Unveiling Transboundary Challenges in The Ciliwung River Flood Management

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Abstract

Due to massive development in urban and rural areas of Greater Jakarta Metropolitan, a dramatic increase in impacted area and amount of economic loss from the Ciliwung River Floods occurs every year. As the longest river basin crossing many cities and regencies, complexity of Ciliwung River flood management has been driven by many driving factors triggered not only by natural, physical, and socio-economic factors, but also by transboundary issues and power sharing. Previous studies addressed these flood drivers, but missed the transboundary issues and power sharing. To tackle future flood events, this paper attempts to unveil transboundary issues and power sharing for river flood and water resource management. In this study, about 13 significant transboundary flood drivers were identified from literature and practices. Using MICMAC, a power-dependency model, this study is able to further recognize strategic key flood drivers from key stakeholders' perspectives obtained from in-depth interviews and FGDs. Findings of the study shows that lack of control of spatial plans and weak stakeholder coordination-cooperation are found to be the critically important drivers to prioritize, since they have strong impact to all other drivers. Finally, this study proposes that a national-level development control regulation and an acting commission are established as a priority action for transboundary flood risk management in Ciliwung River Basin. These findings contribute to the governance of flood risk management literatures by emphasizing the need for a coordinated and integrated approach to mitigate flood risks that extend beyond administrative boundaries, enhancing the overall resilience and sustainability.

Keywords: Flood risk driver, Key flood risk driver, Ciliwung river basin, transboundary flood risk management, MICMAC analysis, Greater Jakarta Flood, Spatial Plan, Stakeholder Coordination and Collaboration

1. Introduction

Jakarta Metropolitan Area, known as Greater Jakarta, is an agglomeration city of Jakarta-Bogor-Depok-Tangerang-Bekasi. This metropolitan has been one of the most appealing locations for both domestic and foreign investment, with a large number of entrepreneurs and skilled laborers, as well as high access to decision-makers (Firman, 1998). To compare, as of 2023 Tokyo Metropolitan Area in Japan was the largest world urban agglomeration, with 36.57 million people living in 7,693 km^2, while Jakarta Metropolitan Area ranked the second with 34 million people living in 7,315 km^2 area (Dyvik, 2023; Rahayu, 2022). According to Euromonitor International, Jakarta Metropolitan will become the most prominent mega city globally, with estimated population of 35.6 million by 2030 (Dyvik, 2023). As defined by the UN, megacity is a city with more than 10 million population.

Greater Jakarta is geographically crossed by 13 river systems, including Ciliwung river which has the longest and biggest river basin. According to Presidential Decree Number 12/2012, the determination of Ciliwung River Basin Area is 140 kilometres long with nearly 438 km^2 catchment area crossing Jakarta Province and three major cities and one regency in West Java Province. Bogor Regency and Bogor City are in the upstream, Depok City is in the middle stream, and Jakarta Province is in

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the downstream. Being situated in a watershed, consequently Greater Jakarta area exposes to hydro-meteorological risks, such as flood. Severe floods due to the Ciliwung River's overflow have been recorded in 1996, 2002, 2007, 2012, and 2013 (Dewi & Ast, 2017), with the most severe one took place in early 2020. A total of 13 administrative units in Jakarta, Banten Provinces, and West Java Provinces were flooded, causing an estimation of loss around IDR 5.2 trillion during that 2020 event. Not to mention that coastal region of Greater Jakarta is exposed to frequent tidal flood.

From the flood vulnerability perspective, approximately 25 million people lives at the Ciliwung River Basin (CRB) with its growth rate around 1.4 percent. The flood-prone areas are primarily located in the densely populated in the Jakarta Province (DKI Jakarta), with about 28,818 households by 2009 (Rahayu & Nasu, 2010) and currently about 34,051 households lived there according to sources from the DKI Housing and Building Department during the study in 2021.

Several factors attributed to the increased magnitude of flood impacts in Greater Jakarta over the past few decades were precipitations, land-use change, sea level rise and land subsidence (Budiyono et al., 2016). However, massive urbanization in Jakarta between 1995-2014 has significantly decreased runoff regulation, green spaces and bodies of water, as well as affected landscape pattern changes (Maheng et al., 2021) and has strongly influenced spatial characteristics, such as industrial parks, mixed-use new towns and large-scale residential areas, and shopping centres (Firman & Fahmi, 2017). As identified by previous study (Silver, 2007), the Jakarta land use change was initiated in the early 1980s, where many agricultures and forest area in suburban of Jakarta were transformed into large-scale subdivisions and new towns. More than 30 large new suburban towns and industrial parks were built in the peripheries of Jakarta City between 1990 and 2010, with average size from 500 to 30,000 hectares (Firman, 2014). As the consequence of these vast peri-urban development, massive conversion of water catchment area, wetland, and green areas have been occurred; this lead also to the increase of flood threat to the Jakarta. Further, the urbanization was clearly seen to increase not only the intensity and volume of inundations, but also the runoff, river flow discharges, which all lead to the increase of flood threat (Priyambodoho et al., 2022). Thus, identifying flood risk drivers needs for expanding the spatial scales from the upstream up to the downstream area (Dawson et al., 2009).

In the last two decades, several scholars have studied drivers of the Ciliwung River Flood. For instance, Texier (2008) identified the root causes of disaster vulnerability in Jakarta Province, Emam et al. (2016) studied the effect of climate and land use change in the Upper Ciliwung River, meanwhile both Asdak et al. (2018) and Texier (2008) have analysed problems in downstream flood, and Sagala et al. (2013) highlighted Greater Jakarta flood vulnerability. Of those studies, however, no one discussed the issues of transboundary flood risk drivers, responsibility sharing, as well as mentioned which drivers are the most critical for the transboundary flood risk management.

While the Ciliwung River Basin Authority (BBWS-CC) under Ministry of Public Works bears responsibility of the whole Ciliwung River Basin management. The complexity of transboundary flood risk drivers have come in those several regions of the river basin with many aspects consequently as part of the megapolitan development. Flood risk managed by a single national authority is indeed complicated enough and becomes much more complex when dealing with the transboundary river. To protect the people at risk toward disaster is under responsibility of local government (Law No. 24 / 2007 Regarding Disaster Management, 2007; Law No. 23 / 2014 Regarding Local Governent, 2014). To untangle the complexity of the Ciliwung River flood, we must dig at the roots instead of just hacking at the leaves. "What are the main transboundary challenges to managing the Ciliwung River flood?" or "What are the most strategic transboundary flood drivers in the Ciliwung River Flood?" up until recently, this question remains unsolved.

