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Epidemic Intelligence and Data Informed Risk Assessment for a System of Early Detection, Readiness, Timely Response and Recovery for Emerging and Re-Emerging Infectious Diseases: A Synthesis of Health System Research and Contextual Knowledge in the COVID-19 Pandemic

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Centre for Health Systems & Policy Research

Health Research Symposium 2024 (26 Nov 2024)

Research Questions for Pandemic Preparedness, Responses and Control

- **How effective** is Hong Kong's **Preparedness and Response Plan** for **Infectious Disease Outbreak** developed for precedent pandemics for the Covid-19 pandemic?
- What **adaptations** are required for the characteristics of the new agent?
- What **Public Health and Social Measures (PHSM)** will be required, will there be **barriers in their implementation** and what will be their **effect and impact**?
- How may **health systems** be better **ready for dynamic changes** in transmission patterns and **resilient in a protracted pandemic**?
- Does **Community Resilience** be considered in calibrating the Public Health and Social Measures?
- How can the **Preparedness and Response Plans** be **Enhanced** for better control?
- Are there **lessons to be learnt** for future Preparedness Plans for Pandemics?

- In an outbreak of a novel emerging infectious disease when evidence is limited and uncertain and expert advice is contested, what **types and sources of information** can be collated, analyzed and synthesized to generate **codified and tacit knowledge for 'Epidemic Intelligence'** ?
- How can the intelligence generated be used in a **risk assessment system to inform decisions** for response and control?

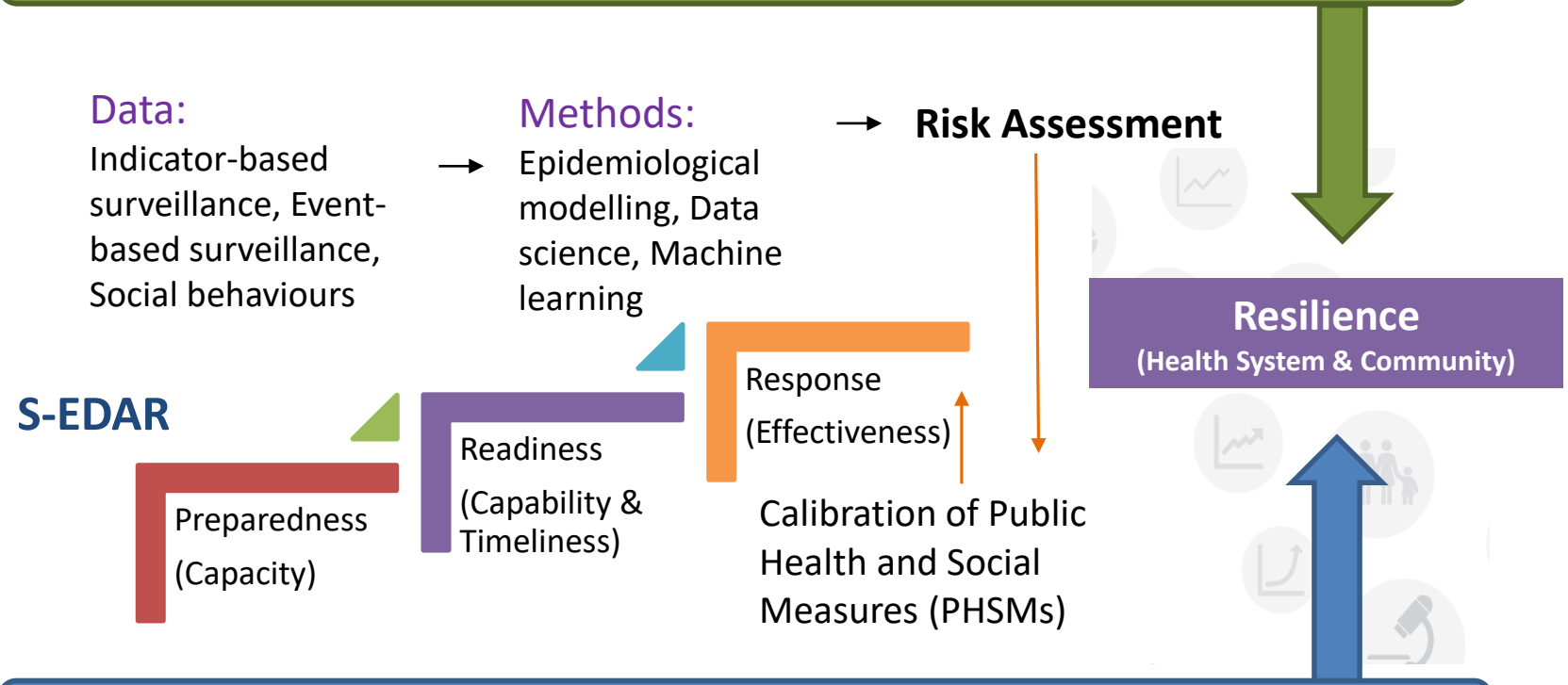
Commissioned Research on the COVID-19

- Investigation of **Hong Kong's early detection, assessment and response (S-EDAR) system** to the new emerging infectious disease outbreak COVID-19 *(COVID190105)* (May 2020 – Jan 2024)
  - Early pandemic
  - Extended phases

- **Epidemic Intelligence and a data informed risk assessment system** to **inform policy decisions** critical for maintaining systems control of COVID-19 in strategies to enhance recovery *(COVID19F03)* (1 April 2021 – 31 March 2024)

We acknowledge the Health and Medical Research Fund of the Health Bureau, HKSAR for the funding support.

Epidemic Intelligence and a data informed risk assessment system to inform policy decisions critical for maintaining systems control of COVID-19 in strategies to enhance recovery *(COVID19F03)*



Investigation of Hong Kong's early detection, assessment and response (S-EDAR) system to the new emerging infectious disease outbreak COVID-19 *(COVID190105)*

Objectives & Methodology

Investigation how Hong Kong's early detection, assessment and response (S-EDAR) system can be enhanced for the control of a protracted pandemic across different transmission scenarios to inform further preparedness and response

Objectives

1. **Develop a system of early detection, assessment and response (S-EDAR)** based on the lessons learnt in the trajectory of different waves in the COVID-19 pandemic

2. **Review of international literature and overseas experiences** in the trajectory of the protracted pandemic to gain insights for a system to calibrate Public Health and Social Measures (PHSMs), and health system and community resilience

3. Include **readiness and health system and community resilience** in the enhanced S-EDAR based on the lessons learnt

A sequential Multi-Level Mixed Methods

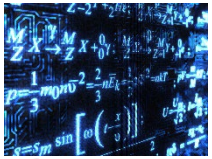
1. **Literature and policy documents review** on (a) the system for early detection, readiness, assessment and response, and b) effectiveness, calibration and adjustment, and impact of public health measures on health system and community resilience;
2. **Expert workshops** to develop the initial components of the enhanced system, and reviewed by international experts;
3. **Comparative case studies** of (a) control, policies, measures, and (b) how health systems adapted and transformed in subsequent transmission waves in 8 jurisdictions;
4. **Modelling studies** for control measures;
5. **Key informant interviews** and **focus groups** in early and later stages of pandemic to investigate barriers and facilitators in implementation and impact of the control measures to inform modified components;
6. **Group Delphi** to affirm the importance and feasibility of the components of the final S-EDAR framework.

Epidemic Intelligence and a data informed risk assessment system to inform policy decisions critical for early detection, readiness, and rapid response in the control of COVID-19 and strategies to enhance recovery

Objectives

1. **Identify evidence, knowledge and information gaps** for the detection and control of different transmission stages in the epidemic, and

2. **Identify tools to source near-time data** from operational systems and knowledge and information from multiple sources in diverse disciplines which can be collated, analysed and synthesised to generate "epidemic intelligence" (EI) for risk assessment to inform policy decisions.



