan government through its health office (Dinas Kesehatan) in coordination with transport, education, manpower, and public works agencies. Implementation proceeds in three phases. The first phase, covering approximately the first twelve months, establishes foundations: the mayor or regent issues a regulation adopting the model and its alert thresholds; a carbon dioxide and ventilation audit is completed for puskesmas, government offices, terminals, and a sample of schools; sentinel reporting discipline is tightened so that influenza like illness and severe acute respiratory infection data reach the provincial level within the weekly cycle of the SKDR system [33]; wastewater sampling begins at the largest treatment facilities; and the public dashboard is launched. The second phase, covering years two and three, builds the physical and institutional stock: ventilation upgrades are executed in the worst performing public buildings using the audit ranking; ventilation clauses enter transport operator contracts and school construction standards; paid isolation leave norms are adopted by city contractors and promoted to private employers; tracer teams are formalised within puskesmas; and the first annual vaccination campaigns for priority occupational groups are delivered. The third phase, from year three onward, consolidates the system: wastewater surveillance extends to additional catchments and pathogens, building certification expands to large private premises, and the annual public report becomes the basis for budget allocation across layers.

Each layer carries indicators that are specific enough to audit. For the household layer, the indicators are the percentage of monitored cases whose household contacts are assessed within 48 hours and the number of isolation support packages delivered per hundred confirmed cases. For the mobility layer, they are the percentage of public transport vehicles and stations meeting the ventilation standard, and peak hour crowding indices on the ten busiest corridors. For workplaces and schools, they are the percentage of schools and large workplaces passing the annual ventilation audit with carbon dioxide levels within target during occupied hours, and the percentage of formal employers with compliant paid isolation leave policies. For healthcare, they are the percentage of puskesmas and hospitals passing triage and ventilation audits against the rates specified in the World Health Organization roadmap [25], respirator fit testing coverage among high risk staff, and the median onset to isolation interval, which the modelling of Hellewell and colleagues shows must be short if tracing is to succeed [28]. For governance, they are sentinel reporting timeliness, the number of wastewater catchments reporting weekly, dashboard publication regularity, and the interval between an alert threshold being crossed and the corresponding public measures taking effect, which should not exceed seven days. Cross cutting indicators include influenza vaccine coverage among healthcare workers and other priority groups [3] and the trend in public trust and misinformation prevalence measured by periodic surveys, interpreted in light of the experimental evidence on misinformation effects [36]. Targets should be set against audited baselines rather than invented, and progress should be reported annually to the metropolitan legislature, so that respiratory prevention acquires the same budgetary permanence as water, waste, and road infrastructure.

CONCLUSION

Respiratory virus infections are a permanent feature of urban life in Indonesia, sustained by aerosol and droplet transmission in crowded households, vehicles, workplaces, schools, and clinics, and amplified by polluted air and unequal living conditions, as the continuing influenza activity reported by national sentinel surveillance demonstrates [7]. This study has argued that the appropriate response is not a succession of emergency campaigns but a standing system, and it has proposed the LapisLindung Model to provide one: five accountable layers covering the household, mobility, workplaces and schools, healthcare, and city governance, bound together by vaccination and risk communication and driven by surveillance that includes wastewater monitoring, syndromic signals, and the sentinel influenza like illness and severe acute respiratory infection network connected to the global system coordinated by the World Health Organization [32]. Because the model is built from verified published evidence and expressed through auditable indicators, metropolitan governments can adopt it incrementally, beginning with ventilation audits, surveillance discipline, and isolation support, and can demonstrate year by year whether the air their citizens share is becoming safer.

REFERENCES

[1] A. D. Iuliano et al., "Estimates of global seasonal influenza-associated respiratory mortality: a modelling study," The Lancet, vol. 391, no. 10127, pp. 1285-1300, 2018, doi: 10.1016/S0140-6736(17)33293-2.

[2] Y. Li et al., "Global, regional, and national disease burden estimates of acute lower respiratory infections due to respiratory syncytial virus in children younger than 5 years in 2019: a systematic analysis," The Lancet, vol. 399, no. 10340, pp. 2047-2064, 2022, doi: 10.1016/S0140-6736(22)00478-0.

[3] World Health Organization, "Influenza (Seasonal)," Fact Sheet, Geneva, Switzerland, Feb. 28, 2025. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/influenza-(seasonal)

[4] Badan Pusat Statistik Provinsi DKI Jakarta, Statistik Daerah Provinsi DKI Jakarta 2024, vol. 16. Jakarta, Indonesia: BPS Provinsi DKI Jakarta, 2024.