Thus, focusing this study on addressing broader issues and complexity of key flood drivers and on unveiling the challenges of transboundary flood risk management are significantly important.

This paper aims to present the identified key flood risk driving variables of the Ciliwung River Flood using Matriced' Impacts Croisés Appliquée á un Classement (MICMAC) analysis, to depict the actual condition of the driving variables, and to recognize the challenges in transboundary Ciliwung river flood management. Holistic data of flood drivers obtained through documents reviews, interviews, survey, and FGDs. By in-depth study using MICMAC on the interrelationships among the

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flood driving variables using the degree of power and dependency criteria, this study is able to provide benefits in understanding how cross-border cooperation and local/regional/national level policies can be synergized to reduce and manage flood risk effectively.

It is belief that by recognizing the issues of transboundary flood risk drivers and its strategic countermeasure for flood risk reduction, this study will enrich the area of flood disaster risk management, water resource management, environmental disaster science and governance of transboundary river management. In particular, this study is relevant for areas of research involving the management of shared water resources, the impact of regional development on flood risk, and strategies to reduce economic losses from flooding. With research emphasises on the cross-border administrative characteristics of the Ciliwung watershed, this study offers a unique perspective on the challenges and solutions associated with flood risk management in a region involving several administrative jurisdiction regions.

2. Framework of Flood Risk Drivers

Floods have emerged as one of society's most dangerous risks (Beese et al., 1999) and the most frequent disaster faced by urban area in Indonesia (Rahayu & Nasu, 2010). There has been a significant increase in damages caused by catastrophic flooding over the past 50 years (Munich Re Group, 2004). The flood risk is created by the combination of flood hazards and vulnerabilities (Beese et al., 1999; UNISDR, 2009), it refers to the likelihood and exposure of elements to flood hazards.

To have better understanding of flood risk, this study defines flood risk drivers as an event that can modify the condition of a flooding system and are characterized using the source-pathway-receptor (SPR) paradigm (E. Evans et al., 2006). A flood source is determined as any event or condition that may cause flooding due to meteorological conditions (e.g., extreme rainfall, sea level rise), while pathways is mechanism to transfer floodwaters to the locations where they may impact receptors, and receptors are people and built environments that may be impacted by flooding.

A source-pathway-receptor (SPR) flood driver framework for Ciliwung River Basin was developed in this study, as represented in **Table 1**, based on document review, field observation and literature reviews of other studies (E. P. Evans et al., 2008; O'Donnell & Thorne, 2020). There are five identified flood source drivers, such as temperature, precipitation, sea-level rise, storm surges, and waves. About nine flood drivers are defined as flood pathway, i.e., river morphology, river vegetation, sediment supply, groundwater flooding, sewer conveyance, urbanization, land-use change, environmental regulation, and stakeholder behaviours. Other five drivers are defined as flood receptor, i.e., urban impact, buildings, infrastructure impact, economic impact, and social impact.

Table 1: Source-pathway-receptor (SPR) Framework for Ciliwung River Basin

Group	Flood Driver
Source	Temperature
	Precipitation
	Sea-level rise
	Storm surges
	Waves
Pathway	River morphology
	River vegetation
	Sediment supply
	Groundwater flooding
	Sewer conveyance
	Urbanization
	Land-use change

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Of the many flood drivers, it is necessary to determine the degree of importance and degree of influence of all the drivers, through holistic mapping documents reviews, interviews, survey and FGDs. MICMAC is significant tool for an in-depth examination of a system (Saxena et al., 1990), by studying the interrelationships among the drivers using the degree of power and dependency criteria, which then classified into four categories: autonomous, dependent, linkage and independent variables (Duperrin and Godet, 1973). Thus, this study is able to provide benefits in understanding how cross-... [29]

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	Environmental regulation
	Stakeholder behaviours
Receptor	Urban impact
	Buildings
	Infrastructure impact
	Economic impact
	Social impact

Extreme precipitation is known to significantly affect Greater Jakarta floods (Mishra et al., 2018). Sudden changes of extreme precipitation in short-duration, which will lead to the increase of water volume, intensity, duration, and location may cause severe flood (O'Donnell & Thorne, 2020). Greater Jakarta Flood occurred not only by upstream precipitation but also due to downstream rainfall. According to rainfall spatial distribution data, most of the Greater Jakarta floods were caused by evenly distributed rainfall along the Ciliwung River Basin (Farid et al., 2021). Floods occur when rivers do not have sufficient capacity to pass flow rates from upstream to downstream (Asdak, 1995). The narrowing of the Ciliwung River's capacity is due to sedimentation and waste, as well as the construction of settlements on uncontrolled riverbanks. To decrease the flow rate, in a higher area, several infrastructures such as Situ (Lake) and Dams in Bogor Regency and Depok City, are built to control flood peak discharge in the up-stream and mid-stream areas of the Ciliwung River Basin (Nugraheni et al., 2020).

As the downstream area, Jakarta experienced more severe floods compared to other regions due to its geographical condition. Despite extensive efforts by the Dutch and Indonesian governments, Jakarta is still prone to flooding since its location in a major river delta (Asdak et al., 2018). Due to land subsidence issues, about 40% of Jakarta City areas are a few meters below sea level, estimated to be 1 to 15 centimetres rates per year both spatially and temporally (Latief et al., 2018). The existing Jakarta flood control system was developed based on Prof. H. Van Breen (1973) concept, in which the overflow rain water from outside Jakarta redirected via flood canals (West Flood canals and East Flood Canals) that circle Jakarta. Run-off within the city of Jakarta is discharged through local drainage system by gravity and discarded with a polder system, including water pump and pond retention in low areas (Kusuma et al., 2010).