Iterative Multi-Stage Mixed Methods

1. **Literature review** for infectious disease hazard risk and to evidence needs and gaps for policy decisions for outbreak detection and control;
2. Collate and synthesise findings from two in-depth studies of decision making for risk assessment and outbreak management in two **International visits;**
3. **Secondary data analysis** from DH and HA on epidemiological characteristics and case control, management and capacity, and health service utilisation;
4. **Public surveys** to understand public perceived susceptibility and protective behaviour;
5. **Longitudinal surveys** in the pandemic trajectory and **Individual interviews** to understand perceived risks and resilience of foreigner domestic helpers, subdivided unit residents, and nurses;
6. **Big data analytics** of user-generated content in social media platform to investigate the patterns and consequences of pandemic information and disinformation;
7. **Mathematical modelling** for risk assessment and surge capacity;
8. **Artificial intelligence** to generate epidemic intelligence for potential risk impact of COVID-19

Data Sources

- **Literature reviews including scoping studies** on effectiveness of PHSM and Readiness

- **Comparative case study:** Australia (New South Wales & Victoria), Hong Kong SAR, Japan, Malaysia, Singapore, Shanghai & South Korea

- **Key stakeholders:** Policy makers, healthcare administrators, business sector, elderly & disability institutions, social & support services (NGOs), healthcare professionals including doctors, nurses, pharmacists, patient groups, and vulnerable communities of subdivided unit residents, foreigner domestic helpers, ethnic minorities, elderly living alone, immunocompromise

- **User-generated contents in Social Media**

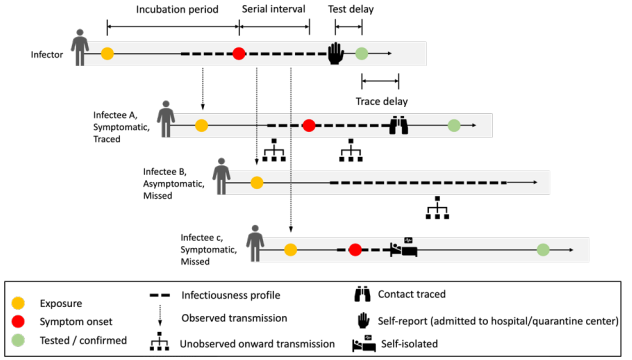
- **Data from Department of Health and Hospital Authority**

Results

Infectious Disease Modelling

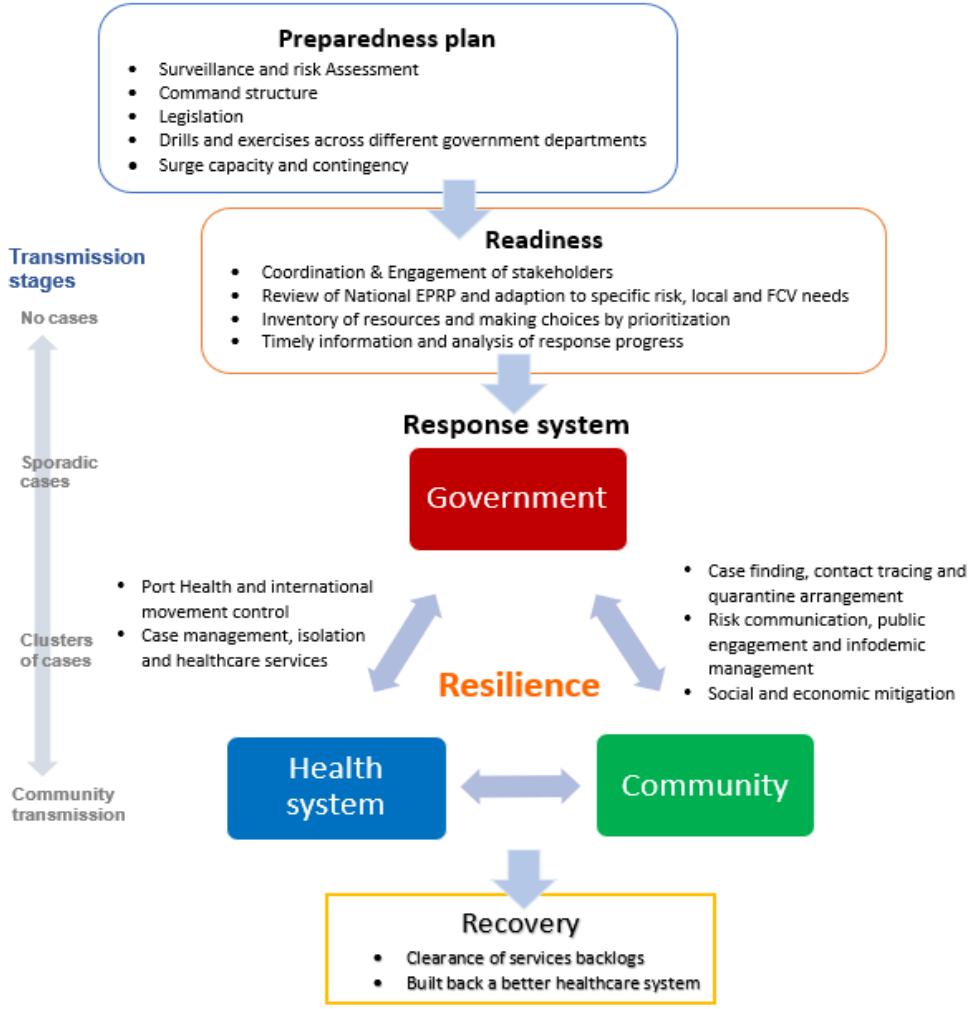
- System dynamic modelling to **assess the risk of local COVID-19 outbreaks among different border screening strategies and inbound passenger volume** (in early stage of pandemic)
  - A deterministic model to depict the transmission dynamics when infected inbound travellers seed an epidemic in the local population:
  - Population-based vaccination campaign are necessary to be imposed on top of border screening strategies (PCR and RAT), to reduce the infection risk of the local population when resuming the international travel network in a long run

- Modelling analysis on the **contract tracing effectiveness** (in later stage of pandemic)
  - Effectiveness of contract tracing highly depends on the disease transmissibility
  - Vaccination coverage, adherence of self-reporting, and proportion of cases traced play a lesser role in affecting the potential of large outbreak in Omicron
  - When transmissibility similar to the influenza and delta variant, especially when the proportion of vaccinated population is not high, a sufficient capacity of tracing (e.g., >80% of cases traced) is likely to contain the large outbreak given a good self-reporting level



4-Phased Enhanced Whole-of-Society S-EDAR

Based on synthesis of research findings from published literature, deliberations from local experts, inputs from international experts and policymaker / stakeholder interviews, using a consensus building process i.e., Deliberative Group Delphi



Enhanced System of Early Detection, Assessment & Response (S-EDAR)

14 domains covering 37 recommendations

Section A: PREPAREDNESS (19 recommendations)

Domain 1: Surveillance and risk assessment
Domain 2: Command structure
Domain 3: Regulation
Domain 4: Drills and exercises across different gov't depts and private sector
Domain 5: Surge capacity and contingency

Contingency plan when surge capacity is exceeded

Structure, actions and processes and roles of government, business and civil society for responding to an undefined public health emergency in a whole-of-society approach

Section B: READINESS (1 recommendation)

Domain 6. Include readiness into the preparedness and response plan based on seven subdomains of the "Operational Readiness Framework" *(see next slide)*

Defined as an intermediate state when a specific defined threat is imminent to ensure the timely development of the capacity and capability for rapid operation response

Integrated surveillance and early waring system to enable readiness. Promptly adapt the preparedness plan to tackle specified threat, linking preparedness to rapid response

Section C: RESPONSE (15 recommendations)

Domain 7: Case finding, contact tracing and quarantine arrangement
Domain 8: Case management, isolation and healthcare services
Domain 9: Social/ physical distancing and community quarantine
Domain 10: Port Health and international movement control
Domain 11: Risk communication, public engagement and infodemic management
Domain 12: Social and economic mitigation

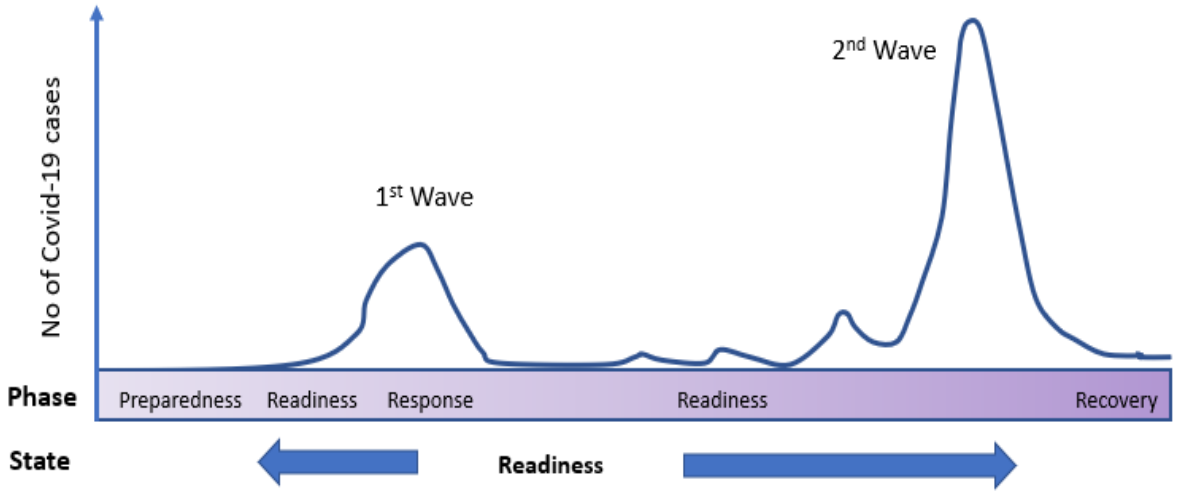
Coordination, implementation strategies at government, healthcare and community levels, and engagement of society. Risk communication for infodemic management

