Journal of Water Resource and Protection, 2021, 13, 498-537
https://www.scirp.org/journal/jwarp
ISSN Online: 1945-3108
ISSN Print: 1945-3094

Evaluation of Transboundary Water Resource Development in Mekong River Basin: The Application of Analytic Hierarchy Process in the Context of Water Cooperation

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How to cite this paper: Lan, N.P. (2021) Evaluation of Transboundary Water Resource Development in Mekong River Basin: The Application of Analytic Hierarchy Process in the Context of Water Cooperation. *Journal of Water Resource and Protection*, **13**, 498-537.
https://doi.org/10.4236/jwarp.2021.137029

Received: June 4, 2021
Accepted: July 23, 2021
Published: July 26, 2021

Abstract

Mekong River is one of the major international freshwater sources in the world. The Lower Mekong Basin (LMB) comprised of four downstream countries, including Thailand, Lao PDR, Cambodia, and Vietnam. The utilization of the basin's water brings not only substantial benefits to the region ranging from hydropower to navigation, but also negative impacts caused by the unbalanced water using. The essential role of Mekong River requires all member nations to cooperate effectively for the sustainable development of the region. One of the most popular methods in the field of water resource management is a trustable tool called the Analytical Hierarchy Process (AHP). AHP is much appropriate for water resource policymaking. The literature, however, points out that there is no study to both structure the water using hierarchy and employ quantitative (objective) criteria to the AHP model in LMB case. With regard to water resource management, there are no previous studies applying AHP models to evaluating sustainable development of transboundary water resource in LMB case. This paper explores the evolution of water cooperation among Mekong countries and subsequently evaluates the water development scenarios in the LMB based on the water cooperation preferences of four LMB countries This study proposes a novel approach to analyzing, assessing water resource development scenarios characterized by sustainability indicators and to assisting in developing a suitable water policy in LMB according to the best cooperation scenario.

Keywords

Analytic Hierarchy Process, Lower Mekong Basin, Transboundary Water Cooperation, Transboundary Water Evaluation, Mekong River Commission,

Mekong River Basin

1. Introduction

Transboundary rivers, usually shared by two or more riparian countries, are vital to human life and global peace and security. A total of 286 transboundary rivers worldwide, accounting for 60 per cent of the world freshwater flow, are currently providing home and livelihoods for more than 40 per cent of the global population [1] [2]. Given the increasing demand for fresh water supplies due to climate change, rapid population growth and industrial development, transboundary water resource management have been widely recognised as a matter of growing concern across the globe. Therefore, water availability and usage in the international context present enormous challenges to water planners and decision-makers. Although differences in socio-economic development, political orientation, national self-interests and institutional and legal frameworks across member states are often considered potential sources of conflict, they open up opportunities for greater cooperation on technical, social and economic issues [3]. Empirical studies have indicated that riparian countries are more likely to cooperate than fight over water despite the coexistence of cooperation and conflict in the transboundary water context [4] [5]. Cooperation on shared waters is becoming more common for some reasons, including mutual interest, shared benefit and the existence of institutional arrangement [6] [7]. Many researchers have acknowledged the essential role of transboundary water cooperation in maintaining the peace and security of the region, providing substantial economic benefits to member nations through as well as increasing the balanced and equitable utilisation of the water resources [3] [8] [9] [10] [11] [12]. Scholars have identified enormous benefits from basin-wide cooperation by assessing the value of water cooperation in the international context [13] [14] [15]. In addition, the United Nations (UN) has highlighted the significant importance of transboundary cooperation in implementing integrated water resources management at all levels by 2030 by making this topic the focus of target 6.5 of Sustainable Development Goals (SDG) [8] [16]. According to Schmeier & Vogel (2018), member states tend to choose cooperation over conflict since the cooperation benefits in the long term will outweigh potential gains from noncooperative actions in the short term [17]. Considering the importance of cooperation, although transboundary river issues can be approached from various perspectives, a better understanding of these issues under cooperative interactions among member countries is becoming increasingly popular and attractive.

In the context of transboundary river management, past research provides different views relating to cooperation issues. Much research emphasis has been placed on figuring out the factors that contribute to the success or failure of shared river cooperation. While there are cases of good practice on cooperation in trans-

boundary rivers, namely the Colorado River and the Rhine river [18] [19], examples of ineffective collaboration can be found in the Syr Darya and the Amu Darya rivers [20] [21]. Many studies have mainly focused on measuring and monitoring transboundary water cooperation using different sets of indicators [22] [23] [24] [25] [26]. Other authors have spent considerable efforts to identify and better understand the challenges and opportunities of transboundary river cooperation [27] [28] [29] and to analyse the benefits of cooperation on international rivers [11] [30]. Despite the growing literature on cooperation over shared water currently, not many empirical works have been done to capture the evolution of the cooperative scale and examine the influence of this change on the water-related decision-making process. In reality, the focus and degree of water-related cooperation among riparian countries have changed over time, with an increased emphasis on emerging issues and water development priorities in a specific period. Therefore, the decision-makers should direct their attention to explore the impacts of the evolutionary pattern of water cooperation on the river basin development.

The Mekong River is one of the longest and most significant rivers globally, stretching on the national territory of six states, namely China, Myanmar, Laos, Thailand, Cambodia and Vietnam [32] [33]. The river system is essential for the comprehensive development of the region since it offers member countries a vital source of natural resources while supporting rich biodiversity and the largest inland fisheries in the world [31] [34]. In terms of geographical location, the Mekong River Basin (MRB) is divided into two sub-basins: 1) the Upper Mekong Basin (UMB), consisting of China and Myanmar; 2) the Lower Mekong Basin (LMB), which starts from Laos to Vietnam (see **Figure 1**). The LMB, accounting for 76 per cent of the total area of the basin with a total population of around 65 million people, serves as a lifeline for the basin's inhabitants and economic development of all four lower countries by bringing enormous benefits from, such as water supply, hydropower generation, irrigation and navigation [31] [35]. Main characteristics of the MRB countries are described in **Table 1** and **Table 2**.

Table 1. Area of member countries in MRB [36].

Member country	Area of the country within MRB (km^2)	As % total area of the basin (%)	As % total area of the country (%)
China	165,000	21	2
Myanmar	24,000	3	4
Laos	202,000	25	85
Thailand	184,000	23	36
Cambodia	155,000	20	86
Vietnam	65,000	8	20
MRB	795,000	100	

Table 2. Population of member countries in LMB in 2015 [31].

Member country	Population in LMB (million)	Share of LMB population (%)	Share of national population (%)
Laos	13.4	22	86
Thailand	6.2	10	91
Cambodia	25.4	39	37
Vietnam	19.8	31	22
LMB	65	100	

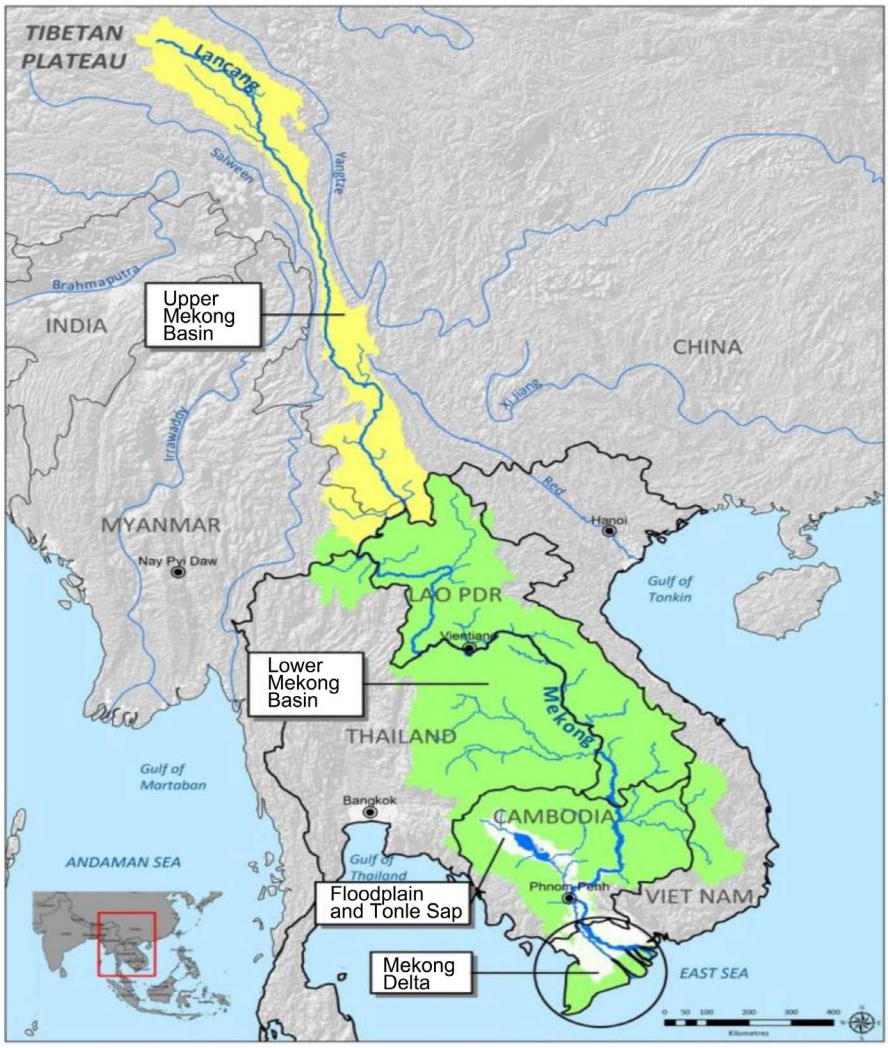

Figure 1. Map of the Mekong River Basin [31].