Apart from natural causing factors, rapid urbanization and massive growth in population led to the increase in the susceptibility and vulnerability to Jakarta flood (Rahayu and Nasu, 2010). The rapid growth of urban sprawl (Maheng et al, 2021, Firman and Fahmi, 2017) have caused massive land conversion from the catchment area to the built environment. A change in land use over time can have significant effects on run-off (Mishra et al., 2018). Uncontrolled land-use change due to poor spatial planning along the Ciliwung River Basin makes the flooding becoming more complicated to handle (Asdak et al., 2018). To control current developments and minimize future risks, strong governance with good long-term spatial planning is needed (Rahayu et al., 2019). It is expected that spatial planning will contribute to flood mitigation in floodplain areas (White & Howe, 2002; White & Richards, 2007) by regulating the land use types, spatial pattern, development scales, and physical structure designs. It can affect the likelihood of floods and its consequential damage (Neuvel & van den Brink, 2009; White & Richards, 2007).

The emergence of Law 23/2014 regarding Local Government resulted in the right and obligatory sharing between national and local government, known also as decentralization. Decentralization and power-sharing expanded disaster management responsibility at local levels with national policy impacting it (Sunarharum et al., 2021). Since Ciliwung River Basin flows along transboundary regions, therefore national, provincial as well as city/regency governments along Ciliwung River Basin are responsible for flood risk management as well. While governments may be able to mitigate flood risk, communities, especially those affected by floods, must be included in flood risk management decisions (Faulkner et al., 2007). However, as flood risk management involves various stakeholders (i.e., governments, communities, academics, media, and privates) and multiple objectives, conflicts may also arise. Up until recently, the coordination among stakeholders in the Ciliwung River

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Basin still meets many challenges and as a result, affects the decision-making (Sunarharum et al., 2021). To have better visualisation, an in-depth primary work of this study described identified flood drivers and flood Source Pathway Receptor as a fish bone diagram shown Figure 1, see also Rahayu et al (2022).

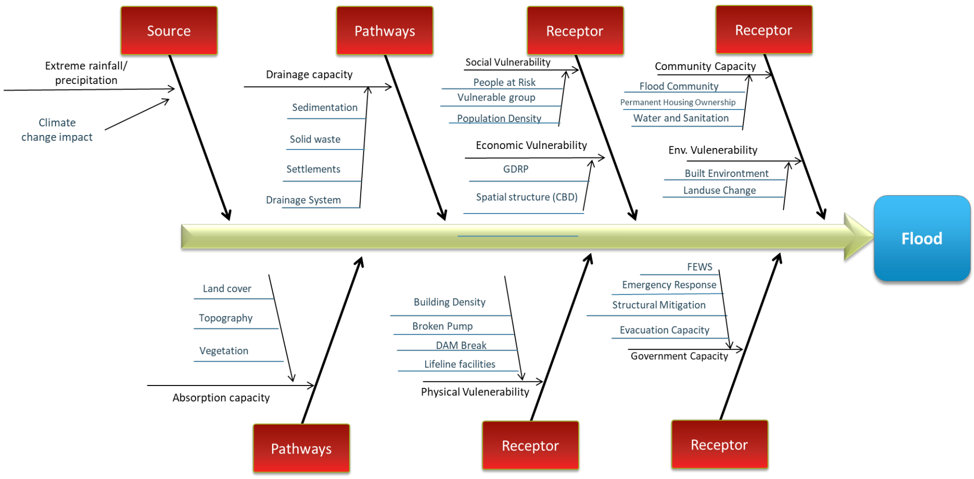

Figure 1: Key Flood Drivers

The Ministry of Public Works Regulation Number 13/PRT/M/2006 regarding the River Management has defined that the Ciliwung River is a transboundary river that crosses two provinces and four cities/regencies and is controlled by the National Government, i.e., Ciliwung-Cisadane River Basin Authority (BBWS CC), in collaboration with local stakeholders. Understanding the transboundary management in flood risk reduction is very critical.

Based on input from the Stakeholders Focus Group Discussion (FGD) conducted by this study on 26 September 2019 under collaboration with National Planning Agency (Bappenas), the Ciliwung River flood drivers on the Table 1 and Figure 1 were refined with few modifications in terms. The FGD was attended by 12 institutions from national, provincial and local government. The final result of identified Ciliwung flood risk drivers is shown in Table 2 below, with thirteen flood driver variables.

Table 2: Identified Ciliwung Flood Risk Drivers

Codes	Key Flood Drivers	Modified Terms and Classification from Table 1
A1	Extreme Rainfall	Precipitation (Source)
A2	Waste and Sedimentation	Sediment Supply (Pathway)
A3	Drainage Capacity	Sewer Conveyance (Pathway)
A4	River Capacity	River Morphology (Pathway)
A5	Urbanization	Urbanization (Pathway)
A6	Growth Population	Urbanization (Pathway) Social Impact (Receptor)
A7	Catchment Area	River Vegetation (Pathway)
A8	Built Environment	Urban Impact (Receptor), Rural Land Management (Pathway)

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Codes	Key Flood Drivers	Modified Terms and Classification from Table 1
A9	Ground Water Exploitation	Groundwater flooding (Pathway)
A10	Stakeholder Cooperation and Coordination (Government, Lifelines, Business, Community)	Stakeholder Behaviour (Pathway)
A11	Land Subsidence	Groundwater flooding (Pathway)
A12	Spatial Plan	Environmental Regulation (Pathway)
A13	Flood Controls / Structural Mitigation (Dams, Levees, Reservoirs, Water Pump, Dikes)	River Conveyance (Pathway)

3. Methodology

To recognize the challenges and complexity of the transboundary management in flood risk reduction, this study involves a qualitative and quantitative approach using primary data from Stakeholder Focus Group Discussion in-depth interviews, and field observations. The 2019 Focus Group Discussion on "Mitigating Hydrometeorological Hazard Impacts Through Transboundary River Management in the Ciliwung River Basin" aims for sensitisation of stakeholders, which has helped to build trust and forge a potential pathway to impact through river basin management policy. The interviews and field observation were conducted from September until December 2020; while amidst that period, there were several Ciliwung flood events that occurred in Greater Jakarta, making the obtained data more relevant and up to date. Face-to-face and online interviews are used for the interview methods as the consequence of Indonesia's Large Scale Social Restriction due to the Covid-19 Pandemic. Both kinds of interview methods perform the same quality of content.