Section D: RECOVERY (2 recommendations)

Domain 13: Recovery plan for normalization of services and clearing back log
Domain 14: Review and build back better

Clearance of services backlogs. After action review to identify the lessons learnt and "build back better" for a resilient health system

Conceptualization of Readiness as a “state”



Hypothetical diagram of a COVID-19 pandemic phases transition

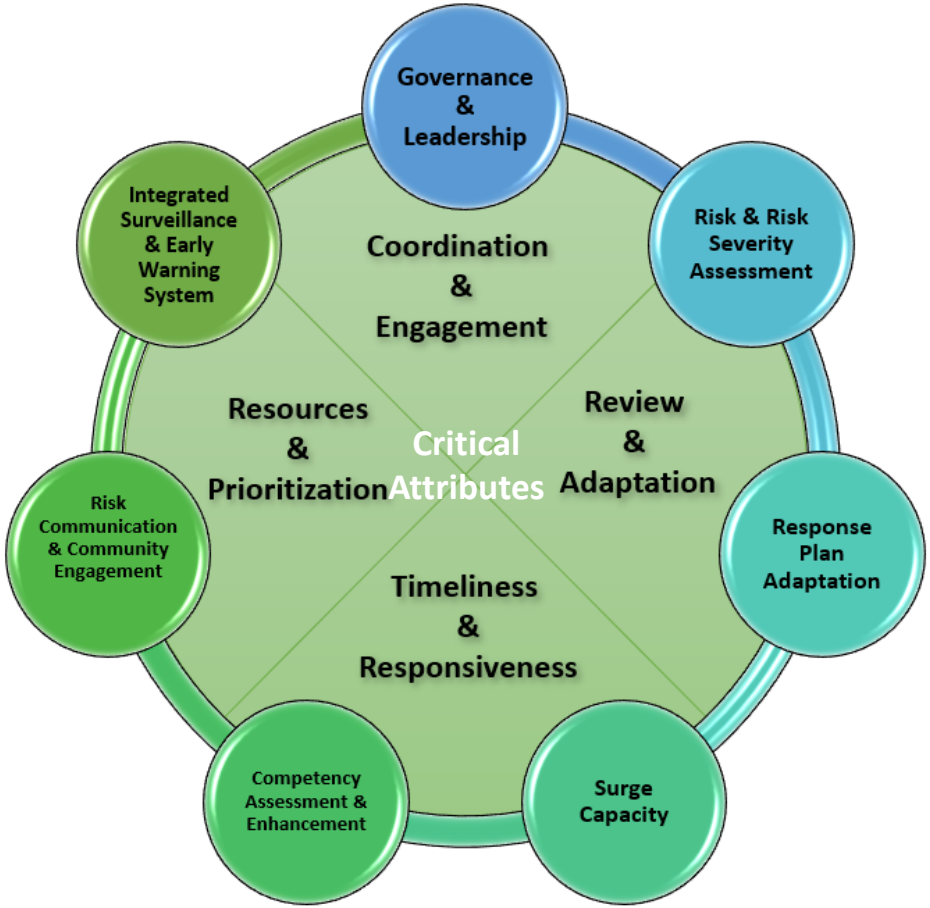
Conceptualization would better serve infectious disease outbreak and pandemic as a “state” for hazards and the changing and unanticipated host, agent and environmental dynamics.

Readiness

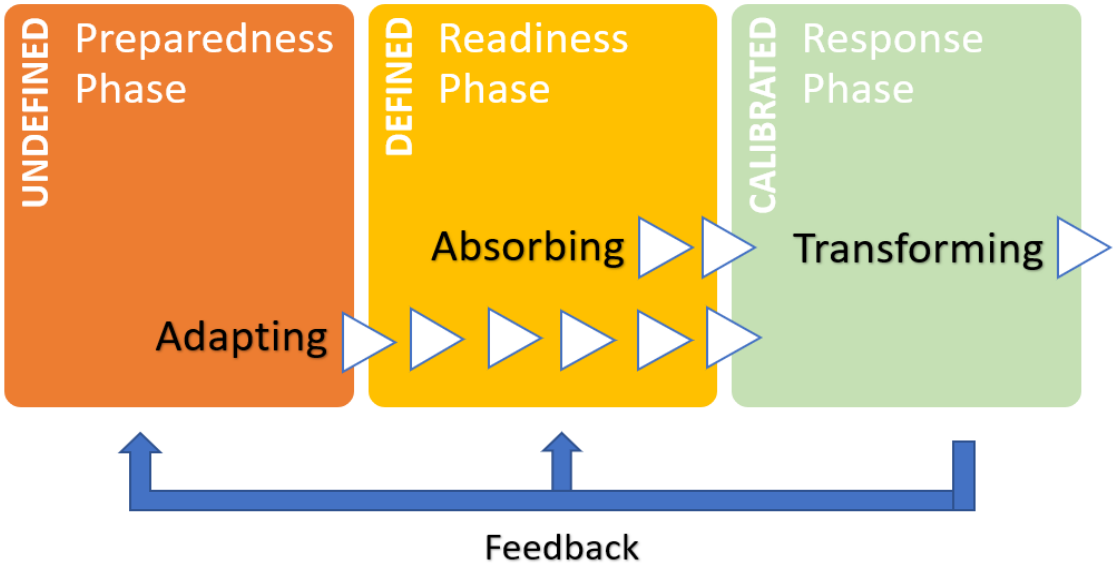
- WHO has differentiated the preparedness and readiness phases, which facilitates the response efficiency
- Synthesis of an Operational Readiness Framework of 7 domains & 4 attributes

- Conceptualization of readiness as a “state” facilitates health system resilience building

Key focuses and activities of 7 domains



Operational Readiness facilitates Health System Resilience



- A generalized and **UNDEFINED** preparedness plan is adapted and modified to a **DEFINED** readiness plan per local context and the threat.
- It delivers **CALIBRATED** responsive controls to absorb the threat. It learns via regular reviews and transform the system.

Resilience development on the operational level of National Emergency Preparedness-Readiness-Response Plan (EPRRP) management

Community Resilience in a Pandemic

- Community resilience is *the ability of communities and groups to adapt and thrive in response to external stressors* (WHO 2018)
- **Five capacities:**
  - Mitigation >> minimize damages and casualties
  - Absorption >> absorb the shock
  - Recovery >> restore normal functions
  - Adaptation >> adjust from the shock
  - Transformation >> developmental process into sustainable situation
- **Factors:** Level of social capital*, economic development, community infrastructure, the availability of communication and information management channels, level of community preparedness and community members wellbeing

*Remark: It refers to the trust, norms, and social networks that plays in solving communities' problems. It builds via commitments, solidarity, and communication between citizens and the government.

