Unveiling Transboundary Challenges in The Ciliwung River Flood Management

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Abstract

Due to massive development in the urban and rural areas of Jakarta Mega City, a dramatic increase in the impacted area and the amount of economic loss from the Ciliwung River Floods occurs every year. The complexity of Ciliwung River flood management has been driven by many driving factors triggered not only by natural, physical, and social factors but also by transboundary issues and power sharing. Even though several research studies have identified the key drivers of the flood risk along the Ciliwung River Basin, addressing the problem has been limited to administrative boundaries. It is important to tackle future flood events using a transboundary approach for Ciliwung river flood and water resource management. About 13 significant flood drivers were identified in this study. Then the study uses MICMAC model to recognize the strategic key flood risk drivers from key stakeholders' perspectives. Among those key drivers, the lack of control of spatial plans and weak stakeholder coordination and cooperation are found to be the critically important drivers to prioritize since they will strongly affect 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 lood disaster risk reduction and its governance 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 of the Ciliwung River Basin.

Keywords: Flood risk driver, Key flood risk driver, Ciliwung river basin, transboundary management, MICMAC analysis, Greater Jakarta

1. Introduction

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

Greater Jakarta is geographically crossed by 13 river systems, with one of them is Ciliwung river. Ciliwung river basin is the longest and biggest river basin. According to Presidential Decree Number 12 of 2012 regarding the Determination of River Area, the Ciliwung River with its length of 140 kilometres long with a catchment area of nearly 438 km^2 crosses three major cities and one regency in West Java Province and Jakarta Province. They are Bogor Regency and Bogor City in the upstream,

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- **Deleted:** Greater Jakarta is geographically crossed with one big river, namely the Ciliwung River.

Depok City in the middle stream, and Jakarta Province in the downstream. The overall population living at the Ciliwung River Basin (CRB) is approximately 25 million with growth rate around 1.4 percent. However, the flood-prone areas are primarily located in the densely populated in the downstream area at DKI Jakarta Province. This Ciliwung River Basin is highly populated by sharply increase low-income community population. By 2009 about 28,818 households lived in the downstream Ciliwung riverbank (Rahayu & Nasu, 2010), however currently about 34,051 households live there according to sources from the DKI Housing and Building Department during the study.

Being situated in a watershed consequently make Greater Jakarta exposed to hydro-meteorological risks, such as flood. Severe floods due to the Ciliwung River's flow have been recorded in 1996, 2002, 2007, 2012, and 2013 (Dewi & Ast, 2017), while the most severe one took place in early 2020. A total of 13 administrative units in Jakarta, Banten Provinces, and West Java Provinces are flooded as of 1 January 2020. The losses due to the 2020 flood tripled from the 2007 event, with an estimation of around IDR 5.2 trillion.

Several factors contributed to the increased magnitude of flood impacts in Greater Jakarta over the past few decades were precipitations, land-use, sea level rise and land subsidence (Budiyono et al., 2016). Meanwhile urbanization in Jakarta between 1995-2014 has decreased runoff regulation, it related to a decrease in green spaces and bodies of water, landscape pattern changes (Maheng et al., 2021) and to spatial characteristics, which included industrial parks, mixed-use new towns and large-scale residential areas, and shopping centres (Firman & Fahmi, 2017). However, massive urbanization in Greater Jakarta has strongly affected the land use change, which leads to the decreased run off regulation. As identified by (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).

While the Ciliwung River bears responsibility as a transboundary river that incorporates the development of megapolitan, complex flood risk drivers have come in those several regions and many aspects consequently.

As Greater Jakarta lies in lowland area with 13 river system, all tributaries and river basins located in the Jakarta Province and its peripheries. The vast peri-urban development in the last three decades may cause the massive conversion of water catchment area, wetland, and green areas; this leads to the increase of flood threat to the Jakarta. (Priyambodoho et al., 2022) identified that 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.

Further studies of flood risk drivers identified the need for expanding the spatial scales from the upstream up to the downstream area (Dawson et al., 2009). In recent years, several scholars have analysed drivers of the Ciliwung River Basin Flood. For instance, Texier (2008) analysed 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, Asdak et al. (2018), and Texier (2008) they both 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 river management, as well as mentioned which drivers are the most critical in the transboundary management of the Ciliwung River flood. Flood risk managed by a single authority is indeed complicated enough and becomes much more complex when dealing with the transboundary river. Thus, 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 unveiling the challenges of transboundary flood risk management is significantly important. It will contribute to the area of flood disaster risk management, water resource management, environmental disaster science and governance of transboundary river management. Moreover, this study is particularly 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,

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this study offers a unique perspective on the challenges and solutions associated with flood risk management in a region involving several administrative jurisdiction regions.