To have reliable results in a case of transboundary river management, the interviews included multi-level governments, i.e., national, provincial, and city/regency governments, along Ciliwung River Basin. The role of river basin-related institutions could be divided as follows (Dewi & Ast, 2017); first is the institution with main role in the planning process at each of the national, provincial, and city/regency levels; second is the institutions responsible for the implementation process of flood management projects, also at each of the national, provincial, and city/regency levels; institutions that have the power of coordination.

Based on these two criteria, thirteen experts related to Ciliwung river flood from different levels and regions are selected as the target respondents, see also **Table 3**.

Table 3: Selected Experts and Their Roles

No	Institution	Roles
1	National Planning and Development Agency (BAPPENAS)	Coordinates Development Planning and Financing for Transboundary Regions
2	Ciliwung-Cisadane River Basin Authority (BBWS Ciliwung Cisadane)	Executes Ciliwung River Program, i.e., flood control development and maintenance
3	Ministry of Spatial Planning (Kementerian ATR)	Coordinates Spatial Planning and Controlling for Transboundary Regions
4	Jakarta Provincial Planning and Development Agency (Bappeda Provinsi DKI Jakarta)	Coordinates Development Planning and Financing in Jakarta Provincial
5	Jakarta Provincial Water Resource Agency (Dinas Sumber Daya Air Provinsi DKI Jakarta)	Executes flood control development and maintenance in Jakarta Provincial
6	West Java Provincial Planning and Development Agency (Bappeda Provinsi Jawa Barat)	Coordinates Development Planning and Financing in West Java Provincial

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No	Institution	Roles
7	West Java Provincial Water Resource Agency (Dinas Sumber Daya Air Provinsi Jawa Barat)	Executes flood control development and maintenance in West Java Provincial
8	Depok City Planning and Development Agency (Bappeda Kota Depok)	Coordinates Development Planning and Financing in Depok City
9	Depok City Public Work and Spatial Planning Agency (Dinas PUPR Kota Depok)	Executes flood control development and spatial planning in Depok City
10	Bogor City Planning and Development Agency (Bappeda Kota Bogor)	Coordinates of Development Planning and Financing in Bogor City
11	Bogor City Public Work and Spatial Planning Agency (Dinas PUPR Kota Bogor)	Executes of flood control development and spatial planning in Bogor City
12	Bogor Regency Planning and Development Agency (Bappeda Kabupaten Bogor)	Coordinates of Development Planning and Financing in Bogor Regency
13	Bogor Regency Public Work and Spatial Planning Agency (Dinas PUPR Kabupaten Bogor)	Executes of flood control development and spatial planning in Bogor Regency

Given a set of flood risk drivers as presented in **Table 2**, all experts, as listed in **Table 3**, were asked to identify the key flood risk drivers of the Ciliwung River flood and its interrelations with justifications. They were also asked to explain the actual condition of each driver based on their empirical knowledge and scope of work. Grounded theory, as the qualitative method, is then used to interpret experts' statements into codes. The grounded theory method involves gathering and analysing data to generate a middle-range theory (Charmaz, 1995). Analytic processes consist of data coding, developing, checking, and integrating theoretical categories, and constructing analytic narratives (Glaser & Strauss, 2017).

To identify driving power (influential) and dependence power (influenced), a quantitative method called Matriced' Impacts Croisés Appliquée á un Classement (MICMAC) is used. Both Attri et al. (2013) and Saxena et al. (1990) argue that MICMAC analysis is a significant tool for an in-depth analysis of system. The method defines the level of power and dependency by analysing the interrelation among the drivers. MICMAC analysis is carried out to scrutinize the impact of driving power and dependency power of the factors (Ansari et al., 2013). Putting the driving power along X-axis and dependency power along Y axis, the factors are classified into four group namely, independent, linkage, autonomous, and dependent (Duperrin & Godet, 1973; Jharkharia & Shankar, 2005). Independent group consists of drivers with strong driving power but low dependence power. These driving factors are rarely influenced by other drivers. Linkage group consists of the driving factors characterised by both high driving and high dependency power. Factors within linkage group both influence other groups as well as being influenced by them. This group represents factors that have strong interconnections and mutual dependencies with factors in other quadrants. Autonomous group consists of driving factors characterised by extremely low driving power while also having low dependency power on factors in other groups. They are self-contained and do not significantly drive or depend on other quadrants. Meanwhile, dependent group consists of driving factors characterised by low driving ability but high reliance power on other groups. These drivers rely heavily on other drivers, any action taken by other drivers will have an impact on the dependent drivers.

In disaster risk reduction, MICMAC analysis was previously used to discover important factors of resilient humanitarian supply chain that emerge during post-disasters (Singh et al., 2018). The study's findings will help government agencies and policymakers make proper strategic decisions to increase resilience. Further, it assists emerging countries in minimizing massive losses and improving economic growth for the benefit of society. However, up to these days, there is no published study in discovering key flood drivers using the MICMAC method.

To summarize, in this study, the MICMAC analysis includes the following steps.:

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1. A literature review, document review and field observation were used to identify the factors influencing flood risk. The flood risk drivers list is presented in **Table 1** and **Figure 1**.
2. Input from stakeholder Focus group Discussion were used to modify **Table 1** to become **Table 2** as final flood risk drivers framework to be used for interview based survey. There are 13 drivers responsible for impacting the flood risk.
3. Through interviews, experts' judgements are used to establish a conceptual link among the drivers. Those drivers could also be impactful to each other. The drivers' relative responses were obtained by calculating the collected opinion in the interviews. Expert judgement assists in depicting the suitable interaction between these drivers. These variables are characterized using a pair-wise relationship as either "influencing" other drivers or being "influenced" by other drivers.
4. Structural Self Interaction Matrix (SSIM) has been acquired to associate among 13 drivers.
5. Using VAXO symbols, four symbols have been defined to demonstrate the linkage between i and j drivers. Then SSIM matrix is converted to Initial Reachability Matrix (IRM) using the specified rules shown in **Table 4**.
6. Then using VAXO symbols, all experts' judgement is mapped in SSIM Matrix as shown in **Table 5**.
7. After creating an SSIM matrix, the symbol of its cells is then converted into IRM value referred to Table 3. The converted cells formed into IRM Matrix shown in **Table 6** to be used for the input of MICMAC.
8. Output of MICMAC application version 6.1.2, developed by Godet and Francois (1989) is a four-quadrant graph. The result and discussion of MICMAC analysis is presented in the result and discussion section.