Enhanced System of Early Detection, Assessment & Response (S-EDAR)

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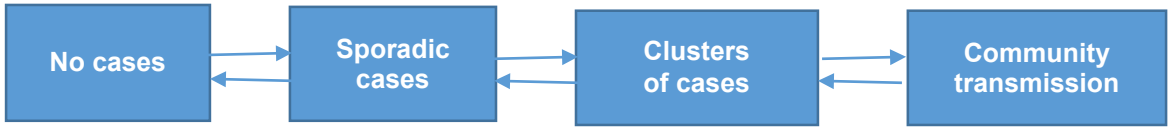
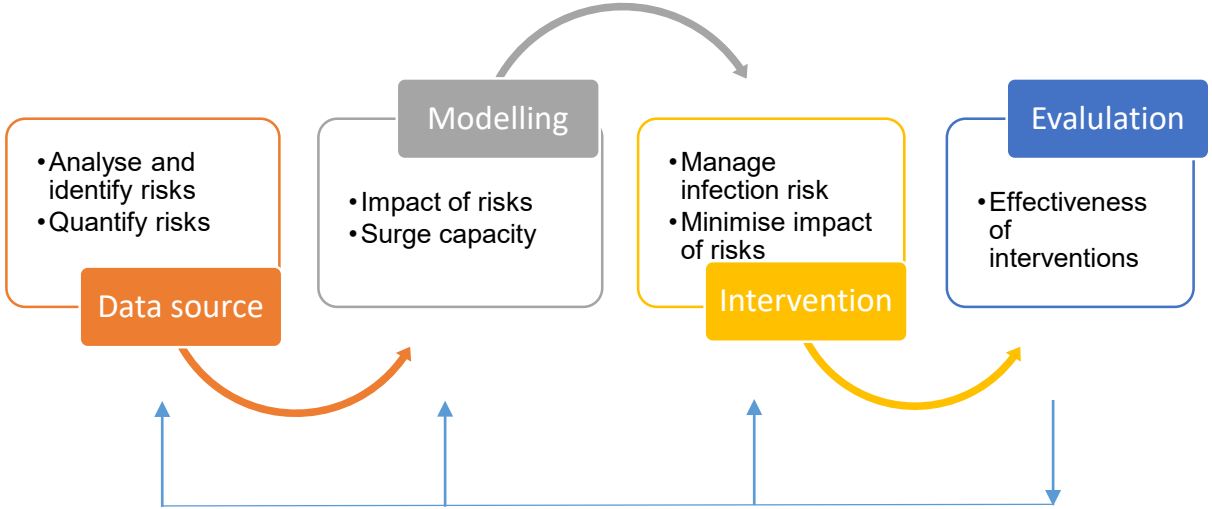
Epidemic Intelligence and a data informed risk assessment system to inform policy decisions, critical for early detection, readiness, and rapid response in the control of COVID-19 and strategies to enhance recovery

Risk Assessment

Different transmission stages of the epidemic



Evidence gaps – Epidemic intelligence



Covid-19 Risk Assessment Framework

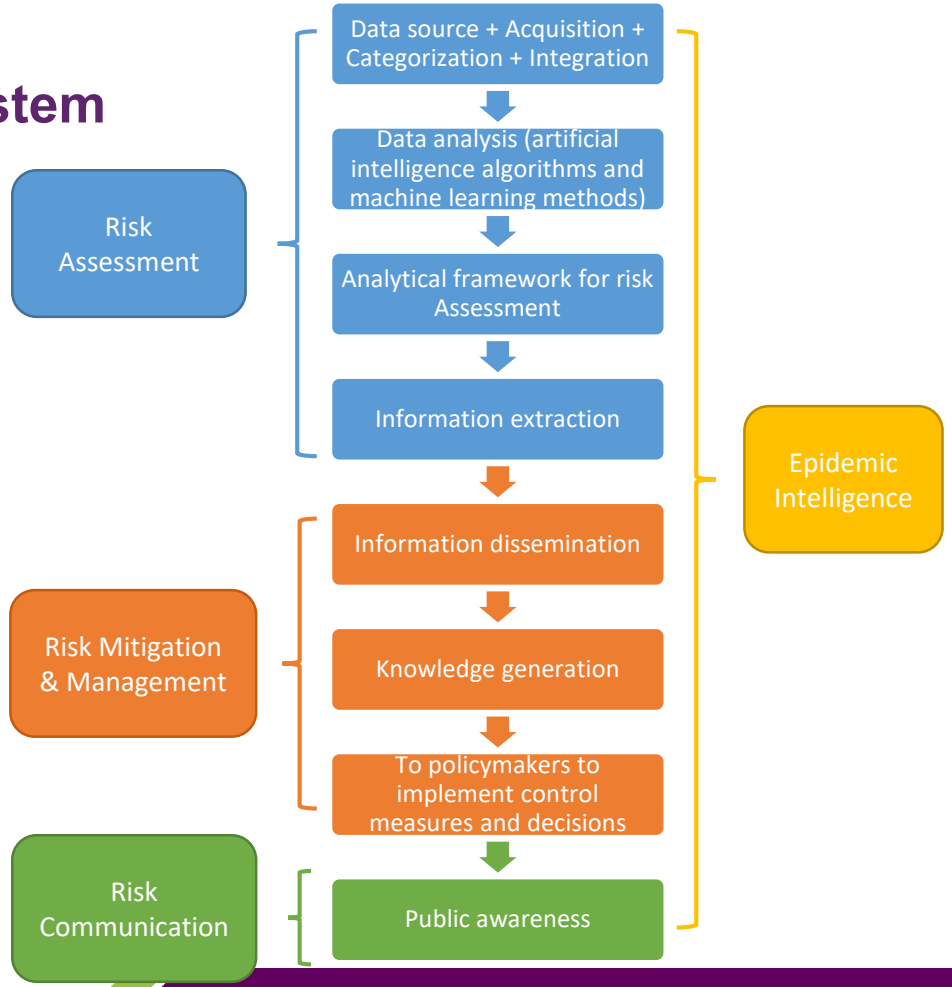
Epidemic Intelligence and A data informed risk assessment system

Intelligence

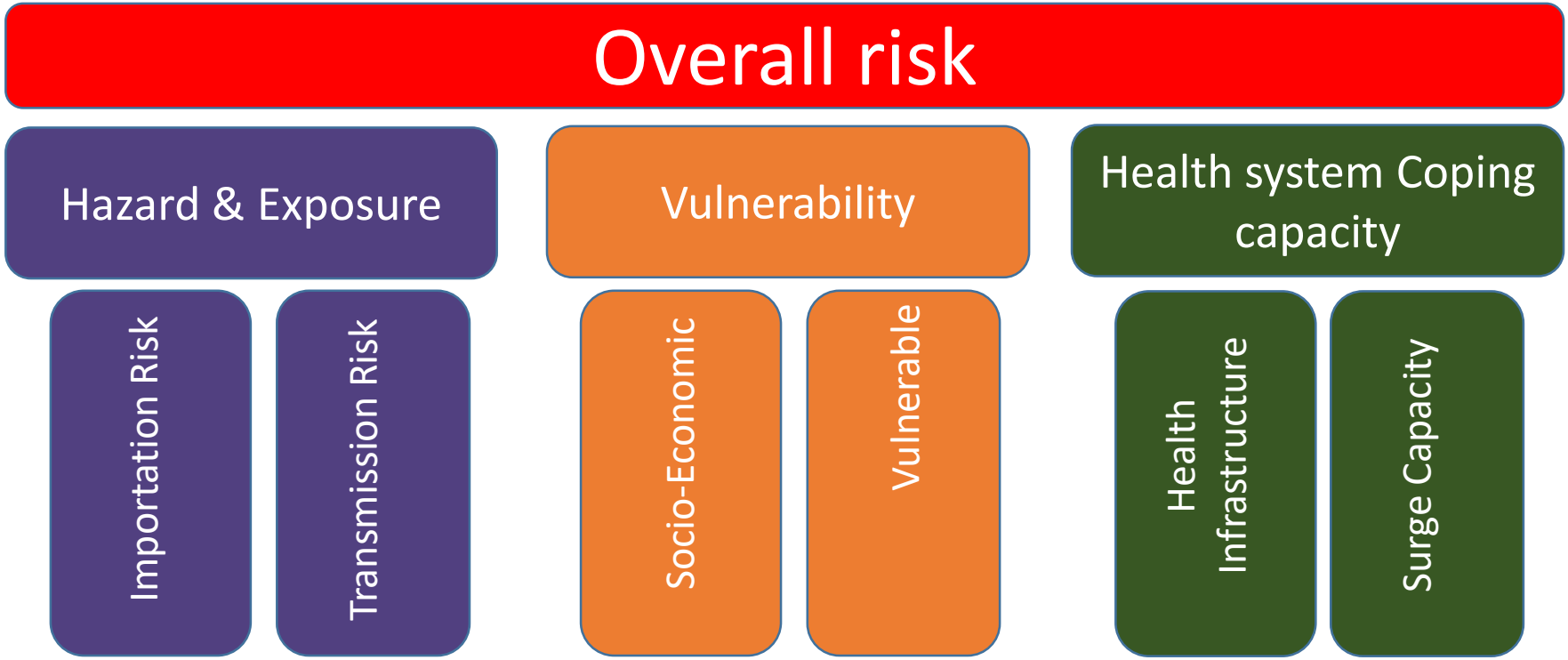
- A process in which information is collected, analyzed and converted to gain insights.

Epidemic intelligence

- Application of principles of intelligence to public health for systematic early detection of health related events, their verification, assessment and investigation so that appropriate public health control measures can be recommended.