[5] L. Morawska and D. K. Milton, "It is time to address airborne transmission of coronavirus disease 2019 (COVID-19)," Clinical Infectious Diseases, vol. 71, no. 9, pp. 2311-2313, 2020, doi: 10.1093/cid/ciaa939.

[6] T. Greenhalgh, J. L. Jimenez, K. A. Prather, Z. Tufekci, D. Fisman, and R. Schooley, "Ten scientific reasons in support of airborne transmission of SARS-CoV-2," The Lancet, vol. 397, no. 10285, pp. 1603-1605, 2021, doi: 10.1016/S0140-6736(21)00869-2.

[7] Kementerian Kesehatan Republik Indonesia, "Kemenkes: Kasus influenza meningkat, tetapi masih dalam rentang kewaspadaan," Press Release, Sep. 28, 2026. [Online]. Available: https://www.kemkes.go.id/id/kemenkes-kasus-influenza-meningkat-tetapi-masih-dalam-rentang-kewaspadaan

[8] J. S. Kutter, M. I. Spronken, P. L. Fraaij, R. A. M. Fouchier, and S. Herfst, "Transmission routes of respiratory viruses among humans," Current Opinion in Virology, vol. 28, pp. 142-151, 2018, doi: 10.1016/j.coviro.2018.01.001.

[9] G. Brankston, L. Gitterman, Z. Hirji, C. Lemieux, and M. Gardam, "Transmission of influenza A in human beings," The Lancet Infectious Diseases, vol. 7, no. 4, pp. 257-265, 2007, doi: 10.1016/S1473-3099(07)70029-4.

[10] K. P. Fennelly, "Particle sizes of infectious aerosols: implications for infection control," The Lancet Respiratory Medicine, vol. 8, no. 9, pp. 914-924, 2020, doi: 10.1016/S2213-2600(20)30323-4.

[11] R. Tellier, Y. Li, B. J. Cowling, and J. W. Tang, "Recognition of aerosol transmission of infectious agents: a commentary," BMC Infectious Diseases, vol. 19, art. no. 101, 2019, doi: 10.1186/s12879-019-3707-y.

[12] N. H. L. Leung et al., "Respiratory virus shedding in exhaled breath and efficacy of face masks," Nature Medicine, vol. 26, no. 5, pp. 676-680, 2020, doi: 10.1038/s41591-020-0843-2.

[13] X. He et al., "Temporal dynamics in viral shedding and transmissibility of COVID-19," Nature Medicine, vol. 26, no. 5, pp. 672-675, 2020, doi: 10.1038/s41591-020-0869-5.

[14] J. Lessler, N. G. Reich, R. Brookmeyer, T. M. Perl, K. E. Nelson, and D. A. T. Cummings, "Incubation periods of acute respiratory viral infections: a systematic review," The Lancet Infectious Diseases, vol. 9, no. 5, pp. 291-300, 2009, doi: 10.1016/S1473-3099(09)70069-6.

[15] S. Hamidi, S. Sabouri, and R. Ewing, "Does density aggravate the COVID-19 pandemic? Early findings and lessons for planners," Journal of the American Planning Association, vol. 86, no. 4, pp. 495-509, 2020, doi: 10.1080/01944363.2020.1777891.

[16] Y. Li, G. M. Leung, J. W. Tang, X. Yang, C. Y. H. Chao, J. Z. Lin, J. W. Lu, P. V. Nielsen, J. Niu, H. Qian, A. C. Sleigh, H. Su, J. Sundell, T. W. Wong, and P. L. Yuen, "Role of ventilation in airborne transmission of infectious agents in the built environment: a multidisciplinary systematic review," Indoor Air, vol. 17, no. 1, pp. 2-18, 2007, doi: 10.1111/j.1600-0668.2006.00445.x.

[17] S. N. Rudnick and D. K. Milton, "Risk of indoor airborne infection transmission estimated from carbon dioxide concentration," Indoor Air, vol. 13, no. 3, pp. 237-245, 2003.

[18] Y. Zhu, J. Xie, F. Huang, and L. Cao, "Association between short-term exposure to air pollution and COVID-19 infection: evidence from China," Science of the Total Environment, vol. 727, art. no. 138704, 2020, doi: 10.1016/j.scitotenv.2020.138704.

[19] T. Jefferson et al., "Physical interventions to interrupt or reduce the spread of respiratory viruses," Cochrane Database of Systematic Reviews, no. 1, art. no. CD006207, 2023, doi: 10.1002/14651858.CD006207.pub6.