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Table 4: SSIM and IRM Value

Relation	SSIM Symbols	IRM value
driver i influencing driver j	V	1
driver j influencing driver i	A	1
drivers i and j influencing each other	X	1
drivers i and j are not associated	O	0

Table 5: SSIM Matrix of Experts' Judgements

i/j	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
A1	V	0	V	V	0	0	0	0	0	0	0	0	V
A2		V	V	V	0	0	0	A	0	A	0	0	V
A3			V	V	0	0	A	0	0	0	0	A	V
A4				V	0	0	A	0	0	A	0	A	X
A5					V	V	0	0	0	0	0	0	0
A6						V	0	V	0	0	0	V	0
A7							V	A	0	A	0	A	A
A8								V	V	0	0	A	0
A9									V	0	V	0	0
A10										V	0	X	V
A11											V	0	V
A12												V	V
A13													V

Table 6: IRM Matrix

i/j	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
A1	1	0	1	1	0	0	0	0	0	0	0	0	1
A2	0	1	1	1	0	0	0	0	0	0	0	0	1
A3	0	0	1	1	0	0	0	0	0	0	0	0	1
A4	0	0	0	1	0	0	0	0	0	0	0	0	1
A5	0	0	0	0	1	1	0	0	0	0	0	0	0
A6	0	0	0	0	0	1	0	1	0	0	0	1	0
A7	0	0	1	1	0	0	1	0	0	0	0	0	0
A8	0	1	0	0	0	0	1	1	1	0	0	0	0
A9	0	0	0	0	0	0	0	0	1	0	1	0	0
A10	0	1	0	1	0	0	1	0	0	1	0	1	1
A11	0	0	0	0	0	0	0	0	0	0	1	0	1
A12	0	0	1	1	0	0	1	1	0	1	0	1	1
A13	0	0	0	1	0	0	1	0	0	0	0	0	1

4. Result and Discussion

The result of MICMAC model is shown in **Figure 2** diagram below. The 13 flood drivers are mapped into four quadrants, i.e., independent, linkage, autonomous, and dependence. Through this analysis, two flood drivers, i.e., Spatial Plan (A12) and Stakeholders Cooperation and Coordination (A10), are emerged as critical flood risk and the most powerful drivers in Ciliwung River Basin. These two drivers are independent drivers, they have the highest driving power and the lowest dependency power; they exert a significant influence on other driver from other groups. These two drivers will take important role in overall system of transboundary Ciliwung river flood management. The intervention on these two factors will have the highest impact to other flood drivers. However, this study found no variables fall in linkage groups. This means that all the stated variables are stable. Meanwhile seven flood drivers are autonomous drivers. They are Extreme Rainfall (A1), Built Environment (A8), Growth Population (A6), Waste and Sedimentation (A2), Urbanization (A5), Ground Water Exploitation (A9), and Land Subsidence (A11). These seven autonomous drivers are characterised by extremely low driving power and low dependency to other drivers' group, they are more self-contained. However, the Extreme Rainfall (A1) and Built Environment (A8) are located closer to independent group, having relatively high driving power. These two will be also discussed further in the next section. The rest of flood drivers show the least driving ability and the high reliance on other groups, they fall in the dependence group. They are drainage capacity (A3), catchment area (A7), flood control-structural mitigation (A13), river capacity (A4). These factors are the weakest in the key flood driver mapping, relying heavily on other drivers. Any action taken by other dirvers will have an impact on these dependence drivers. River capacity appears as the most dependent drivers, indicating the end of the flood driver chain in the overall system of transboundary Ciliwung river flood management.

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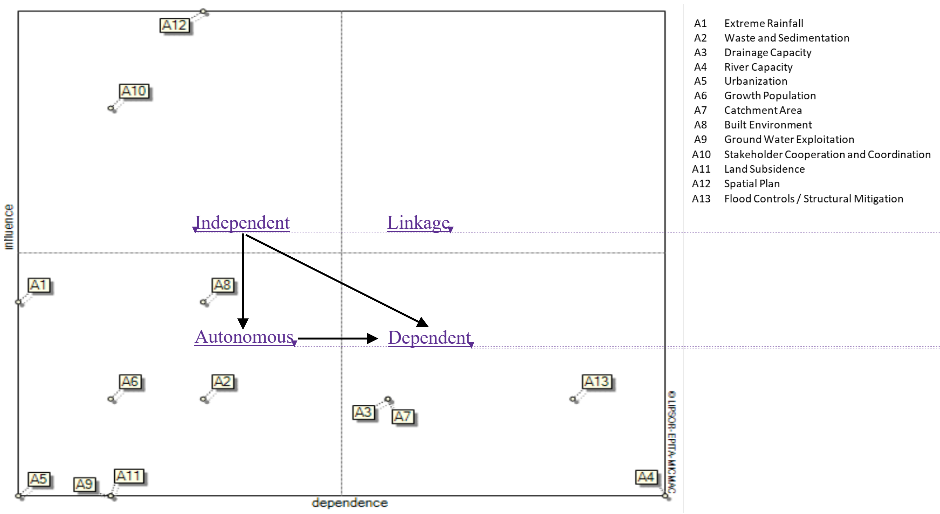

Figure 2: MICMAC model result diagram

Through MICMAC analysis, this study has unveiled the important of two key flood drivers, i.e., non- structural mitigation through spatial planning and stakeholders' cooperation and coordination, covering the issues and challenges of Ciliwung flood risk governance in reducing/managing the Ciliwung River flood risk and achieving sustainable catchment area. Referring to Source-Pathway-Receptor model in **Table 2**, it is found that in the case of Ciliwiung River flood risk management, both "pathway' such as stakeholder behaviour and environmental regulation give the main influence in the set of flood risk drivers. Surprisingly, this study also unveiled that the most dependence drivers are found related with the catchment area and capacity to channel out the flood water, such as drainage capacity, river capacity and flood control. Any action taken on other drivers will give significant impact on these dependence drivers.