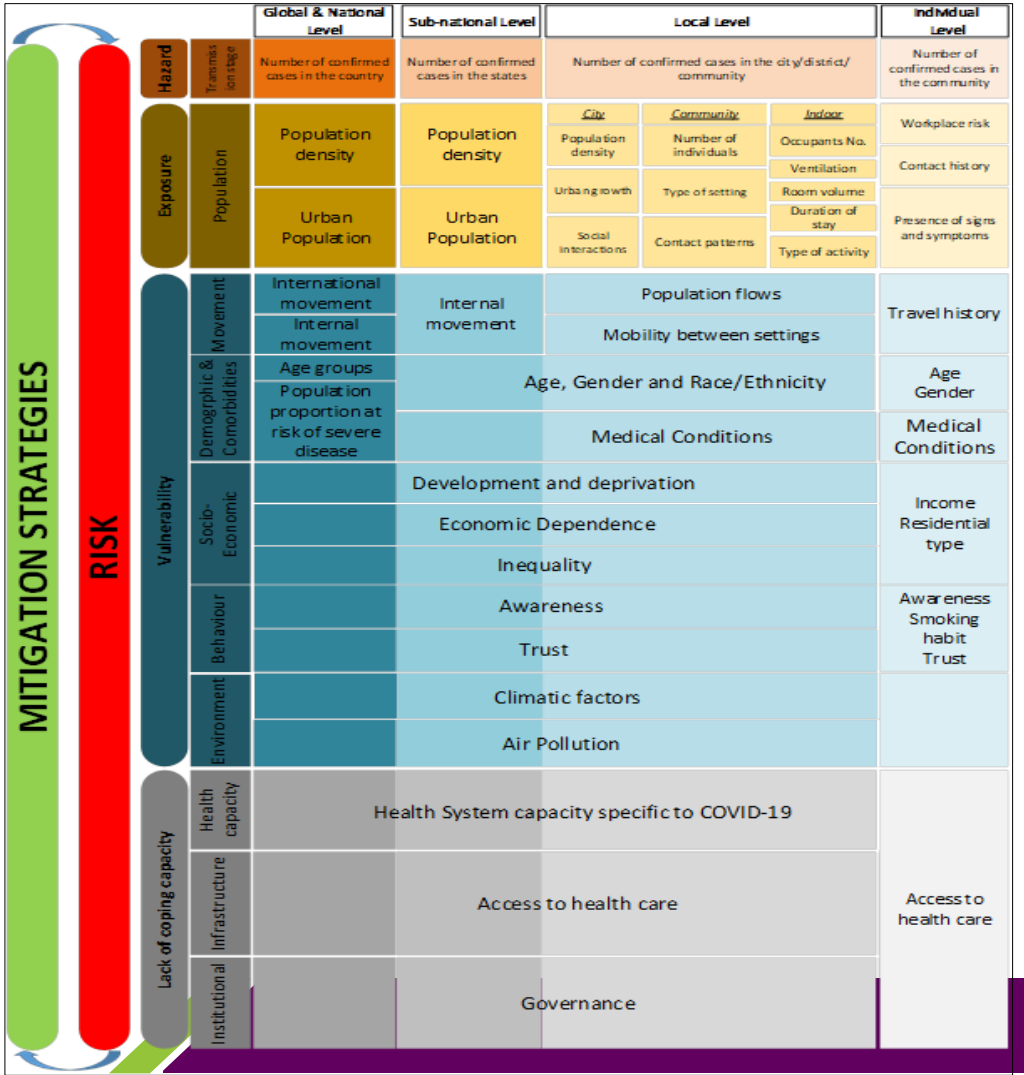
Risk assessment framework



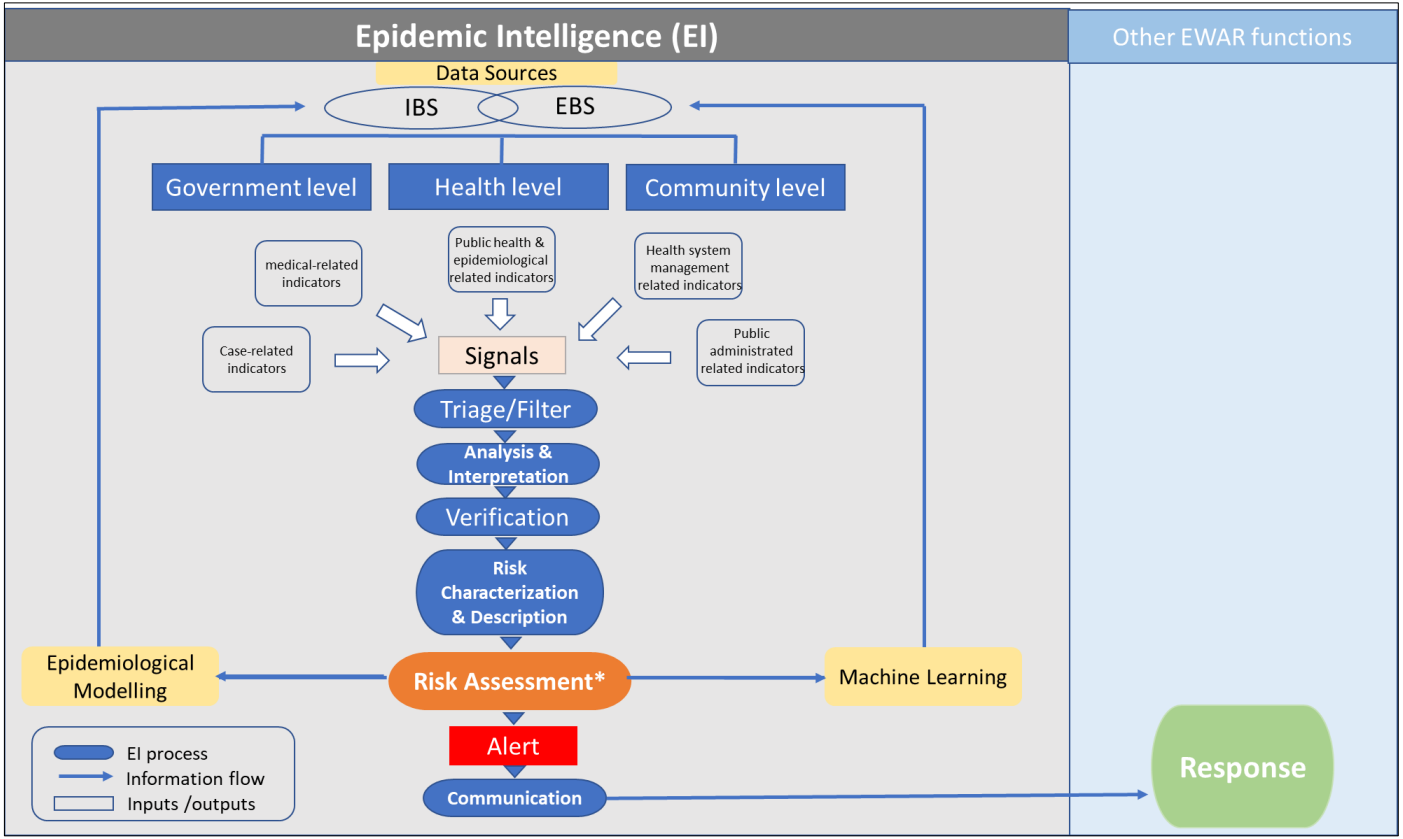
Multi-level COVID-19 risk Assessment Framework

Comprehensive consideration and integration of

- Accounted for spatial and temporal difference
- Data collection at global, national, local and individual levels
- Linking the critical risk dimensions of hazard, exposure, vulnerability & lack of scoping capacity
- Considerations of government mitigation strategies



A contextualized EI System for Risk detection, Characterization and Assessment



The system captures data from diverse types and sources of data at global, national, local and individual levels from both Indicator-based (IBS) and Event-based Surveillance (EBS), linked and structured to enable analysis, interpretation, verification, characterisation and assessment of risk and the impact.