Managing and resolving water-related issues among countries with different levels of development and interests while preserving and maintaining the gains from the river have been posing significant challenges to the LMB members, which require practical cooperation [37]. The cooperation history between lower Mekong countries has started in the early 1950s with considerable efforts of the

United Nations to assist in forming the Mekong River Committee, the first large-scale organisation aiming to promote cooperative water development relating particularly to security issues [38] [39]. However, it was not until 1995 that the birth of the Mekong River Commission (MRC), an international organisation established under 1995 agreement signing by the four lower Mekong countries has marked a historic turning point in the regional cooperative agenda. The mission of MRC is to facilitate joint development and ensure the reasonable and equitable use of water resources in the basin [40]. Similarly, water-related issues in the Mekong region are central to several cooperative mechanisms such as the Greater Mekong Subregion, the Lower Mekong Initiatives or the Lancang-Mekong Cooperation (**Table 3**).

Despite these institutional frameworks, the contribution that MRC has made to foster cooperation among the LMB countries is recognised as substantial [38] [42]. Till date, MRC, as a model of cross-border water management with its intense consciousness of comprehensive development rather than entirely emphasizing on economic achievement, has relatively succeeded in mitigating conflict and boost the riparian states' joint action on water-related issues [43] [44] [45]. Sustaining shared river collaboration is challenging; thus, concerned authorities need to consider the different dimensions of regional cooperation activities on the Mekong River to gain insights into the evolution toward transboundary water cooperation, consequently assist the decision-making process in the LMB.

MRC, with its emphasis on the critical sectors in the LMB, has carried out several

Table 3. Examples of cooperative frameworks in Mekong region (adopted from [40], [41]).

Cooperative framework	Year of establishment	Members	Cooperation objectives/priorities
Greater Mekong Subregion	1992	China (Yunnan and Guangxi province), Cambodia, Laos, Myanmar, Thailand and Viet Nam	Regional connectivity through projects in agriculture, energy, environment, health and human resource development, etc.
Mekong River Commission	1995	Cambodia, Laos, Thailand and Viet Nam (dialogue members: China and Myanmar)	The jointly management of the shared water resources and the sustainable development of the Mekong, including water allocation, navigation, irrigation, hydropower, flood control, fisheries, etc.
Lower Mekong Initiatives	2009	Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam, initiated by the United States	To deliver equitable, sustainable and inclusive economic growth among the five countries
Lancang-Mekong Cooperation	2015	China, Myanmar, Cambodia, Laos, Thailand and Viet Nam	Cooperation under the leading of China relating to political, social and economic issues

basin-wide assessments, in which they formulated a wide range of development scenarios and systematically analysed the socio-economic and environmental impacts. The most recent is the Council Study, a comprehensive study considering the influence of the mainstream hydropower project [46]. More importantly, along with addressing the limitations of previous reports, the Council Study has a broader scope and covers a wide range of development scenarios considering the projected changes in population, hydropower development and potential future effects of climate change [47] [48]. Past researchers have put efforts to access different basin-wide scenarios in the LMB. While most scholars have concentrated heavily on specific scenarios developed in the Basin Development Plan-Phase 2 to 1) estimate trade-offs between the economic benefit from hydropower development and the social/ecological loss using benefit-cost analysis [47] [49], 2) to evaluate diverse impacts of hydropower development [50] [51] or 3) to examine changes in hydrological condition [52], minor empirical works have been done concerning different scenarios generated in the MRC Council Study. Intralawan *et al.* (2019) has compared the cost and benefit of the LMB's hydropower development in four different reports of MRC, including the Council Study. However, the authors simply summarise the impact assessments initially conducted by the MRC and consequently draw a cross-comparison between these reports rather than focusing on the scenarios derived from the Council Study. No research to date has evaluated and compared the economic performance of the Council Study's main development scenarios taking the priority in water cooperation of the LMB countries into consideration.

For all the above reasons, the primary goal of this paper is to explore the evolution of water cooperation among Mekong countries and subsequently evaluate the water development scenarios in the LMB based on the water cooperation preferences of four LMB countries. The author aims to achieve these objectives by answering the following research questions: 1) How has the cooperation over water in the MRB changed during the last 50 years, especially since the establishment of MRC in 1995, and 2) What are the preferred development scenarios of the four LMB countries taking the differences in water cooperation scale into consideration. A multi-criteria decision analysis model is employed for providing an in-depth analysis of decision-making processes in the case of the LMB, which are characterised by multiple criteria and alternative decision options.

The remainder of this paper is organised as follows. After setting the theme for this research in the introductory section, the theoretical framework is presented, defining the specific viewpoint regarding water cooperation in the context of the transboundary river and identifying the key variables that should be included in the evaluation. The following section introduces the research methodology, in which the research model and data collection process are carefully explained. Then, the nature of water cooperation in the LMB and the performance evaluation of development scenarios are accordingly analysed. The final sections discuss the findings and provide some concluding remarks.

2. Theoretical Framework

2.1. Transboundary Water Cooperation

2.1.1. Defining Transboundary Water Cooperation

Despite a large body of research done on cooperative interactions in a transboundary context, very few studies define or explain the term "transboundary water cooperation" carefully. There is no single definition of this term since it is interpreted differently by actors in different settings and can exist in a wide range of forms [12]. The United Nations Economic Commission for Europe, in their policy guidance, has regarded transboundary water cooperation as "the effective cooperation between two or more countries sharing a transboundary river, lake, or aquifer" [53]. Nonetheless, the actors involved in water cooperation activities and the cooperative forms have not been adequately identified in those definitions. Adeel *et al.* (2015) [54] state that "transboundary water cooperation covers various levels of interactions between and among parties, stakeholders, and sectors that are involved in the development, use and management of a water resource; in the delivery of water services; or are impacted from either the actions or the consequences of such involvement". Subsequently, after significant revision, M. J. McCracken (2019) [55] finally defined transboundary water cooperation as "interactions between actors over shared waters that result in establishing mutually beneficial outcomes through a decision-making process; this process could include formal and informal legal and institutional mechanisms depending on the scale and context". M. J. McCracken has successfully captured the legal and institutional basis of cooperation, making it easily applicable to different situations. To this paper, M. J. McCracken's definition is the most relevant, emphasising the essential elements required for full transboundary water cooperation.

2.1.2. Classifying Transboundary Water Cooperation

Early understanding of transboundary water cooperation has established a sound foundation for examining other facets of this term. Cooperation over international waters can take different forms at various levels of operation, which indicate the activities counted as cooperation. Types of cooperative efforts vary from 1) information sharing (data exchange) relating, such as reservoir operations, hydrologic information and flood/drought mitigation, 2) active collaboration in the form of notification/consultation in planned development to 3) joint actions (joint plans, investment or management) [12] [16] [35] [37] [56]. Existing arrangements of transboundary water cooperation differ significantly regarding the extent and intensity of cooperation [2]. An agreement/convention, bilateral/multilateral treaty, protocol, memorandum of understanding and joint declaration between riparian countries is referred to as an arrangement for transboundary water cooperation, which may be at different levels from ministerial to governmental and national to the regional level [57] (see **Table 4**). Similarly, to quantify the extent of collaboration Strategic Foresight Group (2015) [58] specified active water cooperation in low to high order, ranging from ministerial-level

Table 4. Examples of forms and arrangements of transboundary water cooperation (adapted from [2] [57] [60]).

Arrangements of cooperation		Forms of cooperation	
Types of arrangement	**Characteristics**	**Cooperative forms**	**Characteristics**
Exchange of Letters	To set out specific commitments that may have been agreed at a particular meeting, etc.	Information sharing/data exchange	The systematic exchange of different types of information relating to the general conditions of the aquatic environment, the measurement of water flow, extractions, releases from reservoirs, sources of pollution, etc.
Joint Declaration/ Memorandum of Understanding (MOU)	Tend to include broader principles of cooperation and is often adopted at the inter-ministerial level	Notification of Planned Measures/Notification of Emergencies	These systems consist of different procedures to manage crises, in particular monitoring, forecasting, early warning, and evacuation plans in case of catastrophes, etc.
Protocols	Tend to be concluded on the basis of more general founding agreements	Consultations	To exchange information and discuss pending issues, such as the potential impact of actual or proposed uses of the waters and ways to prevent, mitigate, or eliminate their potential or actual adverse effects, etc.
Agreement/Framework Convention/International Treaty	Tend to set out general rules and principals for governing a particular river, and may establish joint institutional arrangements such as intergovernmental commissions, etc.	Negotiations	May be viewed as a process, comprising consultations as a preliminary stage and conducted through normal diplomatic channels, summit discussions
		Capacity-building	Involving forms of human resources development, such as joint education and training schemes, and the organization of academic conferences, symposia, seminars, courses, and discussions, etc.

meetings, collaboration in technical issues, joint monitoring, high political commitment to regional integration. More specifically, Grünwald *et al.* (2020) [59], when taking the evolution of water-related events as crucial issues, pointed out six levels of cooperation intensity, including silent, exploratory, strategic, accountable, affinitive and intuitive cooperation.

While most available literature has focused on the forms or arrangements of transboundary water cooperation, the main challenge that needs to be addressed in classifying water cooperation is how to measure the cooperative level. In practice, some previous researchers have proposed intensity scales to rank transboundary cooperative water events[1]. The first scale to measure the international conflict or cooperation intensity between nations was the 15-point COPDAB Scale introduced by Azar (1980b) [61]: point 1 represents the most cooperative event, and point 15 represents the most conflictive one [62]. However, the most renowned scale is the BAR Scale[2], which was developed in the Basin at Risk (BAR) project of Oregon State University to evaluate the intensity of conflict or cooperative events occurring in the period 1948 to 1999 [63]. BAR scale-origi-

[1]This study uses the definition of water cooperative events proposed by Yoffe *et al.* [63], in which cooperative events are defined as instances of cooperation that occur within an international river basin, involve the nations riparian to that basin, and concern freshwater as a scarce or consumable resource (e.g., water quantity, water quality) or as a quantity to be managed (e.g., flooding or flood control, water levels for navigational purposes).