Therefore, this study aims to address broader issues and complexity of key flood drivers and to unveil the challenges in the Transboundary Ciliwung River Flood Management. The purposes of the paper are (1) to define the key flood risk driving variables of the Ciliwung River Flood using Matriced' Impacts Croisés Appliquée á un Classement (MICMAC) analysis, (2) to depict the actual condition of the driving variables and (3) to recognize the challenges in transboundary Ciliwung river flood management.

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-border cooperation and local/regional/national level policies can be synergized to reduce and manage flood risk effectively.

A total of five sections are presented in this paper. The first section (Introduction) discusses the problems and gaps in previous studies associated with the Greater Jakarta floods, especially Ciliwung river flood. The second one reviews related key flood drivers from the literature and develop key flood driver framework to be examined in this study. The third one explains the ways in which the transboundary approach is used in this study and why MICMAC analysis is a suitable tool to define critical key flood drivers. The next section elaborates upon the result of MICMAC analysis and discussion on the key flood drivers' findings in the Ciliwung River Basin. Then, how the results and findings of those key flood drivers match up with flood drivers' theoretical explanations will be discussed. The last section draws a way forward and a conclusion to tackle the challenges and future research regarding understanding further the key flood risk drivers.

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 flood vulnerabilities (Beese et al., 1999; UNISDR, 2009). It refers to the likelihood and exposure of elements to flood hazards.

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To have better and solid 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 defined by (E. Evans et al., 2006). A flood source can be determined as any event or condition that may cause flooding due to meteorological conditions (e.g., extreme rainfall, sea level rise), pathways to transfer floodwaters to 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 (CRB) was developed in this study, as represented in **Table 1**, based on document review, field observation and other studies (E. P. Evans et al., 2008; O'Donnell & Thorne, 2020). There are five flood source drivers, such as temperature, precipitation, sea-level rise, storm surges, 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. Meanwhile, five drivers are defined as flood receptor, i.e., urban impact, buildings, infrastructure impact, economic impact, and social impact.

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). 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).

However, 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).

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

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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 due to its location in a major river delta (Asdak et al., 2018). Moreover, some of the city areas are a few meters below sea level. It is caused by land subsidence, which is estimated to be 1 to 15 centimetres per year, both spatially and temporally (Latief et al., 2018).

The existing Jakarta flood control system is based on Prof. H. Van Breen (1973) concept, in which load overflow rain 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 an 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 a 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). Thus, 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 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).

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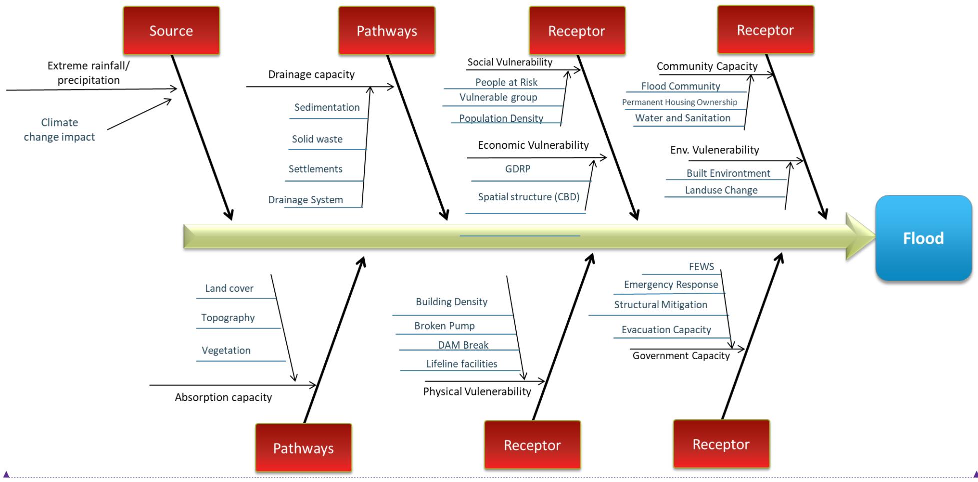

Figure 1: Key Flood Drivers

When rivers cross several administrative jurisdiction, various and multi-tier stakeholders from national, provincial and local are involved in the river management decision-making. 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. Consequently, understanding the transboundary management in flood risk reduction is very critical.