IBS, EBS: Indicator- & Event-based surveillances
EWAR: Early warning Alert Response

Key Data Acquisition and Categorization for Epidemic Intelligence

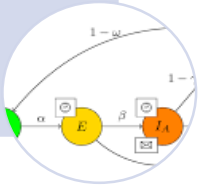
- Identifying information needs from policy perspectives before data collection
- Different data types
- Quantifying data completeness and timeliness
- Connect multiple data streams to build higher quality data

Individual level data	Exposure-level data	Population-level or metadata	Country level data
•Case line-list •Demographics •Morbidity •Mortality	•Individual behavior •Contact tracing •Transmission heterogeneity across different settings and groups	•Population sizes •Mobility •Seroprevalence •Social Behaviours •Morbidity & Mortality rates	•Infection prevention control capability •Case Management Capacity •Recording intervention efforts across time and space •Evaluating intervention efficacy •Healthcare capacity •Socio-economic cost & Impact

Data Analytics: Data source - HA, DH, Survey, Mobility & Social Media

Infectious disease modelling to inform adjustment of PHSMs during a resilience from Omicron outbreak

- Characterization of **unlinked cases** of COVID-19
- Omicron **superspreading potential**
- Comparing **epidemiological characteristics** among Omicron, Delta, BA variants
- **Real-time tracking** of the superspreading potential

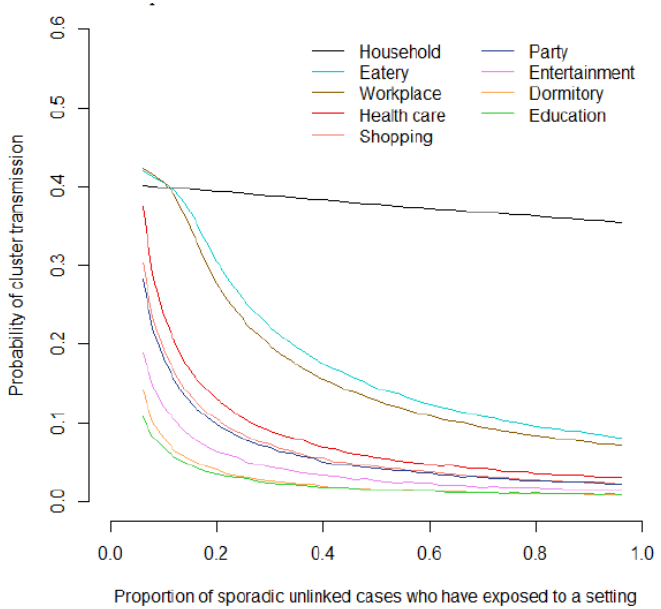


Analyses and synthesis as information or epidemic intelligence to inform public health control strategies

- Utilizing **dining-out mobility as a proxy** for **superspreading**
- Evidence-based **big data analytics of vaccine effectiveness**
- Real-world evidence of **drug interaction** with COVID-19 severity

Characterization of Unlinked Cases of COVID-19 and Implications for Contact Tracing Measures

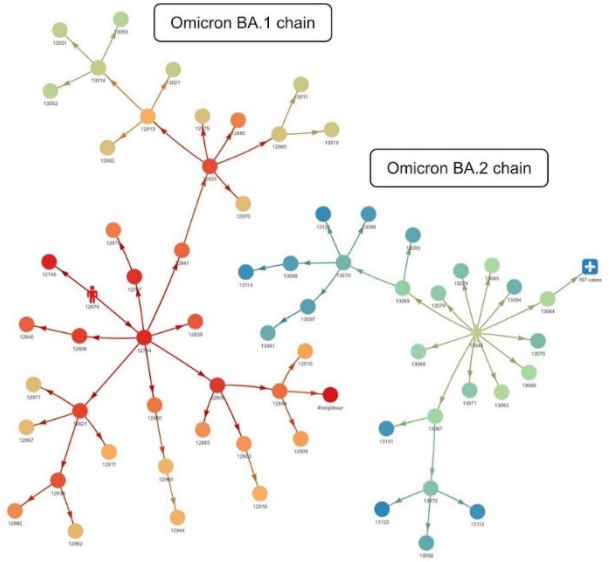
- Eateries and workplaces had high outbreak potentials compared to other settings, with probabilities ranging from around 0.1-0.4 under different values of p_u
- Health care, shopping, and party settings were particularly sensitive to p_u and could have a secondary transmission probability of >0.3 if a small proportion of sporadic unlinked cases had been involved in these settings (ie, low p_u).



Chong KC, Jia K, Lee SS, Hung CT, Wong NS, Lai FTT, Chau N, Yam CHK, Chow TY, Wei Y, Guo Z, Yeoh EK. **Characterization of Unlinked Cases of COVID-19 and Implications for Contact Tracing Measures: Retrospective Analysis of Surveillance Data.** JMIR Public Health Surveill 2021;7(11):e30968
doi: 10.2196/30968 PMID: 34591778

Superspreading Potential of COVID-19 Outbreak Seeded by Omicron

- The Omicron variant exhibited **high superspreading potential** even though stringent public health interventions in January 2022.
- The estimated transmission heterogeneity is higher than the wild strains that prevailed in 2020.
  - Based on two case clusters seeded by the Omicron variants, only 20.3% of the **most infectious cases** generate 80% **of all transmissions**. The **probabilities of observing superspreading events** seeded by Omicron BA.1 and Omicron BA.2 are 4.9% (95%CrI: 1.4%-8.7%) and 6.4% (95%CrI: 3.5%-8.5%), respectively.
  - The risk of **observing more than three generations of infections** in the current epidemic is 20.7%, with a risk of **observing a large outbreak** (>=100 cases) seeded by one case as 12.3%.



Guo Z, Zhao S, Lee SS, Mok CKP, Wong NS, Wang J, Jia, KM, Wang MH, Chow TY, Chong KC, Yeoh EK. **Superspreading potential of COVID-19 outbreak seeded by Omicron variants of SARS-CoV-2 in Hong Kong**. Journal of Travel Medicine. 2022 Apr 18;taac049.

Big Data Analytics to Examine User-Generated Contents in Social Media Platforms

- Engaged a data solutions company in August 2021 to assist in the big data analytics to examine the user-generated contents in social media platforms for the development of a novel method for generating epidemic intelligence

Development of

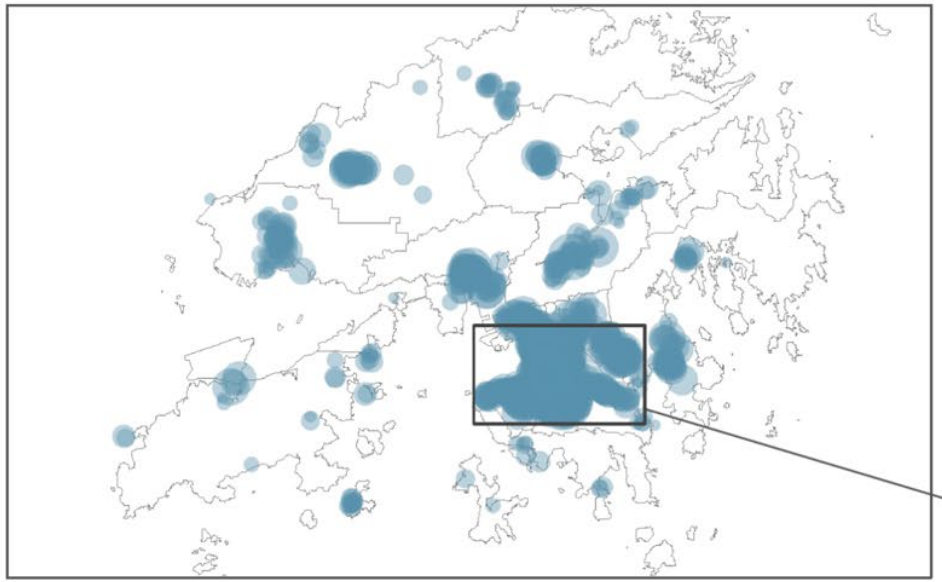
a) An integrated data platform such as data lake and data warehouse to conduct big data analytics based on raw data;

b) A distributed scraper system to ingest a large variety of information and social network data for the data platform; and

c) A content portal to publish and distribute findings and insights on epidemic intelligence to all stakeholders, especially the public

OpenRice Network Analysis provides insights of social behaviors on virus transmission

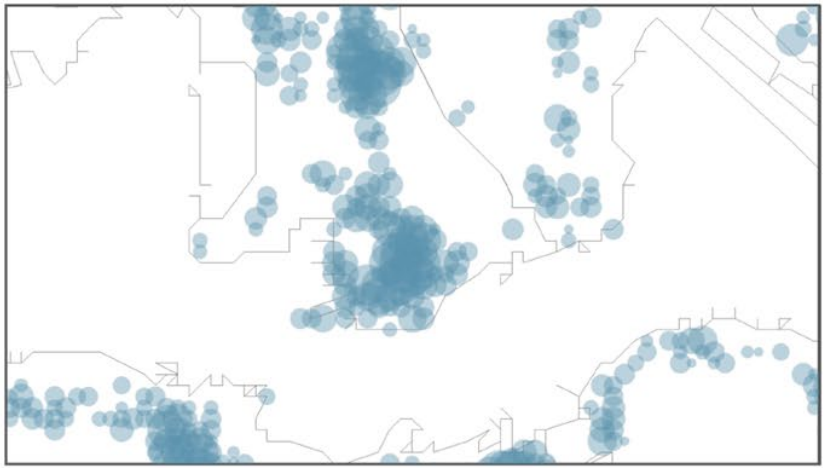
Eatery mobility heatmap



Hong Kong

Dining out popularity is a close measure of people's mobility. The eatery mobility data aggregated from openrice's number of comment by time shows what areas are potentially at risk due to crowd gathering.