[2]BAR Scale of Intensity of Conflict and Cooperation.

nated from COPDAB Scale with some modifications-ranges from −7 to +7, representing the change from the highest level of conflict to the highest level of cooperation, respectively. Later, to revise the BAR scale in more practical and relevant to international water concerns, Kalbhenn & Bernauer (2012) [64] introduced the International River Cooperation and Conflict (IRCC) Scale with conflict and cooperative levels ranging from −6 to +6, respectively. More recently, Feng *et al.* (2019) presented a 7-point cooperative scale based on the status of water cooperation in the Lancang-Mekong River Basin. In this study, the author will introduce a 5-point scale to evaluate the evolution of water cooperation in the LMB in forty years, combining the BAR and Feng scale[3] [65]. More specifically, while using the full Feng scale to create the new scale, only the BAR scale representing the cooperative levels from +1 to +7 point will be included (**Table 3**). The reasons for selecting the two scales are 1) to make it comparable between them; and 2) to ensure consistency between the cooperative events and their respective scales since this study employs the cooperative event datasets constructed by the BAR project and Feng *et al.* (2019) [65], as will be explained later on in Section 3.1.

2.2. Multi-Criteria Decision Analysis—Analytic Hierarchy Process Approach

Transboundary river management is generally recognised as a difficult task due to the complexity of socio-economic systems, involving various stakeholders pursuing multiple and sometimes conflicting objectives [66]. Therefore, the decision-making process in the international river context requires considering various quantitative and qualitative criteria measured in different units while attempting to evaluate and compare the performances of various water-related alternatives. Scholars have developed methods to support making decisions in those situations, especially techniques capable of improving the audibility and transparency of the decisions. Multi-criteria decision analysis (MCDA) has been demonstrated as beneficial for solving international water-related matters, characterised by multiple criteria and alternative decision options [67]. Flexibility in analysis design [68] and the ability to improve transparency in decision procedure [67] is typically seen as the appeal of the MCDA method. This method proves to be a powerful approach to facilitate collaborative processes [69] [70] and considerably improve the decision-making process and public acceptance [71]. MCDA consists of different approaches and analytical tools that allow stakeholders to rank and evaluate different alternatives against multiple criteria while considering their preferences [72]. Over the last few decades, the application of MCDA methods has increased and advanced significantly [73]. Particularly, MCDA has been mentioned as a critical component of decision support system in the field of water resources management [74]-[79]. In this field, water policy evaluation, planning of water supply, selection of infrastructure have been the most common applications of MCDA before 2007 [67]. Water shortage problems, water

[3]The short name of water cooperative scale introduced by Feng *et al.* (2019) [65].

use management, water quality problems and water allocation are recently primary topics for publications using MCDA methods [80].

There are a large number of MCDA approaches that can be applied to cope with water-related issues. One of the most commonly used techniques is Analytic Hierarchy Process (AHP), developed by Saaty (1980) [81], a flexible and effective tool to solve complex problems and support the strategic decision-making process in many fields, such as in economics [82] [83] [84], healthcare [85], social science, engineering [86] [87], environmental management [88] [89] and water management [90] [91] [92] [93]. The motivation behind the development of AHP has not been only by its simplicity to combine quantitative and qualitative criteria in the priority-setting process [94] [95] [96], but also by its ability to make qualitative criteria measurable for prioritising or producing relative importance [97]. The basic concept of AHP describes the selection process of the best (more beneficial) alternative concerning each criterion. An AHP model comprises the following steps:

1) Constructing a model for the decision: a complicated decision-making problem is decomposed into a hierarchical structure of goals, criteria and alternatives.

2) Deriving weights for the criteria: Through pairwise comparisons of the relative importance of each set of criteria regarding the expected goal, the weights of criteria are obtained.

3) Deriving priorities for the alternatives: By following the same process as described in Step 2 (*i.e.*, making pairwise comparisons of alternatives concerning each criterion), the alternative priorities are obtained, and then the overall priorities of all alternatives are established, taking into account the weights of criteria. The pairwise comparisons are made using a ratio scale proposed by Saaty (1977) [81] (**Table 5**). The consistency ratio is calculated to guarantee a reasonable and acceptable consistency level. In the case that inconsistency happens, a review and revision of judgements are required.

Table 5. Saaty's scale for pairwise comparison.

Importance	Saaty's scale	Explanation
Equally importance	1	Two criteria *i* and *j* are equally important
	2	(*)
Moderately importance	3	Criterion *i* is moderately more important than criterion *j*
	4	(*)
Strongly importance	5	Criterion *i* is strongly more important than criterion *j*
	6	(*)
Very strongly importance	7	Criterion *i* is very strongly more important than criterion *j*
	8	(*)
Extremely importance	9	Criterion *i* is extremely more important than criterion *j*

Note. (*): 2, 4, 6, 8: intermediate values.

4) Synthesis of the model by ranking the alternatives based on the order of their overall priorities. The final decision is made by selecting the alternative with the highest priority ratio.

AHP is well suited to water resources management in general and decision making for water development policy. Research by Zolghadr-Asli *et al.* (2021) [98] underlines that of all Multi-criteria Decision Making (MCDM)[4] approaches, AHP is the technique most widely utilised to support the water-related decision-making process, providing decision-makers with a valuable tool to assign weights to the evaluation criteria. Relevant applications of AHP to water resource management include the analysis of water allocation [99] [100], water quality [101] [102], watershed management [103] [104], water resources planning [105], groundwater management [106] [107], flood management [108] [109], etc. Nonetheless, few studies focus on utilising the AHP model to deal with international water-related issues concerning transboundary river management. Gallego-Ayala & Juízo (2014) [91] stresses the potential applicability of the AHP model to integrate stakeholders' preferences into the selection process of different water resources management plans in the lower Incomati river basin a shared river between Mozambique, Swaziland and South Africa. Other scholars attempt to solve the water allocation problems in transboundary river basins, such as identifying the best water allocation strategy or developing an effective benefit-sharing mechanism for water allocation between riparian countries [97] [110] [111]. There has been no study on water resources development in the LMB case, especially evaluating the water scenarios proposed in the Council Study. As to analysing the AHP model used in water resource management by application objectives, there are three groups consisting of selection, prioritisation and evaluation issues.

Supporting the decision making relating to the evaluation problem is highlighted as the most frequent application of AHP [92]. In this paper, different water development scenarios in the LMB will be evaluated by the economic benefits that riparian countries can receive from the major water-related sectors considering these countries' preferences for each sector. Therefore, a traditional economic approach to accessing alternatives is insufficient for that purpose, particularly when applying to evaluate against a range of economic criteria with different measurement units. A new approach, which can accommodate qualitative factors while maintaining the significant effect of economic issues and, simultaneously, can be transparent and easy enough to implement while avoiding biased judgements, is much needed. Under those circumstances, AHP is believed to fulfill all the requirements as a promising solution to the decision-making problem in the transboundary river basin.

3. Methodology

3.1. Water Cooperation Event Database

Previous researchers have spent considerable efforts to compile global datasets

[4]MCDM is also known as MCDA and these two concepts are generally used interchangeably.

on interactions between states, involving both conflict and cooperative interactions, that can contribute to the study of cooperation over international river basins, either directly or indirectly. In addition to the Conflict and Peace Data Bank (COPDAB) 1948-1978 [61], there are some other datasets, for example, Global Event Data System introduced by the Global Database of Events, Language, and Tone (GDELT) project and Environment and Security Water Conflict Chronology developed by Gleick (1993) [112]. However, while many of those datasets mainly focus on diplomatic and military interactions between countries, none specifically pay attention to water interactions in transboundary river basins. The International Water Event Database (IWED)[5] developed from the Basins at Risk project of Oregon State University is recognised as the first attempt to provide a global description of water interactions over the transboundary river between riparian states [4] [113] (see **Table 6**). IWED is an online searchable database that reports conflict and cooperative events occurring in

Table 6. Examples of water events in the MRB from BAR water event database (extracted from http://gis.nacse.org/tfdd/internationalEvents.php and the author's self-analysis).

Issue type	Date	Event summary	BAR scale
Hydropower	1995/2/24	China's Yunnan Province welcomes foreign investors to develop a large-scale hydropower plants & is poised to consider cooperation with Thailand in construction of dams.	1
Joint management	1994/11/25	Four countries have cleared the last hurdle to use the mainstream Mekong River during the dry season, which held up agreement for 3 years, & will initial an historic agreement on managing the river. The countries have been negotiating a framework for water use in the Mekong for purposes such as irrigation, hydropower, navigation, flood control, fisheries, transportation of timber & tourism.	3
Technical cooperation/ assistance	1993/7/27	In late July, Khondahak, chief of the Houai Sai District, Bokeo Province (Laos) and Zhong, chief of La District, Yunnan Province, People's Republic of China, signed a cooperation memorandum for surveying a small hydroelectric generation project in Houai Sai District.	4
Joint management	1991/1/1	Cambodia requests reactivation of Mekong Committee.	2
Navigation	1990/6/18	China and Laos completed their first joint survey of the Mekong River to determine the possibility of opening the waterway to more trade.	3
Water quantity	1980/2/4	A memorandum of irrigation cooperation between the delegations of the Laos Agriculture, Forestry, and Irrigation Ministry and the Vietnamese Water Conservancy Ministry was signed in Vietiane.	4
Economic development	1975/1/31	Joint declaration of principles for utilization of the waters of the Lower Mekong Basin, signed by Cambodia, Laos, Thailand, and Vietnam	4

[5]Accessible at https://transboundarywaters.science.oregonstate.edu/content/international-water-event-database.

1948-2008 concerning a wide range of water issues. Regarding water cooperation in the MRB, Feng *et al.* (2019) has constructed Lancang-Mekong Water Cooperative Events Database (LWCED) based on IWED and other several official sources, covering events from 1995 to 2015. The major difference between the two datasets is that IWED covered both conflict and cooperative events in all transboundary river basins worldwide in the period 1948-2008 while the LWCED provided updated data on only cooperative events happening in the MRB from 1995 to 2015. To collect adequate data for the analysis of water cooperation in the MRB, the author develops a combined event dataset using data extracted from LWCED and IWED. A new scale was developed to measure the cooperative level of each event by revising and adopting the BAR scale and Feng scale, as previously mentioned in Section 2.1. Two specific periods (1975-1995 and 1995-2015) are subsequently compared and assessed for trends in international water cooperation in the LMB.