Findings of this study could be as the inputs for other cities/metropolitan which has similar problem transboundary of river flood management. Further, the two highest key flood drivers, i.e., spatial planning and stakeholders' cooperation and coordination, the moderate high key flood driver, i.e., extreme rainfall, as well as the most dependence flood drivers, i.e., flood controls, will be discussed.

4.1 Spatial Plan

A holistic approach is needed in the development of flood risk management, covering the upstream, midstream, and downstream. Controlling the river basin development through integrated spatial planning from upstream, midstream, and downstream are necessary to reduce flood risk in the river basin. Spatial planning is a system concerned with long- or medium-term objectives and strategies for the regions development, and consists of planning processes, space utilization and control of space utilization. The spatial plan basically is composed of spatial structure and spatial pattern. The spatial structure arranges residential and business centres, and all supporting infrastructure networks and facilities for related socio-economic activities of the community. The spatial pattern distributes space allocation by considering protection functions as well as cultivation and/or development function.

Since Ciliwung river is one of the longest river basins passing through 2 province and 5 regencies/cities, the role of transboundary coordination in water resource and flood risk management become very critical from the perspective of ego sectoral as well as ego area jurisdiction.

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This is in line with the findings of the study, that shows the spatial plan (A12) and stakeholder cooperation and coordination (A10) are the most critical flood risk driver in Ciliwung River Basin management. Both key flood drivers are independent drivers having the most powerful influence on other key flood drivers.

Most flood risk reduction regulations are included in each city/regency as well as provincial spatial plans, such as land use regulation, structural mitigation development, catchment area preservation, and river maintenance. The integration of these disaster risk reduction countermeasures into spatial planning regulation have studied by several works. For example, flood risk avoidance is often used for controlling spatial development in floodplain area including relocation plan (Kang et al., 2009) while flood risk defence is for preventing the region from flood water by building river dykes (Voorendt, 2017). Meanwhile flood risk mitigation is for reducing flood impact loss by structural mitigation or nature base solution for flood detention (Sayer et al, 2013), flood retention (Wingfield et al., 2019), and flood passages (Kang et al., 2009). Last but not least, the flood risk preparedness is used for evacuation plans and flood risk recovery is used for developing post recovery plan and critical infrastructure protection (Meng et al., 2022; Sayers et al., 2013).

In the case of Ciliwung river, these city/regency as well as provincial spatial plan often developed only to suit their own needs and objectives, without considering broader needs, such as for regional flood risk management. To bridge the transboundary issues and challenges of spatial planning as tools for flood risk management, the Ministry of Spatial Plan established the Greater Jakarta Spatial Plan in Government Law Number 60/2020 to incorporate all those related local and provincial spatial plans. This Greater Jakarta Spatial Plan is expected to function as transboundary spatial plan. However, until now, it is not fully enforced yet for water resource and flood risk river management.

Further, Ciliwung-Cisadane River Basin Agency has formulated a plan in the Ministry of Public Works Decree No 26/KPTS/M/2015 regarding integration of Ciliwung and Cisadane river basins, which means also combining both Ciliwung-Cisadane river management programs. During the FGD, the Ciliwung-Cisadane River Basin Authority (BBWS Ciliwung Cisadane) stated that "There were massive land use change at the upstream of river basin, where this became main flood driver. However, the flood itself was worsened by the extreme rainfall". Ministry of Environment and Forestry (KLHK) – Agency for Citarum-Ciliwung River Basin Management (BPDAS – Balai Pengelolaan Daerah Aliran Sungai Citarum-Ciliwung) assumed that the land use and land cover change become primary contributor to Ciliwung River Basin flood. For example, the deforestation of the upstream Ciliwung River Basin may cause flooding on the midstream and the downstream. Thus, the spatial plan needs to consider the land use change as well as the flood risk reduction.

National Planning and Development Agency (BAPPENAS) said that starting from 2010, average runoff coefficient has been recalculated due to land use change. There was an increase up to 0.4 and 0.5 in 2014. Meanwhile, West Java Planning and Development Agency (Bappeda Jabar) assumed that the development in the catchment area should consider transboundary commitment for rehabilitation of conservation and protected area. The more land use change, the less water catchment area, which lead to flood.

During FGD, several experts judge that development control in the Ciliwung River Basin appeared to be weak as land-use changes emerged at the upstream, midstream, and downstream. Urban and regional development is increasingly not considering catchment area provision over time due to economic pressure. Although spatial plans have been created on many levels, development control remains powerless to retain the catchment area. Some upstream regions have been turned into residences, hotels, villas, and restaurants, resulting in increased water run-off, but in Jakarta, new settlements are created without regard for spatial planning, affecting water absorption.

Since, it appears from the results of the MICMAC model that spatial planning has significantly affected drainage capacity, river capacity, catchment area, built environment, stakeholder cooperation, and flood control development, thus improving, strengthening and integrating the spatial plan related with Ciliwung river basin of Jakarta Province, Depok City, Bogor City and Bogor Regency is main priority in order to have better result of overall sustainable flood risk management.

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4.2 Stakeholder Coordination and Cooperation

As the second critical key flood drivers, the stakeholder cooperation and coordination (A10) are playing important role in transboundary Ciliwung River Basin management. It is independent drivers which has the most powerful influence on other key flood drivers. A river basin sustainable development and management need to consider the basin as a whole, with multiple interactions of water-ecosystem-economy from the upstream, midstream, and downstream areas (Cheng et al., 2014). Meanwhile, Lorenz et al (2001) defined sustainable river basin management through interaction model among social capital, human capital, natural capital and man-made capital. This model generated laws, regulations, information flow for triple helix stakeholders, i.e., government, business and community.

Based on the interviews in this study, the stakeholder cooperation and coordination among governments, communities, academics, lifelines, and business significantly affect other drivers, such as waste and sedimentation, river capacity, catchment area, built environment, groundwater exploitation, spatial and development plan, and flood controls.