YTM area

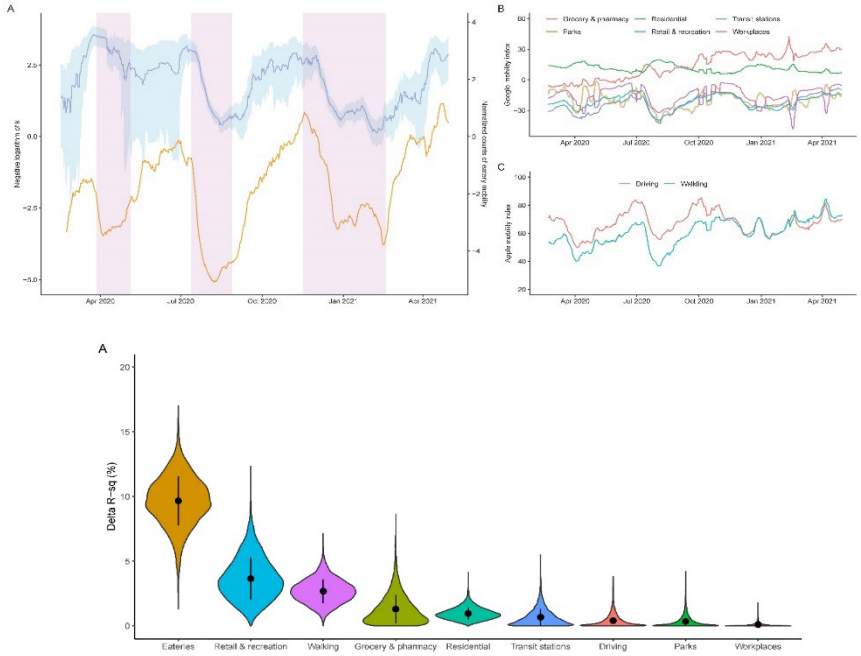


Dining-out Behavior as a Proxy for Superspreading Potential

- We employed the **mobility proxy of dining-out in eateries** to examine this association in Hong Kong with COVID-19 outbreaks highly characterized by superspreading events.

- A high correlation between dining-out mobility and superspreading potential was observed. Compared to other mobility proxies derived by Google and Apple Inc, the mobility of dining-out behavior explained the highest variability.

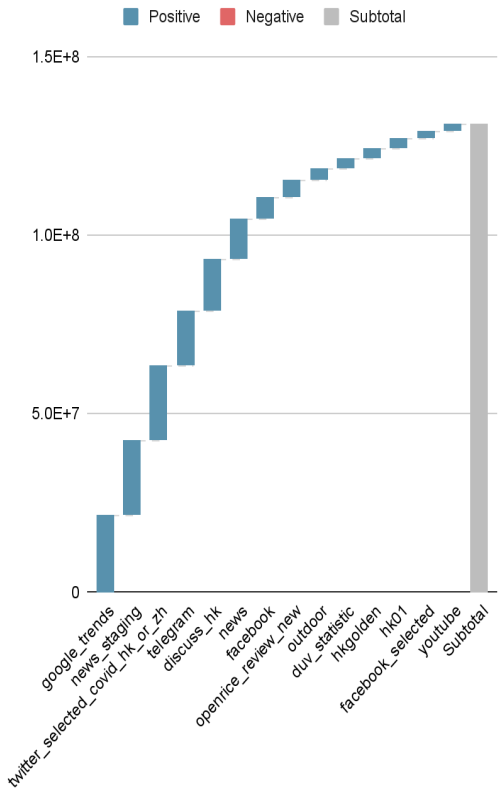
- We demonstrated that there was a strong link between dining-out behaviors and the superspreading potential of COVID-19. The methodological innovation suggests a further development utilizing digital mobility proxies of dining-out patterns to generate **early warnings** of superspreading events.



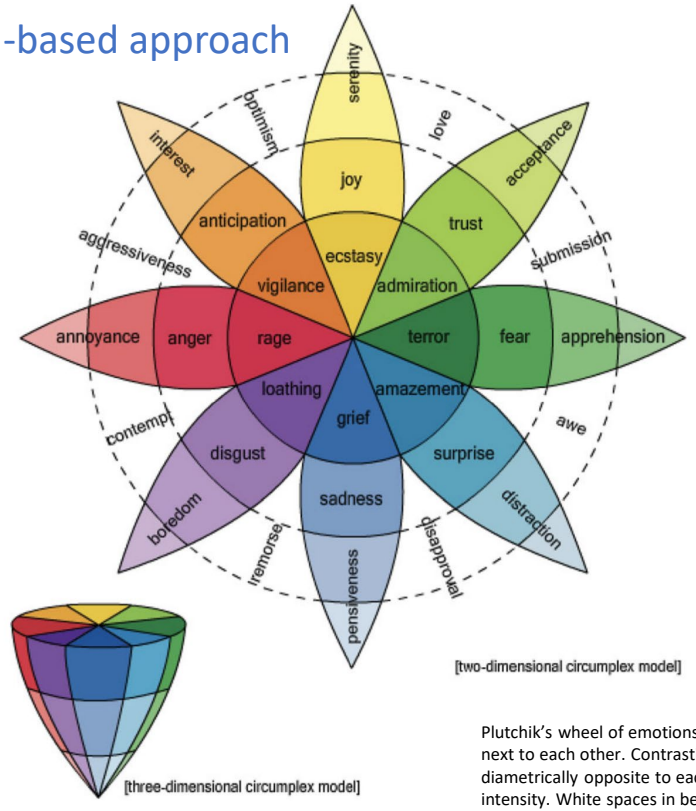
Chong KC, Li K, Guo Z, Jia KM, Leung EYM, Zhao S, Hung CT, Yam CHK, Chow TY, Dong D, Wang H, Wei Y, Yeoh EK. . **Dining-out behavior as a proxy for superspreading potential of SARS-CoV-2 infections: Modelling analysis**. . Under review.

Sentiment analysis of social media with Cantonese emotion lexicon

Acquisition: 158 million records in warehouse (+4M from June 2023, mainly news media)

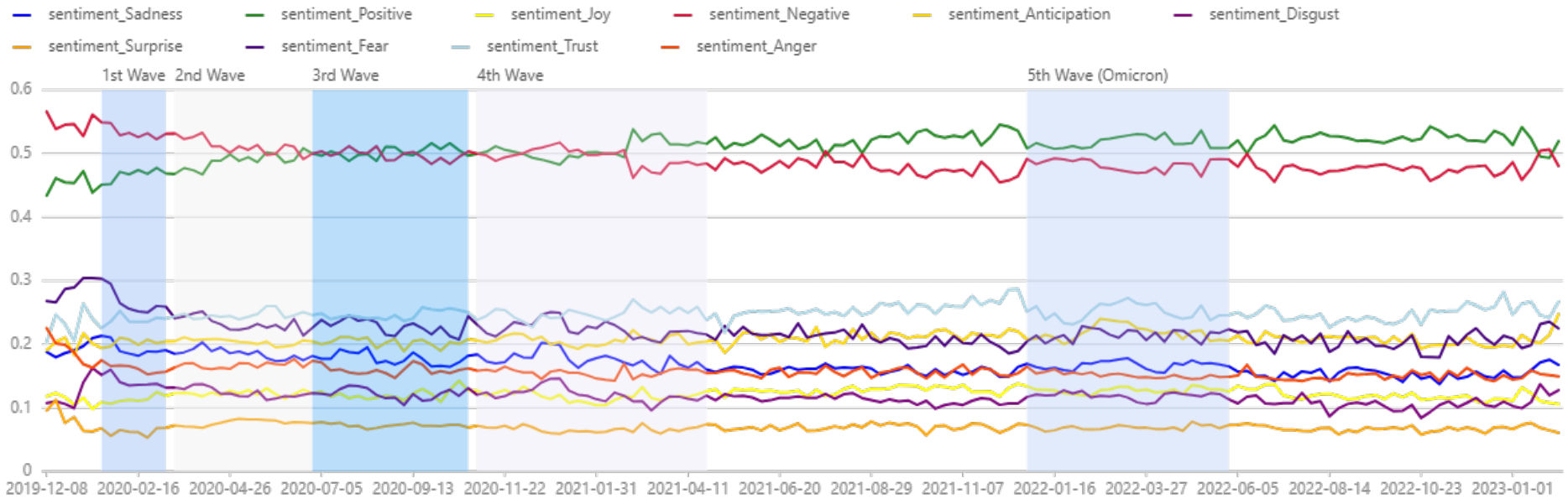


Lexicon-based approach



Plutchik's wheel of emotions. Similar emotions are placed next to each other. Contrasting emotions are placed diametrically opposite to each other. Radius indicates intensity. White spaces in between the basic emotions represent primary dyads—complex emotions that are combinations of adjacent basic emotions. [1]