The author produced a new cooperative scale combining the BAR and Feng scales to make the two datasets comparable. The author first carefully investigated the IWED and LWCED scale descriptions to identify the differences and similarities of the events assigned to each cooperative level in these two datasets. The events with similar characteristics (or belongs to a similar cooperative form) were grouped to produce a new cooperative level, assigned a particular point. A new 5-point cooperative scale was introduced at the end of this process (**Table 7**). In addition, it should be noted that the objectives of water cooperation events reported in the two datasets are diverse and partly different. To construct a new event dataset, this study, thus, selects only the water events concerning the same cooperative objectives in the two datasets, including hydropower, navigation, water use, joint management and comprehensive development. Finally, the cooperative point of each objective was calculated by multiplying their frequencies with their cooperative levels to explore the preference of riparian countries on each cooperative objective.

This study expands the current literature on water cooperation in the MRB in several ways. First, compared to Feng *et al.* (2019), which analyses water cooperation events in the MRB from 1995 to 2015, this study considers a more extended period (from 1975 to 2015) that covers periods pre- and post-establishment of the MRC. Second, the author combines two datasets of Oregon State University and Feng *et al.* [65] to construct a new cooperative scale and accordingly compares these two datasets to examine the development of water cooperation activities in the MRB over time and explore to some extent the reasons underneath any change in the LMB's water cooperation.

3.2. AHP Model of the LMB Case

3.2.1. Identifying Evaluation Criteria and Alternatives

As pointed out earlier, this study aims to evaluate water development in the LMB using the main development scenarios derived from the Council Study of MRC. Therefore, three main scenarios, which are characterised by different levels of

Table 7. Levels of transboundary water cooperation (modified from [63] [65] [114] and the author's own construction).

BAR Scale		Feng scale		Combined Scale		
Point	Event Description	Point	Event Description	BAR scale	Feng scale	Final scale
1	Minor official exchanges, talks or policy expressions-mild verbal support: Meeting of high officials; conferring on problems of mutual interest; visit by lower officials for talks; proposing talks; requesting support for policy; stating or explaining policy.	1	Willingness-the lowest cooperative level, which means that cooperation has just been initiated	1	1	1
2	Official verbal support of goals, values, or regime: Official support of policy; allowing entry of press correspondents.	2	Discussion-indicates that parties are trying to establish common targets.	2	2, 3	2
3	Conducting or enacting friendship agreements; conducting cultural or academic agreements or exchanges. Agreements to set up cooperative working groups.	3	Research-a higher level than "Discussion", and occurs when parties are working toward some common targets through joint research.	3, 4	4	3
4	Legal, cooperative actions between nations that are not treaties; cooperative projects for watershed management, irrigation, poverty-alleviation.	4	Consensus-a medium level, and indicates that parties are cooperating to reach some common targets.	5	5	4
5	Joint programs and plans to initiate and pursue disarmament.	5	Declaration and/or Memorandum of Understanding (MOU)- occurs when parties negotiate a draft inter-governmental non-binding agreement.	6	6, 7	5
6	International Freshwater Treaty; Major strategic alliance (regional or international): joining or organizing international alliances	6	Agreement-indicates that parties have adopted a formal inter-governmental agreement.			
7	Voluntary unification into one nation: Merging voluntarily into one nation (state); forming one nation with one legally binding government.	7	Practice-means that the relevant agreements are implemented.			

socio-economic and environmental development, particularly taking into account the impacts of mainstream hydropower projects, were utilised as three alternatives in the AHP model of the LMB. Additionally, a sub-scenario, derived from scenario M3, was utilised as the fourth alternative, aiming to highlight the difference between the scenario with and without climate change. The four development scenarios are described as follows:

- Scenario M1—Early Development Scenario 2007

The baseline scenario M1 presents the state of water infrastructure development in the MRB as of 2007. This scenario depicts how the Mekong mainstream flow regime was still regarded to be in its natural state. The M1 scenario represents the baseline conditions of the Council Study and the reference conditions and attributes by which the other development scenarios are compared.

- Scenario M2—Definite Future Scenario 2020

All existing (before and after 2007), under-construction and expected (to the year 2020) development of hydropower, agriculture, land use, biodiversity, flood control are included in this scenario.

- Scenario M3—Planned Development Scenario 2040

In addition to the development described in scenario M2, all water resources development that is planned in hydropower, agriculture, land use, biodiversity, flood control… are included in this scenario. On a timescale, this scenario covers the expected development occurring by 2040 if fully implemented.

- Scenario M3CC—Planned Development Scenario 2040 under climate change.

M3CC is a sub-scenario derived from scenario M3, adding the estimated climate change condition (warmer plus seasonal change).

Table 8 summarized the major characteristics of four water development scenarios utilized in the AHP model of the LMB.

After identifying the alternatives (development scenarios) of the AHP model, it is necessary to select the appropriate evaluation criteria. Even though riparian countries follow their plan to exploit a shared river, given the importance of the river to national development, it is understandable that the starting point for any consideration of cooperation is generally associated with the legitimate goals of extracting maximum benefits from the river. In this regard, economic benefits are frequently the primary justification for deciding water issues, particularly on hydropower development, one of the most significant matters of concern in the LMB. This study thus utilises criteria representing the economic benefits of different sectors to assess three main scenarios, noticing that those benefits are not assigned direct but indirect forms of economic value where data is not sufficient. The LMB countries have widely agreed upon the potential areas for cooperative development, which are also highlighted in many reports and working papers published by MRC. Hydropower, navigation, flood management and mitigation, irrigation, fisheries, domestic water supply and tourism are the cooperative areas of paramount importance to the sustainable development of the LMB [31] [40] [115].

- Hydropower

Despite concerns relating to environmental issues, hydropower still plays a significant role in the economic growth of the LMB countries, serving both local and export markets and representing 10% of the electricity demand of member countries [31]. From 2005 to 2015, the hydroelectricity production in the LMB increased around 3.5 times, from 9.3 to 32.4 GWh, reaching a gross value of more than USD 2 billion [116]. By 2015, 59 hydropower projects developing in the LMB had provided up to 35% of the total hydropower potential estimated for

Table 8. Description of council study main scenarios [46].

Scenario		Level of Development for water-related sectors						Flood Plain settlement
		ALU	DIW	FPI	HPP	IRR	NAV	
M1	2007	2007	2007	2007	2007	2007	2007	2007
M2	2020	2020	2020	2020	2020	2020	2020	2020
M3	2040	2040	2040	2040	2040	2040	2040	2040
M3CC	2040CC	2040	2040	2040	2040	2040	2040	2040

the LMB [31]. And by 2030, MRB riparian countries are planning to construct 88 additional dams along the river to meet the basin's projected energy demand [41].

- Fisheries

Fisheries in the MRB, which comprises the world's highest production volume, is a vital source of food and livelihood for the people in the basin [42] [116]. In 2015, the total capture fisheries production in the LMB, which constituted 45% of four riparian countries' national output on average, was valued at USD 11 billion [31] [116].

- Navigation

The Mekong River serves as a vital interior waterway for goods and passenger transportation and provides important international trade routes for riparian countries. Between 2007 and 2014, the volumes of cargo transported across four LMB countries increased by nearly 6.5% each year. The estimated annual net economic value of cargo transportation in 2014 reaching around 23 million tons [31]. The navigation sector is expected to increasingly contribute to the basin's economic development, especially to the economic growth of Cambodia and Vietnam [116].

- Flood control

Since severe floods in the MRB have led to devastating consequences and flood damages is expected to increase five to ten times by 2040 [116], flood control is becoming more and more essential to the development of the LMB. Therefore, this study attempts to qualify the effect of flood protection for different scenarios to present the economic benefit of the flood control system.

As a consequence, four criteria along with nine sub-criteria were selected (**Table 9**), and a hierarchical structure describing the decision-making problem in the LMB was introduced (**Figure 2**).

Table 9. Identified criteria for evaluating water development scenarios in the LMB.

Criteria	Sub-criteria
C1- Hydropower	NPV of the hydropower sector for the three main scenarios (billions of US dollars)
C2- Navigation	C2.1- Annual total IWT cargo volume (ton)
	C2.2- Annual net economic value of IWT cargo volume (billions of US dollars)
	C2.3- Annual total IWT passengers (pax)
	C2.4- NPV of navigation sector (billions of US dollars)
C3- Flood control	C3.1- Effectiveness of Flood defense
	C3.2- NPV of investment in Flood protection (millions of US dollars)
C4- Fisheries	C4.1- NPV of fisheries sector for main scenarios (billions of US dollars)
	C4.2- Estimated monetary value of fisheries production for the corridor zones (US dollars)
	C4.3- Total fish production by development scenario across corridor zones (tons)