[20] A. Wilder-Smith and D. O. Freedman, "Isolation, quarantine, social distancing and community containment: pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak," Journal of Travel Medicine, vol. 27, no. 2, art. no. taaa020, 2020, doi: 10.1093/jtm/taaa020.

[21] L. Morawska et al., "How can airborne transmission of COVID-19 indoors be minimised?" Environment International, vol. 142, art. no. 105832, 2020, doi: 10.1016/j.envint.2020.105832.

[22] D. K. Chu et al., "Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review

and meta-analysis," The Lancet, vol. 395, no. 10242, pp. 1973-1987, 2020, doi: 10.1016/S0140-6736(20)31142-9.

[23] K. Prem, Y. Liu, T. W. Russell, A. J. Kucharski, R. M. Eggo, N. Davies, M. Jit, and P. Klepac, "The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study," The Lancet Public Health, vol. 5, no. 5, pp. e261-e270, 2020, doi: 10.1016/S2468-2667(20)30073-6.

[24] R. M. Viner et al., "School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review," The Lancet Child and Adolescent Health, vol. 4, no. 5, pp. 397-404, 2020, doi: 10.1016/S2352-4642(20)30095-X.

[25] World Health Organization, Roadmap to Improve and Ensure Good Indoor Ventilation in the Context of COVID-19. Geneva, Switzerland: World Health Organization, 2021.

[26] C. R. MacIntyre and A. A. Chughtai, "A rapid systematic review of the efficacy of face masks and respirators against coronaviruses and other respiratory transmissible viruses on the community, healthcare workers and sick patients," International Journal of Nursing Studies, vol. 108, art. no. 103629, 2020, doi: 10.1016/j.ijnurstu.2020.103629.

[27] J. H. Verbeek et al., "Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff," Cochrane Database of Systematic Reviews, no. 4, art. no. CD011621, 2020, doi: 10.1002/14651858.CD011621.pub4.

[28] J. Hellewell et al., "Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts," The Lancet Global Health, vol. 8, no. 4, pp. e488-e496, 2020, doi: 10.1016/S2214-109X(20)30074-7.

[29] W. Ahmed et al., "First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: a proof of concept for the wastewater based epidemiology approach," Science of the Total Environment, vol. 728, art. no. 138764, 2020, doi: 10.1016/j.scitotenv.2020.138764.

[30] J. Peccia et al., "Measurement of SARS-CoV-2 RNA in wastewater tracks community infection dynamics," Nature Biotechnology, vol. 38, no. 10, pp. 1164-1167, 2020, doi: 10.1038/s41587-020-0684-z.

[31] J. Ginsberg, M. H. Mohebbi, R. S. Patel, L. Brammer, M. S. Smolinski, and L. Brilliant, "Detecting influenza epidemics using search engine query data," Nature, vol. 457, no. 7232, pp. 1012-1014, 2009, doi: 10.1038/nature07634.

[32] World Health Organization, "Global Influenza Surveillance and Response System (GISRS)," Geneva, Switzerland. [Online]. Available: https://www.who.int/initiatives/global-influenza-surveillance-and-response-system

[33] Kementerian Kesehatan Republik Indonesia, Decree of the Director General of Disease Prevention and Control No. HK.02.03/C/1800/2023 on the Designation of Influenza Like Illness and Severe Acute Respiratory Infection Surveillance Sites, COVID-19 Sites, and Reference Laboratories. Jakarta, Indonesia, Mar. 27, 2023.

[34] V. Demicheli, T. Jefferson, E. Ferroni, A. Rivetti, and C. Di Pietrantonj, "Vaccines for preventing influenza in healthy adults," Cochrane Database of Systematic Reviews, no. 2, art. no. CD001269, 2018, doi: 10.1002/14651858.CD001269.pub6.

[35] J. J. Van Bavel et al., "Using social and behavioural science to support COVID-19 pandemic response," Nature Human Behaviour, vol. 4, no. 5, pp. 460-471, 2020, doi: 10.1038/s41562-020-0884-z.

[36] S. Loomba, A. de Figueiredo, S. J. Piatek, K. de Graaf, and H. J. Larson, "Measuring the impact of COVID-19 vaccine misinformation on vaccination intent in the UK and USA," Nature Human Behaviour, vol. 5, no. 3, pp. 337-348, 2021, doi: 10.1038/s41562-021-01056-1.