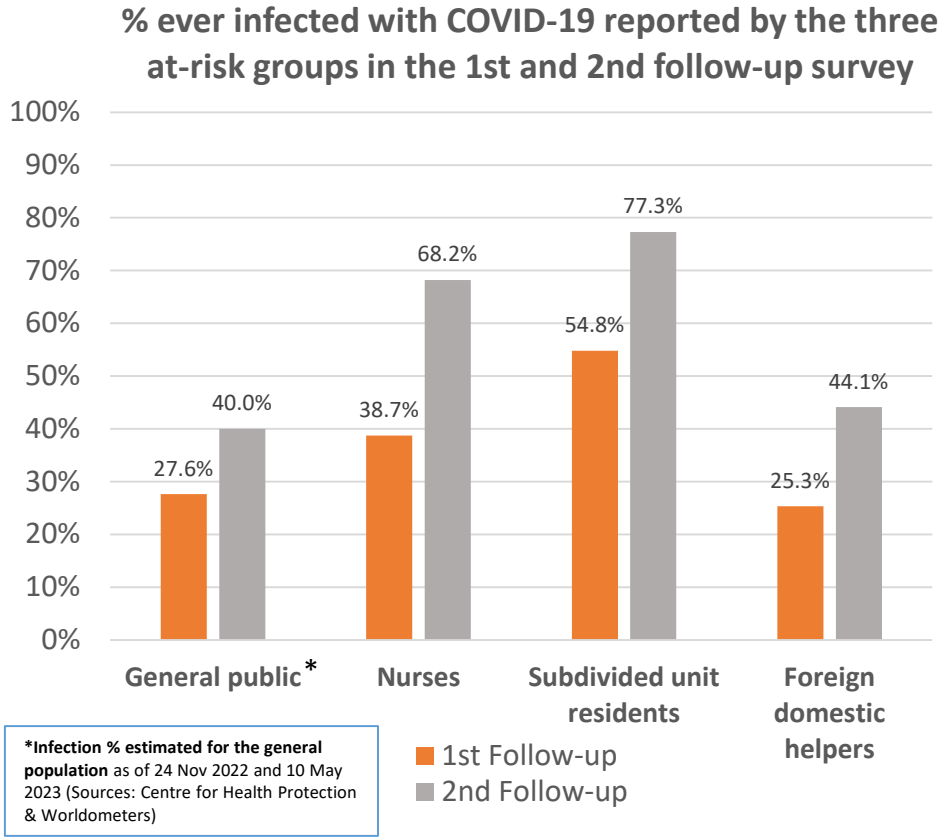
Sentiment related to COVID-19 policy (by type and by time)



Population Survey & Longitudinal Survey for three at-risk groups

COVID-19 Infection

- Baseline (5th wave, Dec 2021 - May 2022)
  - 1,150 general public
  - 1,014 nurses
  - 651 subdivided unit residents
  - 621 foreign domestic helpers
- 1st Follow-up for three at-risk groups (End of 5th wave, Sep - Nov 2022)
  - 865 nurses
  - 512 subdivided unit residents
  - 544 foreign domestic helpers
- 2nd Follow-up for three at-risk groups (End of pandemic, Apr – May 2023)
  - 796 nurses
  - 432 subdivided unit residents
  - 347 foreign domestic helpers



***Infection % estimated for the general population** as of 24 Nov 2022 and 10 May 2023 (Sources: Centre for Health Protection & Worldometers)

Population Survey & Longitudinal Survey for three at-risk groups

Risk Perception

Significant reductions in perceiving serious/very serious effect on health if infected

% of feeling serious/ very serious effect on health if infected

	Baseline	1st follow-up	2nd follow-up
SDU residents	88.3%	73.5%	61.1%
Nurses	51.0%	32.8%	31.1%
FDHs	47.8%	40.0%	28.2%

Baseline (5th wave, Dec 2021 - May 2022)

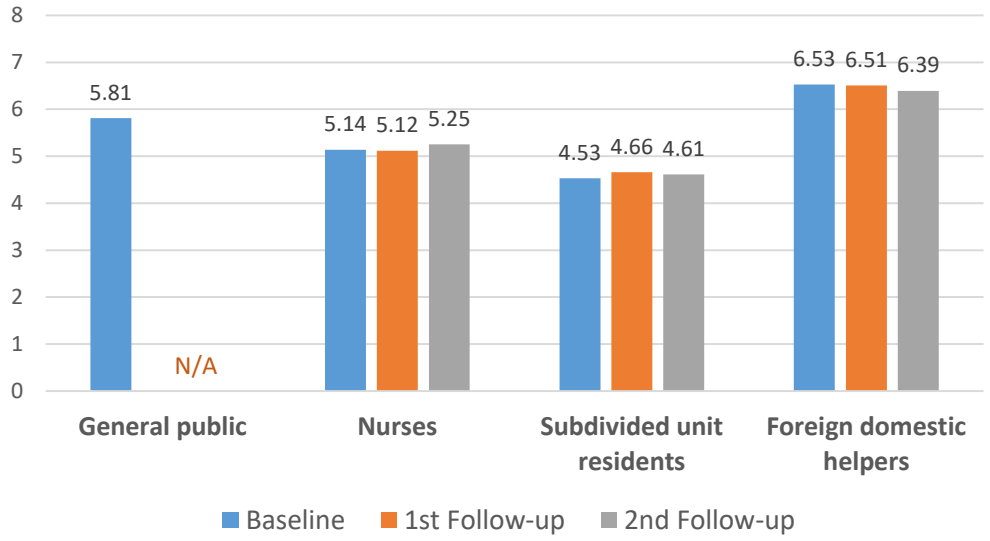
1st Follow-up for three at-risk groups (End of 5th wave, Sep - Nov 2022)

2nd Follow-up for three at-risk groups (End of pandemic, Apr – May 2023)

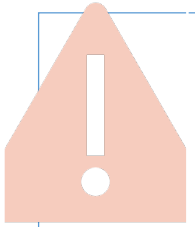
Well-being

Resilience

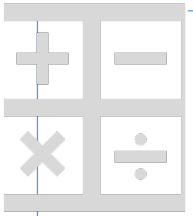
(measured by CD-RISC2, score range 0-8, higher scores means greater resilience)



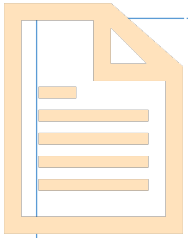
Epidemic Intelligence and A data informed risk assessment system



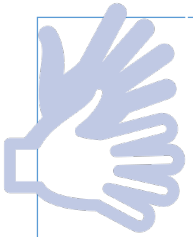
•Using machine-learning methods for epidemic intelligence and the risk assessment framework, information on risk levels can be generated in order to provide analyses for government's decisions



•Infectious disease modelling studies incorporating risk and intervention policies over different time periods also fulfill information needs of policy makers



•Inform decision for mitigation and management



•Strategies for risk communication and public involvement

Conclusion

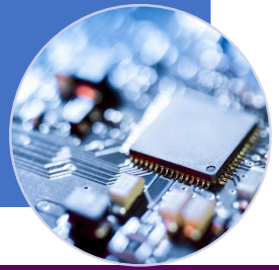
Conclusion

- A robust evolutionary system to enable **preparedness, operational readiness, timely response** for strengthening health system and community resilience for future pandemics
- Highlights **critical readiness** and **health system & community resilience** based on the lessons learnt in the trajectory of different waves in the pandemic

Enhanced S-EDAR

- To **source near-time data** from diverse disciplines, which can be collated, analysed and synthesised to generate “epidemic intelligence” for risk assessment to inform policy decisions
- **Investments in data linkage infrastructures and automation modernisation** are critical for early detection and risk assessment of health hazards to inform decision-making.
- To invest in **capacities and capabilities for IBS and EBS surveillance systems** and collaborate with animal health surveillance, guided by the One Health perspective.

Epidemic Intelligence and data informed risk assessment system



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