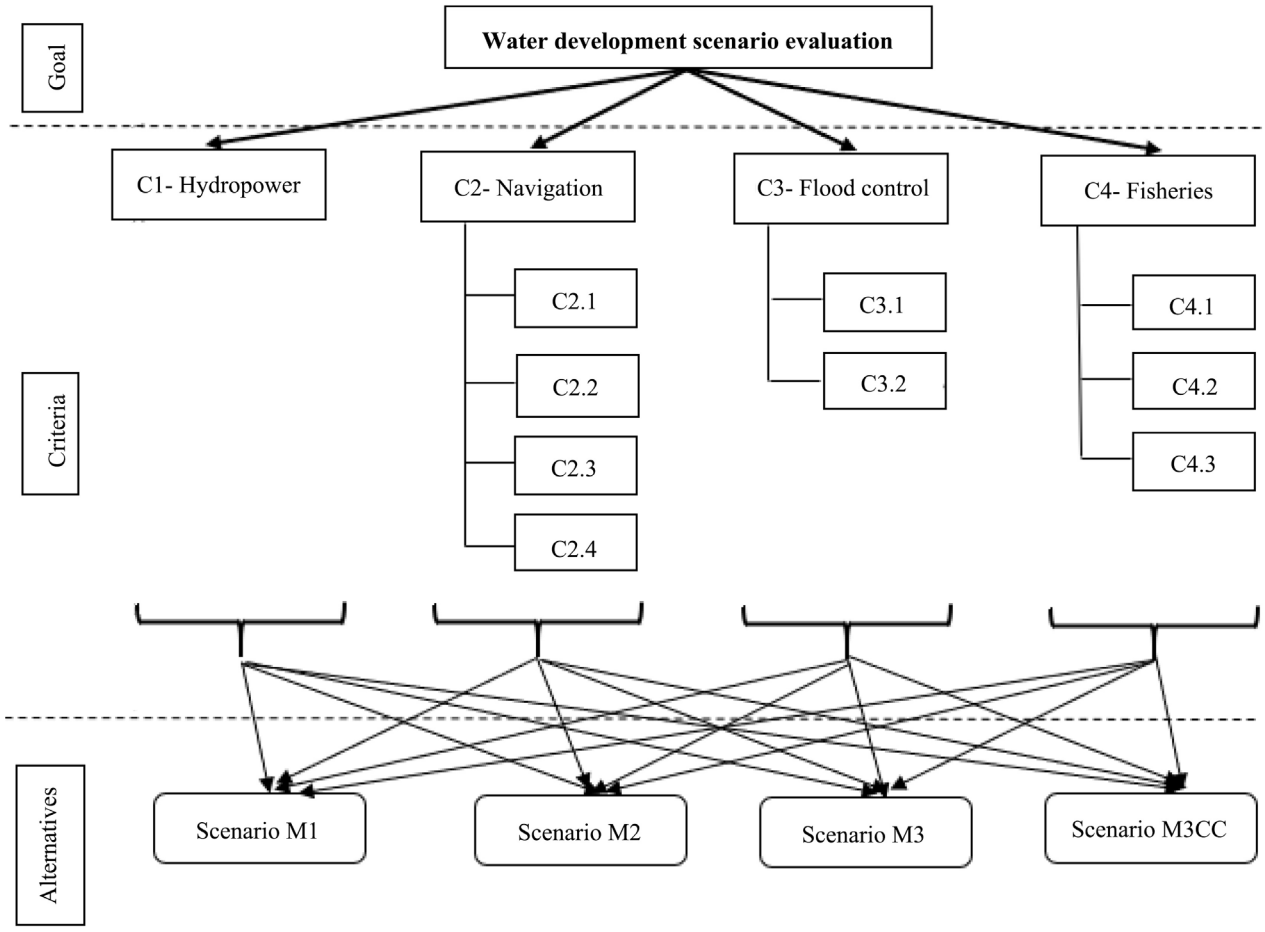

Figure 2. AHP model for evaluating water development scenarios in the LMB.

3.2.2. Weighting Criteria

Once the hierarchy has been constructed, pairwise comparisons, which includes comparing each criterion with all the other criteria at a particular hierarchical level regarding the ultimate goal, are used to identify preferences (relative weights) in the AHP model and, accordingly, a matrix with pairwise comparisons of criteria is formed as illustrated in Equation (1)

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

where $\left[a_{ij}\right]$ = the Saaty's point for comparison between criterion *i*-th and criterion *j*-th ($i, j = 1, 2, ..., n$), and $\left[a_{ij}\right]$ indicates the relative importance of criterion *i*-th when being compared with criterion *j*-th,

$$a_{ij} = 1 \text{ for } i = j; a_{ij} = \frac{1}{a_{ji}} \text{ for } i \neq j,$$

n = number of criteria for comparison.

Pairwise comparisons are made to obtain each criterion's relative weight (rel-

ative importance) in relation to the other criteria, using Saaty's scale. Decision-makers commonly perform this process making their judgements based on their preferences when considering two criteria simultaneously.

Due to the differences in the perception of the importance of criteria, the weights assigned to a particular criterion may largely vary, which subsequently causes the inability of decision-makers to give such an accurate and rational evaluation. To overcome this major drawback, the author presents a so-called "cooperative point" developed to determine the relative weights of criteria, which to the best of our knowledge, is the first model to propose a new method of obtaining relative importance of criteria in the AHP model. The cooperative point is calculated for each criterion using a combination between the cooperative level and the frequency at different cooperative levels of each criterion, which is extracted from Feng *et al.* (2019) after using several mathematical transformations as follows:

- First, data on the frequencies and cooperative levels of all criteria and their cooperative points based on the Feng scale are obtained from below Equation:

$$CP_i = \sum_{i=1}^{4} x_i y_i \quad (2),$$

where: CP_i = cooperative point of criterion i-th;

x_i = Feng scale's point of criterion i-th in a particular water cooperative event;

y_i = frequency of criterion i-th at a particular cooperative level.

The cooperative points of all criteria are clearly presented in Table 10.

- Second, the differences in cooperative points between each pair of criteria are calculated by following equation:

$$\Delta_{ij} = CP_i - CP_j \quad (3),$$

where: Δ_{ij} = differences in cooperative points between criterion i-th and criterion j-th.

The pairwise differences of cooperative points are illustrated in Table 11.

Table 10. Cooperative points of all criteria.

Level of cooperation	Feng scale's point (x_i)	Frequency of criteria at every cooperative level (y_i)			
		C1-Hydropower	C2-Navigation	C3-Flood control	C4-Fisheries
Practice	7	8	2	0	1
Agreement	6	4	2	1	1
MOU/Declaration	5	4	2	0	0
Consensus	4	0	3	1	0
Research	3	2	1	0	0
Discussion	2	2	2	5	0
Willingness	1	3	1	2	0
Cooperative point (CP_i)		113	56	22	13

Table 11. Pairwise differences between criteria.

	Pairwise differences	Arranging in descending order		Ranking
Δ_{12} = C1 − C2	57	Δ_{14}	100	1
Δ_{13} = C1 − C3	91	Δ_{13}	91	2
Δ_{14} = C1 − C4	100	Δ_{12}	57	3
Δ_{23} = C2 − C3	34	Δ_{24}	43	4
Δ_{24} = C2 − C4	43	Δ_{23}	34	5
Δ_{34} = C3 − C4	9	Δ_{34}	9	6

- Third, the differences in cooperative points are transformed to a so-called "relative Saaty's points" using a combination between Saaty's scale and following equation:

$$S_{ij} = 1 + 8 * \frac{\left|\Delta_{ij} - \Delta_{\min}\right|}{\left(\Delta_{\max} - \Delta_{\min}\right)} \left(S_{ij} = \overline{1.9}\right) \quad (4),$$

where: S_{ij} = relative Saaty's point of pairwise comparison between criterion *i*-th and criterion *j*-th, which indicates the relative importance of criterion *i*-th over criterion *j*-th when making a pairwise comparison.

This formula assures to limit the relative Saaty's point within the range of values from 1 to 9, which follows the 9-point Saaty's scale. Accordingly, the relative Saaty's points will be normalised to original Saaty's points (Table 12).

This new method of determining the relative importance of each criterion differs from the traditional method by assuming that: 1) Pairwise comparisons are made by considering the cooperative point of two criteria at one time rather than deriving from decision-maker evaluation, and 2) the more the cooperative point of a particular criterion (water-related issue) is, the more important it is with respect to the other criterion.

3.2.3. Checking Consistency of the Pairwise Comparison of Criteria

The AHP model's consistency test is presented using the theory of maximum eigenvalues derived from eigenvectors of pairwise comparison matrix of criteria, and the consistency index and consistency ratio proposed by Saaty (1980) as follows:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (5)$$

where: CI = consistency index

$\lambda_{\max}$ = maximum eigen values of pairwise comparison matrix of criteria

n = number of criteria for comparison

$$\text{And} \quad CR = \frac{CI}{RI} \quad (6)$$

where: CR = Consistency Ratio

RI = Random Consistency Index, varies according to the number of criteria used for comparison (n) as shown in Table 13.

Table 12. Saaty's points of pairwise comparisons.

	S_{ij}	Saaty's point		Saaty's point
a_{12}	5.56	6	a_{21}	1/6
a_{13}	8.28	8	a_{31}	1/8
a_{14}	9.00	9	a_{41}	1/9
a_{23}	3.72	4	a_{32}	1/4
a_{24}	4.44	4	a_{42}	1/4
a_{34}	1.72	2	a_{43}	1/2

Table 13. Random consistency index [117].

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

And, finally, the obtained CR is acceptable if the CR is less than 10% (0.01). If the obtained $CR > 0.01$, the pairwise comparisons should be revised and adjusted. At the end of this step, the local priorities of all alternatives with respect to each criterion are derived.

3.2.4. Ranking the Alternatives and Reaching the Conclusion

In the last step, the alternatives' overall priorities are obtained as a weighted-sum taking into account each criterion's weight the local priorities of the alternatives. The ranking of the alternatives is presented, and the alternative at first rank is the best choice.

4. Results

4.1. The Evolution of Water Cooperation in the MRB

The following sections detail the key findings relating to water cooperation issues in the MRB before and after the establishment of MRC. Cooperative objectives, along with their distribution and frequency and intensity distribution of water cooperation events, are discussed separately in order to highlight the noticeable differences between the two time periods and describe the historical patterns of water cooperation in the MRB.

4.1.1. Objectives of Water Cooperative Events

As can be seen from Table 14, over forty years (1975-2015), water cooperation events in the MRB encompassed a wide range of aspects of water resource management, from general objectives to very particular ones. While mainly focusing on six cooperative issues from 1975 to 1995, the MRB countries extended their cooperative objectives to a much broader spectrum in the next 20 years, covering the sustainable development issues of the basin, such as flood control and environmental conservation. It was observed that four issues-hydropower, navigation, water quantity/water use and joint management are the popular water-related

Table 14. Changes in cooperative issues in the MRB between two time period 1975-1995 and 1995-2015.