The imperative issue takes place in coordination and cooperation among governments. The transboundary governance forum for Ciliwung River Basin management has been reformed many times. Two previous forms are the Ciliwung River Basin Forum in 2007, led alternately by the Governor in the Ciliwung River Basin, and the Ciliwung Water Resource Management Coordination Team in 2011, led alternately by each of the Planning and Development Agency in the Ciliwung River Basin. ccording to experts' experience obtained during FGD, the reformation keeps occurring due to the ineffectiveness of the forum mechanism, the powerless leader, and the conflict of interest. There was no clear framework for the forum and no legal agreement about how coordination and cooperation among institutions should work. This eventually resulted in no clear action. Each institution merely understands its own jobs and pays attention to their interest or said as sectoral egos. Also, there was no strong figure who could lead the forum.

Meanwhile, the Ministry of Environment and Forestry (KLHK) – Agency for Citarum-Ciliwung River Basin Management (BPDAS – Balai Pengelolaan Daerah Aliran Sungai Citarum-Ciliwung) stated that Ciliwung river is very complex in its governance. Jakarta Provincial Government responsibility is at the downstream, while West Java Provincial Government responsibility is at the upstream only. The transboundary river management should have one leader. If the Ministry of Environment and Forestry (KLHK) take a lead, it will be difficult for managing the inter and cross sectoral issues. For example, good lesson learned from the management of Citarum River, which was assigned to Citarum Harum lead by National Military based on the presidential decree. Thus, the Ciliwung river management needs to have similar governance structure, since the existence of Coordinating Board for Jakarta Metropolitan Area Development (BKSP Badan Kerja Sama Pembangunan) has not been optimal and sustainable.

To compare with Brantas River Basin tranboundary governance in East Java Indonesia, crossing several area jurisdictions, there has been a good water governance of the basin development and management handled by the central government (Brantas River Basin Executing Agency-BRBEA, known as the Brantas Project-BP), collaborated with state own enterprises, i.e., PT Indra Karya and PT Brantas Abipraya, since its beginning of 1960s with massive constructing projects of 8 large dams, 6 barrages, and rubber dams along the Brantas river for Irrigation, hydropower, flood control, and recreation purposes (Roestamy & Fulazzaky, 2022). However, its main challenges are related with technical issues, institutional frameworks, and regulatory instruments to fulfil the needs of various stakeholders from various area jurisdiction (Roestamy & Fulazzaky, 2022). Water Resource Law 7/2004 has formalized the paradigm shift from project oriented to integrated river basin development, beside created, and empowered the institutional framework. Therefore by 2007, BRBEA has been fully taken over by national institutions in handling strategic issues of Brantas River Basin (Roestamy & Fulazzaky, 2022).

Meanwhile, National Planning and Development Agency (BAPPENAS) said that the transboundary coordination function for Ciliwung River could be managed by the Project Management Officer (PMO) of Jakarta Metropolitan Area (Greater Jakarta), which will be later substitute the Coordinating Board for Jakarta Metropolitan Area Development (BKSP) in

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coordinating the three provinces, i.e., Jakarta, West Java and Banten provinces. However, this seemed to be in effective since there is no involvement of national government. In the future, it is expected that there is coordinating body lead by Minister of Agrarian Affair and Spatial Planning with Minister of National Planning and Development Agency as the vice, with its think tank at the existing Coordinating Board for Jakarta Metropolitan Area Development (BKSP).

5.3 Extreme Rainfall

Even though, the extreme rainfall (A1) is acknowledged in this study as an autonomous driver with moderate driving power and lowest dependency power. It is supposed to be characterised by self-contained and do not significantly drive or depend on other drivers. However, the position the extreme rainfall in autonomous group is closer to independent group. It means that this driver has relatively moderate influence power to affect other drivers. For example, the extreme rainfall may cause flood due to insufficient drainage capacity, poor catchment area, inappropriate flood controls/structural mitigation, and poor river capacity due to illegal settlement at riverbanks, trash sedimentation at the river and several other drivers.

In the last few decades, the climate change has impacted to the pattern of rainy season, as well as to the occurrence many extreme precipitations which caused severe flood. The fact that climate change is likely a factor contributing to the heavy rainfall has been discussed by many scholars, i.e., intensified short duration heavy rainfall (Tamm et al., 2023). Compounded with vulnerability factors, such as socio-demographic, economic, physical and environment factors, this heavy rainfall will lead to the increase the flood risk.

Extreme precipitation is known to significantly affect Greater Jakarta floods (Mishra et al., 2018). Sudden changes of extreme precipitation in short-duration precipitation, which lead the water volume, intensity, duration, and location may cause severe flood (O'Donnell & Thorne, 2020). Ciliwung River Flood occurred not only by upstream precipitation but also due to downstream rainfall. According to rainfall spatial distribution data, most of the Jakarta floods were caused by evenly distributed rainfall along the Ciliwung River Basin (Farid et al., 2021).

Floods occur when rivers capacity (A4) and drainage system (A3) do not have sufficient capacity to pass flow rates from upstream to downstream (Asdak, 1995). The narrowing of the Ciliwung River's capacity is due to sedimentation and waste, as well as the construction of settlements on uncontrolled riverbanks. To decrease the flow rate, in a higher area, several infrastructures such as Situ (Lake) and Dams in Bogor Regency and Depok City, are built to control flood peak discharge in the up-stream and mid-stream areas of the Ciliwung River Basin (Nugraheni et al., 2020).

The impact and severity of these drivers are likely to increase, making changes in transboundary policy, planning, practice, and coordination among the responsible agencies imperative across jurisdiction. Several works on climate change adaptation and flood disaster risk reduction in Jakarta conducted were identified (Rahayu et al., 2020).

4.4. Flood Controls / Structural Mitigation

The study found that flood control and structural mitigation is a driving factor with lowest driving power but highly dependency power. This means that this driver is the weakest in the key flood driver mapping, relying on the influence of other drivers. It gets easily inclined by other strong drivers. The experts' judgments were only focused on structural flood control, such as building dams, levees, dykes/flood canals, reservoirs, polders, and pump system.