Therefore, the Ciliwung River flood drivers on the **Table 1** and **Figure 1** were refined based on input from the Stakeholders Focus Group Discussion conducted by this study on 26 September 2019 under collaboration with National Planning Agency (Bappenas), with a few modifications in terms. The FGD was attended by attended by 12 national, provincial and local government institutions See also the results in **Table 2** below as identified Ciliwung key flood risk drivers. There are thirteen variables to be the flood drivers of the Ciliwung River Basin.

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)
A9	Ground Water Exploitation	Groundwater flooding (Pathway)
A10	Stakeholder Cooperation and Coordination (Government, Lifelines, Business, Community)	Stakeholder Behaviour (Pathway)

Codes	Key Flood Drivers	Modified Terms and Classification from Table 1
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 become critically important. 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):

1. Institution with main role in the planning process at each of the national, provincial, and city/regency levels.
2. 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
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

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No	Institution	Roles
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 required 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 coding data, 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 the program or 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, autonomous, independent, linkage, and dependent (Duperrin & Godet, 1973; Jharkharia & Shankar, 2005).

1. Independent group: driving factors in this group characterised by highest driving power but weak dependency. These factors are rarely influenced by other drivers and consist of drivers with strong driving power but low dependence power.
2. Linkage group: driving factors in this group are characterised by both high driving and high dependency power. Factors within linkage group both influence other groups and are influenced by them. This quadrant represents factors that have strong interconnections and mutual dependencies with factors in other quadrants.
3. Autonomous group: driving factors in this group are 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.
4. Dependent group: driving factors in this group are 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 was 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 are used to modify **Table 1** to become **Table 2** as final flood risk drivers framework to be used for interview 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 next section.

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
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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. **Figure 2** shows that two flood drivers, i.e., Spatial Plan (A12) and stakeholders Cooperation and Coordination, are independent drivers (Quadrant I). Since they have highest driving power and lowest dependency power, they exert a significant influence on other driver from other quadrants. These two drivers are the most powerful drivers and will take important role in overall system of transboundary Ciliwung river flood management. The intervention on these two factors will have the impact to other flood drivers. These two key drivers will be discussed further in the next section.

This study found no linkage variables, fall in linkage groups (Quadrant II). This means that all the stated variables are stable. Meanwhile seven flood drivers are autonomous drivers (Quadrant III). 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). However, in this quadrant the Extreme Rainfall (A1) and Built Environment (A8) are located closer to quadrant 1, having relatively high driving power. These two will be discussed further in the next section.

While the rest of flood drivers show the least driving power, they fall in dependence group (Quadrant IV). They are drainage capacity (A3), catchment area (A7), flood control-structural mitigation (A13), river capacity (A4). Therefore, these factors are the weakest in the key flood driver mapping, relying on the influence of other flood drivers from other quadrants. 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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Run the MICMAC graph
After formulating the IRM matrix, a four-quadrant graph can be used using the MICMAC application version 6.1.2, developed by Godet and Francois in 1989. The result of MICMAC analysis is presented in the next section.
Result
The results of MICMAC

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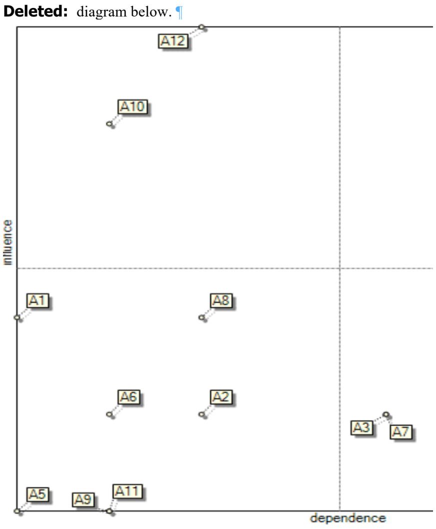