Cooperative issues	1975-1995	1995-2015
Hydropower	▲	▲
Navigation	▲	▲
Water quantity/water use	▲	▲
Joint management	▲	▲
Economic development	▲	
Infrastructure development	▲	
Fisheries		▲
Flood control		▲
Data sharing		▲
Comprehensive development		▲
Environmental conservation		▲

matters that all stakeholders inconsistently promoted in their cooperative agenda throughout the time. As to development issues, riparian countries revealed a tendency toward collaboration on the comprehensive development of the basin as a whole rather than emphasising a particular development aspect, for example, economic or infrastructure development. This change is understandable since the MRC was established to first and foremost manage the Mekong water resources and facilitate the sustainable development of the MRB through cooperation. Therefore, riparian countries under the MRC's cooperative framework are likely to collaborate on extensive and long-term issues like comprehensive development, covering all other development aspects of the MRB.

4.1.2. Distribution (Frequency) of Water Cooperation Objectives

It should be noted that the number of water cooperation events that occurred between 1995 and 2015 far outweighed those recorded between 1975 and 1995, with 87 and 35 events, respectively. The reasons behind this difference are embedded in some aspects. Firstly, due to the increasing pressure on the environment and natural resources and population growth in the MRB over time, there has been a growing demand for collective action between Mekong countries, covering wide-ranging issues. Secondly, the establishment of the MRC has created a sound basis for further cooperative activities between the LMB countries and other countries and organisations. For the distribution of cooperative objectives, the results reveal some differences between the two time periods. Although joint management and hydropower remain their dominant roles as two of the most frequent cooperative topics in the MRB, their rankings differ over time: joint management stood at the first place, and hydropower ranked in third place, accounting for respectively 37% and 17% of the total cooperative events in the period 1975-1995, whereas hydropower (26%) was the most preferred issue

followed by joint management (24%) during the 1995-2015 study period (Figure 3). This finding shows a similarity with a study by Wei *et al.* [118] that confirms the significance of hydropower as one of the vital cooperative topics in MRB that appeared in newspapers from 1991 to 2018. Remarkably, before the establishment of the MRC, special attention was given to cooperation on water quantity/water use in the Mekong River, which made up 26% of the total cooperative objectives. In contrast, this was a matter of much lower concern in the next 20 years, comprising only 6% of all cooperative events. The data also indicate that navigation events were more frequent after 1995, and the proportion of cooperative events

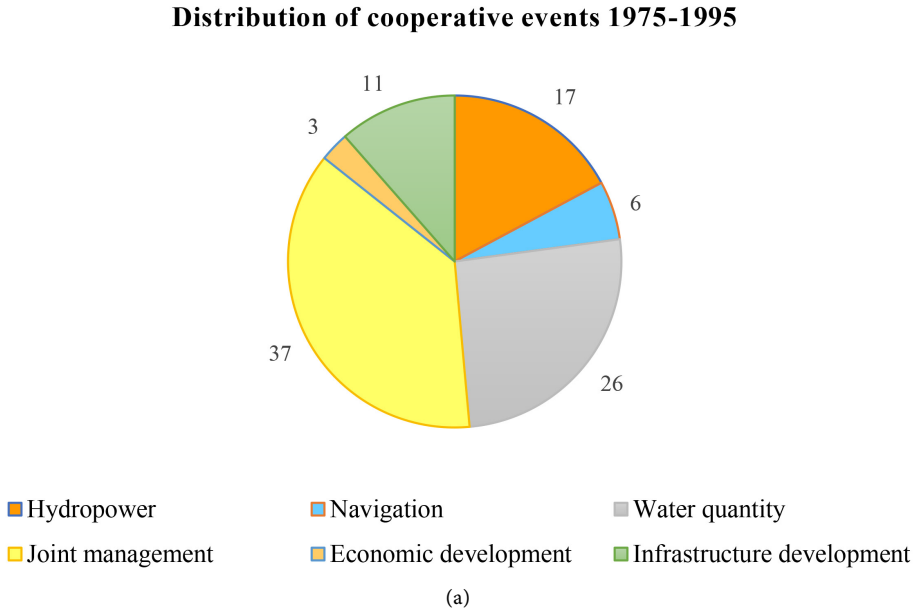

Figure 3. Distribution of cooperative events. (a) Distribution of cooperative events from 1975 to 1995; (b) Distribution of cooperative events from 1995 to 1995.

associated with navigation has more than doubled from 6% to 15% in forty years.

4.1.3. Cooperation Intensity Distribution

As explained in Section 3.1, a 5-point cooperative scale was introduced combining BAR and Feng scale to compare the two event datasets. Thus, in this section, the cooperation intensity distribution will be analysed based on this new scale to depict the diversity in cooperative levels of water events in two time periods.

1) In the period 1975-1995

From 1975 through 1995, cooperation on hydropower, water quantity and infrastructure development occurred at the intermediate level (3-point) (Figure 4). For example, medium cooperative events concerning those three issues comprised at least 56% to 75% of the total events related to each topic. Notably, although there were minimal economic development and navigation events before 1995, all of them occurred at a relatively high cooperative level (3-point) compared to other events. In contrast, more than 50% of events related to joint management, the most frequent cooperative issue, was primarily recorded at the lowest cooperative level (1-point).

2) In the period 1995-2015

About the distribution of cooperative levels during the 1995-2015 study period, extremely cooperative events (5-point) mainly spanned objectives relating to hydropower, joint management and navigation, while environmental conservation was the only issue with no event at the highest cooperative level (Figure 5). In particular, 52% of hydropower events, 33% of joint management events and 31% of navigation events were extremely cooperative. Across all cooperative events, the number of events that occurred at the lowest cooperative level, on the contrary, comprised only 14% of the total. In addition, although there were minimum events concerning fisheries, all of them were at the highest cooperative level.

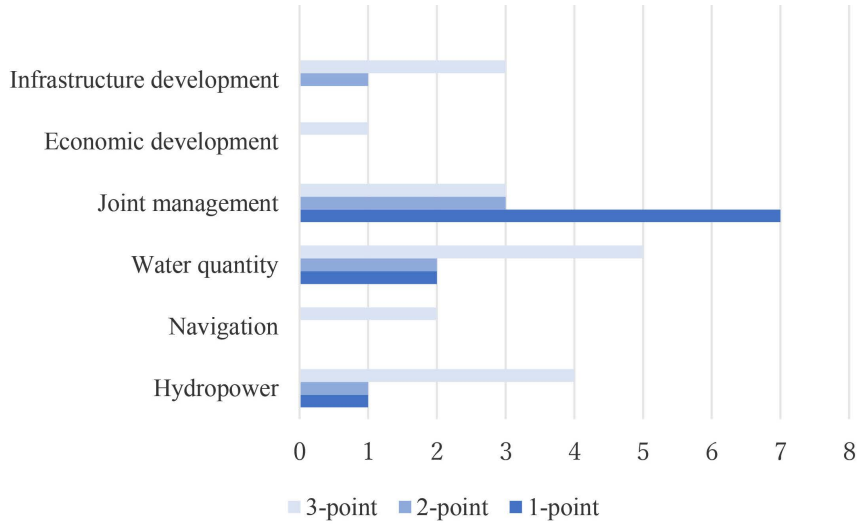

Figure 4. Cooperation intensity distribution in the period 1975-1995.

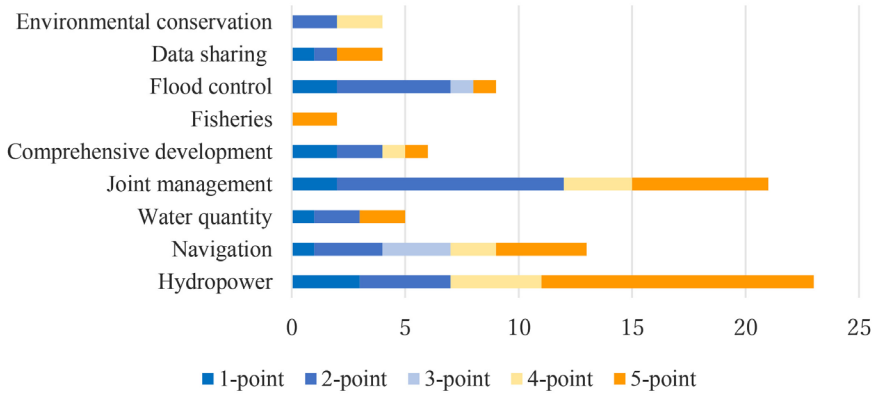

Figure 5. Cooperation intensity distribution in the period 1995-2015.

3) Comparing two time periods

As shown in **Figure 6**, cooperative scales of events in the two periods were considerably different. Of all events recorded between 1975 and 1995, there were no events at the two highest cooperative levels (4-point and 5-point) no governmental agreement was signed, and no institutional organisation was established between riparian countries. All cooperative events before 1995 were at intermediate and low cooperative levels (from 1 to 3-point), with a majority of them at the 3-point cooperative level, accounting for approximately 50% of total events. In contrast, the events that happened between 1995 to 2015 covered all cooperative scales, especially at the highest level (5-point), which made up about 35% of all events. On the contrary, only about 5% of post-1995 events happened at the intermediate cooperative level (3-point). The high proportion of cooperative events at 4-point and 5-point levels (48%) after 1995 indicates that the riparian countries had a strong incentive to collaborate more closely under the institutional changes (the establishment of the MRC).

As described earlier, there are several water-related issues recorded in both periods, including hydropower, joint management, navigation and water quantity/water use. The comprehensive development issue of the 1995-2015 period is considered equal to the combination of economic and infrastructure development issues of the 1975-1995 period. Subsequently, the author constructed a table with data on five common issues from 1975 through 2015 to examine the evolution of water cooperation in the MRB over time (see **Table 15**).

The data in Table show the rankings of five regular water-related cooperative objectives in the MRB based on their cooperative points[6]. It can be concluded that water cooperation in the MRB has significantly evolved after establishing the MRC. Before 1995, joint management was the most significant issue to cross-border cooperation between MRB countries, followed by water quantity/water and navigation proved to be the least preferred issue in the cooperative scheme of the MRB states. While hydropower ranked in third place on the priority list of water cooperation in 1975-1995, it stood at the first position, with joint

[6]The calculation of cooperative points was previously explained in Section 3.1.