Unless the flood control/structural mitigation are mainstreamed in spatial planning, the sustainable flood risk management will not be achieved (Meng et al., 2022). However, Jakarta has the highest people living at flood risk area, i.e., flood plain area, riverbanks. Alerting those people at risk before flood is significantly important. The existing flood early warning system needs to me improved by adopting people centre early warning system (Rahayu et al., 2020), by having reliable the four components, i.e., Monitoring and Warning Service, Dissemination & Communication, Risk Knowledge, and Response Capability. The first one is part of upstream component, while the rest are downstream component.

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The existing flood monitoring and detecting in most river in Jakarta including Ciliwung River relied on manual water level measurement at the flood gate or dams. The real time advance monitoring, detecting and well as real time impact-based flood model are ongoing process of development for Greater Metropolitan Jakarta area. Alerting the people need to be advanced from the existing sirens, CCTV, community-based alerting system (Rahayu & Nasu, 2010). The community response and readiness of the stakeholder toward flood warning should be improved and tested regularly.

5. Recommendations and Conclusion

Land use plans are supposed to substantially impact the basin's development (Wang et al., 2010). Therefore, spatial planning is a critical tool for reducing flood risk (Neuvel & van den Brink, 2009). Budiyono et al. (2016) investigated the great potential for urban planning to mitigate flood risk. It demonstrates that if Jakarta's land use follows the 2030 spatial plan, flood risk will be reduced by 12%. This highlights the great potential of land use planning for flood risk reduction.

Having a solid and integrated spatial plan is not enough to reduce flood risk unless followed by robust development control. Strict development control must be applied at the basin level, which means not only in Jakarta Provincial but also in Depok City, Bogor City, and Bogor Regency as part of the Ciliwung River Basin regions.

Development control regulation in the Ciliwung River basin may differ from upstream to downstream municipality depending on physical, environmental, and institutional characteristics. Development control in the upstream area mainly aims to preserve the catchment area, while in the downstream area, it primarily aims to prevent groundwater exploitation and higher physical vulnerability. The national government, along with the local government, must create tight instruments for development control, while the local government itself must carry out strict surveillance and give penalties for all development violations.

To strengthen development control in the Ciliwung River basin, a holistic regulation regarding development control (mechanism, instrument, zoning technique, and executor (i.e., task force)) in the Ciliwung River basin level must be legalized as a national policy. The President should make this a national priority program, considering the areas impacted and the number of losses that the Ciliwung River flood has generated. Up until recently, integrated development control policy in the Ciliwung river basin has not been developed yet, even though there has been the Greater Jakarta Spatial Plan (Law of President Number 60/2020) is expected to be holistic transboundary spatial plan and Ciliwung-Cisadane River Basin management program (Ministry of Public Works Decree No 26/KPTS/M/2015).

However, difficulties may arise in their management and governance when dealing with transboundary river management. Several critical institutions are involved in flood risk reduction, i.e., Governments at national, sub-national, and local levels, utility companies, private businesses, and community groups (Jha et al., 2012). Coordination is required both between actors at different authority levels (vertical coordination) as well as among actors within administrative boundaries (horizontal coordination).

Meanwhile, as transboundary river basin governments have many flood drivers to overcome, it has to meet concrete criteria to have an appropriate arrangement for river basin management. Firstly, clear roles and responsibility-sharing among river management institutions are essential for effective coordination (Jha et al., 2012). A negotiation procedure and coordination mechanism are required (Barbazza & Tello, 2014). Secondly, a coordination mechanism is also important to enhance information and data flows and coordinate decision-making and implementation. Thirdly, leadership and power to enforce coordination contribute to the fragmentation of the institutional arrangement (Brown, 2005). Therefore, an effort to make a governance forum in the Ciliwung River Basin must follow those three criteria to waive ineffectiveness.

According to Millington (2006), there are two types of river basin forum. Those are (1) the river basin coordinating committee and (2) the river basin commission. A river basin coordinating committee is formed for stable and mature river basin management. This model mainly relies on the fair cooperation and participation of its members. The committee has no

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executive authority and cannot override the member organization's tasks and operations. The coordinating committee would be made up of major water-related agencies from each of the basin's states.

Further, when problems happen frequently, a river basin committee is formed. A basin commission is a more formalized group than a committee. It would consist of a management board that would establish objectives, goals, policies, and strategic direction. The commission would be supported by a technical office of water, natural resource, socioeconomic planning, and management experts, many of whom would be drawn from existing agencies in the basin. To offer ultimate power, a Ministerial Council could lead the commission, and the basin commission would then focus on strategic natural resource management of the rivers and catchments. The fact that Ciliwung River Basin management still meets conflict and is not stable in management attests that the river basin commission might be the fittest model for Ciliwung river basin governance.

This study addresses broader issues of key flood driver in transboundary flood risk management. The Ciliwung river floods are very complex and influenced by tremendously development as a megapolitan region. This development has contributed to complex water-resource issues, such as increased flooding. Since the previous Greater Jakarta flood impacts trillion IDR losses, it is essential to avoid future flood events by unveiling critical challenges among complex drivers. Determining the degree of importance and degree of influence of all key flood drivers based on holistic document reviews, interviews, and FGDs sing, this study provides benefits in understanding how cross-border cooperation and regional/national level policies can be implemented to manage flood risk effectively.

Result of MICMAC analysis, it is found the spatial plan, and the stakeholder cooperation and coordination are key flood risk drivers in the transboundary management perspectives. While the former one brings issue in the lack of development control, the latter one carries issue in the failure of transboundary river governance arrangement. “How to strengthen development control in the Ciliwung river basin?” and “What suitable form for transboundary river governance in Ciliwung river basin?”. Concentrated efforts to address both challenges are paramount above others to reducing the flood risk.

Finally, to accelerate Ciliwung flood risk reduction, this study suggests a formulation of national policy regarding development control in the Ciliwung river basin and establishment of the Ciliwung river basin commission to improve governance of transboundary river flood management. Furthermore, to formulate an in-depth strategy, future research to deeply investigate development control problems in each region and transboundary institutions' interaction in the Ciliwung River Basin management are required.

To conclude, the research findings on the key flood drivers is very important. They may influence the entire flood risk management system. A proposal is given for a cross-border river basin governance model that can be adapted for flood risk management in other areas with similar characteristics.

Data Availability Statement

All data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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