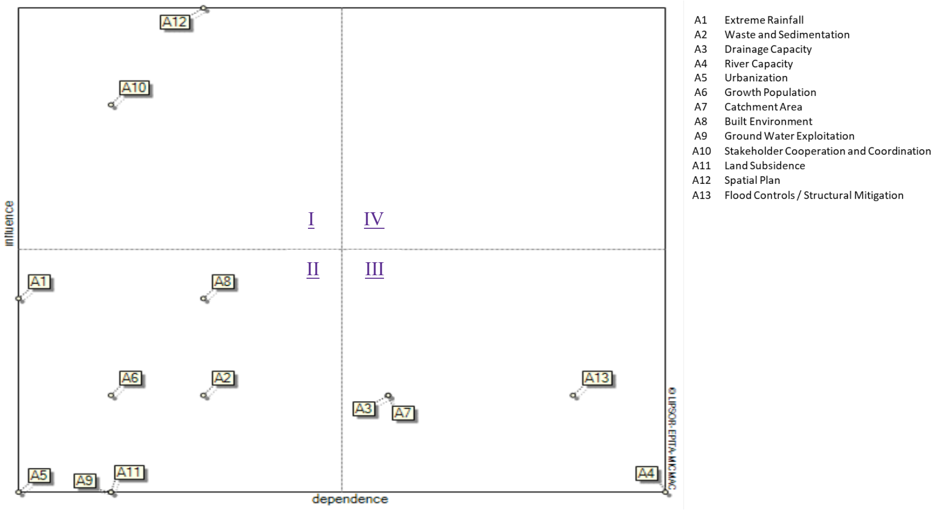

Figure 2: MICMAC model result diagram

This study has emphasized on the important of non- structural mitigation through spatial planning, covering the issues and challenges of Ciliwung flood risk governance in reducing/managing the Ciliwung River Basin flood risk and achieving sustainable catchment area. Findings of this study could be as the inputs for other cities/metropolitan which has similar problem transboundary river flood management.

Through MICMAC analysis, spatial plan, as well as stakeholders' cooperation and coordination, are emerged as critical flood risk drivers in Ciliwung River Basin. Refer to SPR (Source-Pathway-Receptor) model in **Table 2**, it is found that in the case of the Ciliwung River Flood, while flood management is conducted across transboundary regions, 'pathway 'such as stakeholder behavior and environmental regulation gives the main influence in the set of flood risk drivers.

4.1 Spatial Plan

A holistic approach is needed in the development of flood risk management, covering the upstream, midstream, and downstream. Controlling the upstream and midstream development through integrated spatial planning are necessary to reduce flood risk at the downstream. Since Ciliwung river is one of the longest river basins passing through 3 province and 5 regencies/cities, the role transboundary coordination in water resource and flood risk management become very critical from the perspective of ego sectoral as well as ego area jurisdiction.

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 which the most powerful influence on other key flood drivers.

Most flood risk reduction regulations are included in spatial plans, such as land use regulation, structural mitigation development, catchment area preservation, and river maintenance. Meanwhile, each of the administrative units (2 provinces and 3 cities/municipalities) in the Ciliwung River Basin has its own local and provincial spatial plan. To bridge transboundary issues and challenges in river flood risk management and spatial planning, 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.

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Deleted: **Figure 2** shows the flood drivers mapping into four quadrants: autonomous, linkage, dependent, and independent. Extreme rainfall, built environment, population expansion, waste and sedimentation, urbanization, groundwater exploitation, and land subsidence are autonomous drivers with low driving power and dependability. Only a few strong drivers are strongly linked to them. ¶
River capacity, drainage capacity, catchment area, and flood controls are the drivers that have a low driving power but a high dependence power. In other words, they get inclined by other strong drivers. River capacity appears as the most dependent driver, indicating it is the end of the driver chain in the system. ¶
In this study, there are no linking parameters, which means all the stated drivers are stable. Further, spatial planning, as well as coordination and cooperation among stakeholders, are the independent drivers that impact other drivers. These are termed as key drivers, which have the most powerful influence on other drivers.¶
Discussion¶

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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.

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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. Since, it appears from the interviews that spatial planning has significantly affected drainage capacity, river capacity, catchment area, built environment, stakeholder cooperation, and flood control development.

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 downstream. Thus, the spatial plan needs to consider the flood risk.

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.

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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.

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4.2 Stakeholder Coordination and Cooperation

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As the second critical key flood drivers, the stakeholder cooperation and coordination (A10) are playing important role transboundary Ciliwung River Basin management. It is independent drivers which the most powerful influence on other key flood drivers.

Based on the interviews, 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.

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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.

According 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.

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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 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.

National Planning and Development Agency (BAPPENAS) said that the transboundary coordination function 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 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

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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 Quadrant III is closer to Quadrant I. It means that this driver still has influence power to affect other drivers, even though moderate.

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 and drainage system 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 this drive 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. 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.

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 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

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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 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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