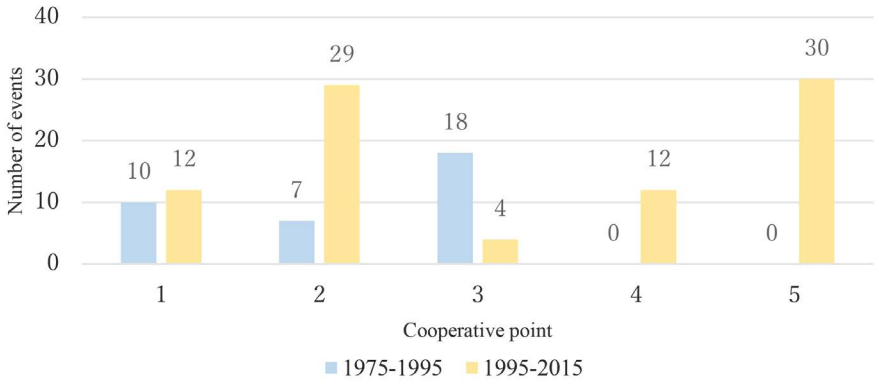

Figure 6. Distribution of cooperative events with respect to cooperative levels.

Table 15. Ranking of five common cooperative objectives in the MRB between 1975-1995 and 1995-2015 period.

Cooperative objectives	1995-2015		1975-1995	
	Point	Ranking	Point	Ranking
Hydropower	87	1	15	3
Joint management	64	2	22	1
Navigation	44	3	6	5
Comprehensive development (economic + infrastructure development)	15	4	14	4
Water quantity/water use	15	4	21	2

management and navigation coming afterwards 1995-2015. Water quantity/water use, the second-ranked cooperative issue during 1975 to 1995, stood near at the end of the priority list at fourth place, similar to the rank of comprehensive development issue in the period 1995-2015.

4.2. Analysis of AHP Model for the LMB Case

4.2.1. Criteria Weights

As explained in Section 3.2.2, this study proposes a revised technique of making pairwise comparisons in the AHP model. Table 16 presents the results of the pairwise comparison matrix for four main criteria.

Accordingly, the relative weights (priority vector) of the main criteria were obtained using the normalisation principle with the acceptable results of pairwise comparisons equal to 0.07 (less than 0.1). As shown in Table 17, objective C1 (hydropower) (0.667) is the most important criterion to be considered in the LMB's decision-making process, followed by C2 (navigation) (0.200) and C3 (flood control) (0.08). Objective C4 (fisheries) with the relative weight of 0.053 ranked in the last place among four main criteria. The higher preference for flood control than fisheries (0.08 > 0.053) reveals the positive change in stakeholders' perception toward prioritising essential factors for sustainable development rather than merely focus on the one with a high monetary benefit. The fact that

Table 16. Pairwise comparison matrix for main criteria.

Criteria	C1- Hydropower	C2- Navigation	C3-Flood control	C4- Fisheries
C1- Hydropower	1	6	8	9
C2- Navigation	1/6	1	4	4
C3- Flood control	1/8	1/4	1	2
C4- Fisheries	1/9	1/4	1/2	1

Table 17. Global weights of main criteria.

Criteria	C1	C2	C3	C4	Priority vector	Ranking
C1	0.7129	0.8000	0.5926	0.5625	0.667	1
C2	0.1188	0.1340	0.2963	0.2500	0.200	2
C3	0.0891	0.0333	0.0741	0.1250	0.080	3
C4	0.0792	0.0333	0.0370	0.0625	0.053	4

Consistency Index (*CI*) = 0.063; Consistency Ratio = 0.07 < 0.1, acceptable.

hydropower was reported to be the dominant criterion in the overall ranking of main criteria is understandable, drawing from its significant role in the sustainable development and benefit-sharing scheme of the LMB. The Mekong River is under constant pressure from hydropower development with many completed, under-construction or being-planned hydropower dams in both mainstream and tributaries of the river. This substantial development provides riparian countries with considerable economic benefit but, on the other hand, alters ecosystems, change the hydrology and even negatively impact human livelihoods. From an economic perspective, hydropower is recognised as a potential source of electricity supply to ensure regional energy security and a source of export earnings, especially for the poor Mekong countries. The overarching effects of hydropower require policy-makers and water managers to place it at the centre of the decision-making process in most cases.

The local and global weights of all sub-criteria are clearly described in Figure 7. While the global weights of the main criteria were obtained using pairwise comparisons, the local weights of sub-criteria were determined directly based on their economic meaning. For example, the three sub-criteria associated with C4 can be classified into two groups with equal weight values (0.5 for each group): one group concerning monetary value of fisheries (including C4.1 and C4.2), and another one relating to fisheries production capacity (C4.3). Then, the local weights assigned for C4.1, C4.2 and C4.3 were 0.025, 0.025 and 0.5, respectively. Similarly, the local weights of the other sub-criteria were identified later on. Accordingly, the global weights of sub-criteria were determined by multiplying their local weights with the global weights of their respective main criteria.

4.2.2. Final Ranking of the Scenarios

1) For the LMB

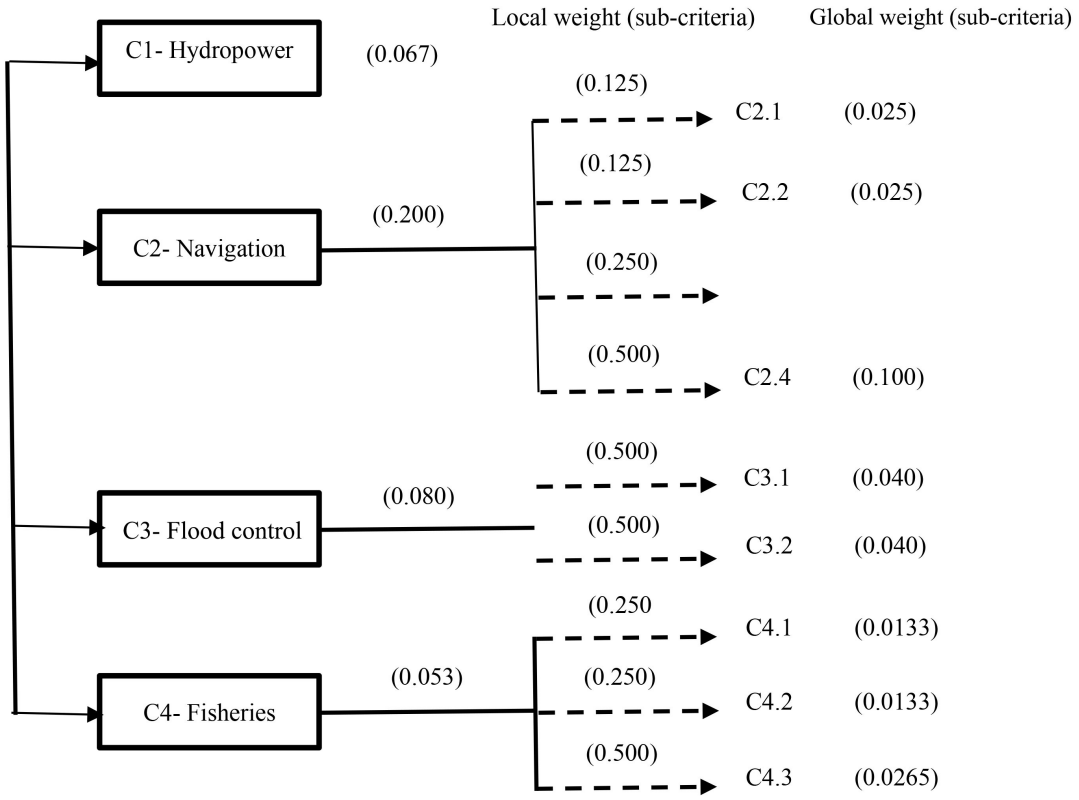

Figure 7. Local weights and global weights of sub-criteria.

After calculating the global weights of main and sub-criteria, the alternatives' priority, which represents preferences of decision-makers on each development scenario against all criteria, are illustrated in Table 18. The AHP analysis result of the LMB surprisingly reveals that M3CC, the development scenario under climate change situation, was perceived as the most beneficial scenario for riparian countries, followed closely by M3-planned development scenario. When being evaluated against all criteria, the baseline scenario M1 ranked last in the priority list, with a minimal performance score of 0.060. Notably, the two first-ranked scenarios received the total global weight (performance score) 3.3 times higher than that of the two last-ranked scenarios, M1 and M2 (0.796 compared with 0.231). It can thus be suggested that despite the intense pressures from population growth and extreme events from climate change, water utilisation of the Mekong River economically benefits member states in the future, particularly from activities relating to the LMB's key development sector like hydropower, navigation and fisheries. Since each development scenario (alternative) was evaluated against all criteria and sub-criteria, the rankings of them would be changed by selecting different sub-groups of evaluation criteria. For example, considering only criterion C4 (consisting of three sub-criteria C4.1, C4.2 and C4.3), M1 was the most preferred scenario with the performance score of 0.0154 (=0.0042 + 0.0037+ 0.0075), followed by M2 (0.0131), M3CC (0.0123) and M3 (0.0121), respectively. In the case of ranking using criterion C3, the preference

order of four scenarios was M3CC in the first place, then comes M1, M3 and M2, respectively.

2) For the four LMB countries

Tables 19-22 described the global weights of criteria and the scenarios' final ranking of four LMB countries in detail. Generally, the preference orders of development scenarios are the same for all countries, with the ranking order from the best to the worst was M3CC, M3, M2 and M1. Similar to the LMB case, although M3CC, the most favourable scenario, was of higher priority than the second-ranked scenario M3, the difference in performance scores between them was pretty low in each country's case. In contrast, considering the two last-ranked scenarios, M2 and M1, M2 was valued much higher than M1 (approximately three to four times higher than M1). Scenario ranking was different across countries when considering each main criterion. For instance, M1 was the most,

Table 18. Priority of four alternatives (water development scenarios) in the LMB.

Scenarios	Criteria										Final weight	Final rank
	C1	C2				C3			C4			
		C2.1	C2.2	C2.3	C2.4	C3.1	C3.2	C4.1	C4.2	C4.3		
M1	0.0148	0.0010	0.0005	0.0025	0.0041	0.0115	0.0107	0.0042	0.0037	0.0075	0.060	4
M2	0.1191	0.0023	0.0017	0.0064	0.0098	0.0107	0.0075	0.0032	0.0033	0.0066	0.171	3
M3	0.2646	0.0109	0.0114	0.0206	0.0431	0.0083	0.0055	0.0029	0.0032	0.0060	0.376	2
M3CC	0.2684	0.0109	0.0114	0.0206	0.0431	0.0095	0.0164	0.0029	0.0031	0.0063	0.393	1

Table 19. Priority of four alternatives (water development scenarios) of Laos.

Scenarios	Criteria										Final weight	Final rank
	C1	C2				C3			C4			
		C2.1	C2.2	C2.3	C2.4	C3.1	C3.2	C4.1	C4.2	C4.3		
M1	0.0083	0.0008	0.0007	0.0030	0.0041	0.0016	0.0005	0.0056	0.0051	0.0110	0.041	4
M2	0.1463	0.0021	0.0019	0.0063	0.0100	0.0124	0.0066	0.0032	0.0034	0.0066	0.199	3
M3	0.2496	0.0110	0.0112	0.0203	0.0430	0.0129	0.0045	0.0023	0.0024	0.0047	0.362	2
M3CC	0.2628	0.0110	0.0112	0.0203	0.0430	0.0130	0.0283	0.0022	0.0023	0.0042	0.398	1

Table 20. Priority of four alternatives (water development scenarios) of Thailand.

Scenarios	Criteria										Final weight	Final rank
	C1	C2				C3			C4			
		C2.1	C2.2	C2.3	C2.4	C3.1	C3.2	C4.1	C4.2	C4.3		
M1	0.0035	0.0013	0.0004	0.0047	0.0059	0.0018	0.0001	0.0053	0.0055	0.0102	0.039	4
M2	0.0995	0.0025	0.0015	0.0072	0.0078	0.0180	0.0031	0.0031	0.0034	0.0065	0.153	3
M3	0.2813	0.0106	0.0116	0.0191	0.0431	0.0000	0.0090	0.0025	0.0022	0.0051	0.385	2
M3CC	0.2827	0.0106	0.0116	0.0191	0.0431	0.0201	0.0278	0.0024	0.0021	0.0047	0.424	1

Table 21. Priority of four alternatives (water development scenarios) of Cambodia.

Scenarios	Criteria										Final weight	Final rank
	C1	C2				C3		C4				
		C2.1	C2.2	C2.3	C2.4	C3.1	C3.2	C4.1	C4.2	C4.3		
M1	0.0000	0.0010	0.0005	0.0042	0.0061	0.0100	0.0172	0.0039	0.0039	0.0078	0.055	4
M2	0.1443	0.0024	0.0017	0.0065	0.0110	0.0101	0.0106	0.0033	0.0032	0.0066	0.200	3
M3	0.2624	0.0108	0.0114	0.0196	0.0415	0.0100	0.0015	0.0031	0.0031	0.0061	0.369	2
M3CC	0.2602	0.0108	0.0114	0.0196	0.0415	0.0098	0.0107	0.0030	0.0030	0.0060	0.376	1

Table 22. Priority of four alternatives (water development scenarios) of Vietnam.

Scenarios	Criteria										Final weight	Final rank
	C1	C2				C3		C4				
		C2.1	C2.2	C2.3	C2.4	C3.1	C3.2	C4.1	C4.2	C4.3		
M1	0.0526	0.0009	0.0005	0.0024	0.0039	0.0102	0.0119	0.0036	0.0034	0.0071	0.097	4
M2	0.1237	0.0023	0.0017	0.0064	0.0097	0.0100	0.0079	0.0033	0.0033	0.0066	0.175	3
M3	0.2450	0.0109	0.0114	0.0206	0.0432	0.0100	0.0054	0.0030	0.0033	0.0062	0.359	2
M3CC	0.2458	0.0109	0.0114	0.0206	0.0432	0.0097	0.0148	0.0034	0.0033	0.0066	0.370	1

and M3CC was the least beneficial scenario if valued against criterion C4 (fisheries) in any case. Therefore, it can be realised that the total benefit that the LMB countries receive from the basin is increasing over time, but the benefit derived from each sector might differ.

5. Discussion

It is essential to understand the evolution of water cooperation in transboundary river context to be able to explore the impact of riparian countries' attitudes towards cooperation on the evaluation of different development scenarios. This paper presented an insightful analysis of water cooperation activities in the MRB from 1974 to 2015 and assessed water development scenarios in the LMB. As the findings have shown, there have been substantial changes in cooperative objectives and levels between the MRB countries when comparing two periods of time (1975-1995 and 1995-2015). The considerable increase in the number of cooperative events and the further extension of issues discussed across the time indicates the willingness and commitment of member states to collaborate for the comprehensive development of the basin. Although each country has its emphasis on utilising Mekong River water, it is common for Mekong countries to cooperate to ensure regional water security and enhance their national strengths. More importantly, the progress on cooperation between Mekong countries, illustrated by the higher cooperative levels on all issues, shows that institutional mechanisms like the MRC can help address the water-related matters of significant concern and foster inter-state cooperation. The establishment of the MRC

under the signing of the 1995 Agreement has provided essential support for member states to cooperate more actively and closely, as also emphasised in research by Schmeier [119]. By facilitating communication between riparian countries and ensuring compliance with other international laws and rules [120], MRC helps to build mutual trust and provides a solid basis for further cooperation between countries. The findings provide evidence to dispel the doubt by previous researchers like I. Campbell (2009) regarding the MRC's contribution to enhancing regional cooperation.

More specifically, the analysis of water cooperation in the MRB portrays the following basic characteristics of evolutionary cooperation in the basin.

1) Hydropower is recognised as the critical issue for cooperation along the Mekong River, as similarly highlighted by a study of (Wei *et al*., 2021) that hydropower is the most frequent topic of cooperation in the Mekong basin. The overarching impact of hydropower development on various water-related sectors, such as navigation, irrigation and fisheries, provides more potential space for cooperation negotiations.

2) The Mekong countries have been transitioning from initial cooperation, focusing on matters of national interest like hydropower and water quantity, to in-depth collaboration concerning the environment and human beings. This substantial change coincides with member states' perceptions toward the importance of maintaining mutual benefit and sustainable development of the basin.

For the LMB's assessment of water development scenarios, the assessment results describe a common trend to both the basin and member states towards the ranking of four scenarios. Note that not only water resource development but, more importantly, the future development of hydropower projects in the mainstream of the Mekong River were included in the scenarios. Since hydropower was the issue of highest priority to all member states and the AHP model only concentrated on the economic benefit brought by main sectors, M3 and M3CC, the scenarios formulated with the existence of a large number of hydropower dams, are the two most beneficial scenarios to all LMB countries.

This study sets out to develop a framework to integrate the evolution of riparian countries' attitudes toward water cooperation into the process of evaluating water development in a transboundary river context. The analysis result of water cooperation in the MRB is constrained by the scope and the length of time coverage of the dataset on water cooperative events. The availability of more recent and updated data extracted from the various dataset on water interactions in the international river basin will help to gain a proper understanding of progress on inter-state cooperation between Mekong countries. Moreover, to make the results of pairwise comparisons of the AHP model more practical and meaningful, it is essential to consider cooperative water events but also the conflict zones due to the inevitable coexistence of cooperation and conflict in the context of transboundary river management. With the limitation of current data available on the monetary benefit of key water-related sectors in the LMB, the number of criteria selected for the AHP model is relatively small. Irrigation is also one of the sig-

nificant economic activities in the Mekong River but is not included in this study, leading to inappropriate evaluation. As the model is applied to more cases, an adequate set of criteria should be employed and, also, different scenarios underestimated climate change situation and human activities should be incorporated into the AHP model to produce a comprehensive assessment result.

6. Conclusions

Water cooperation is broadly regarded as a valuable method to resolve disputes over shared waters and a prerequisite for facilitating river basin's sustainable development. By capturing the advancement in cooperative scales and objectives, this paper presents an insightful overview of the gradual transition in the MRB's cooperative scheme to underpin future transboundary water management and negotiations in the basin. The evaluation of water development scenarios in the LMB is of significant importance, as it serves as the basis for basin planning and supports the decision-making process. There exists a strong need for implementing economic assessment of shared water to enable more practical river planning and provide economic incentives that can affect the riparian countries' attitudes [121]. This study has shown the applicability of the AHP as a potential method to making decisions in the transboundary river context.

Furthermore, this method appears to be effective in incorporating stakeholders' perceptions into the decision-making process.

The analysis of water cooperation in the MRB suggests several implications for policy-makers. Firstly, due to the rapid changes of climate, hydrological condition and geopolitical sensitivity of the Mekong River, cooperative activities in the Mekong River should focus on water security matters, increasingly becoming solid incentives for collaboration between member states. Cooperation on issues concerning water security with the involvement of all Mekong countries can mediate national interests, which, in turn, will help to resolve conflicts over water in the MRB [122]. Cooperative security implies strengthening both national and regional security as a whole through communication and cooperation. Secondly, since the international organisation like MRC is considered the legal backbone of international cooperative efforts, the role of the MRC should actively provide member states with a clear cooperation plan that can attract member states' willingness to join. Besides, water cooperation in the Mekong River should be regarded as a helpful resolution for any conflict over water in the basin. Thirdly, although bringing more economic benefit to the LMB countries, planned development scenarios in the LMB should also be carefully examined based on the inter-sectoral impacts to show a complete evaluation of future development of the LMB. This study can be further expanded to 1) explore and estimate the future evolutionary pattern toward both cooperation and conflict over Mekong water to address the significant issues that riparian countries should take into account in their planning process; 2) focus on other economic sectors in the LMB to provide a more extensive assessment of development scenarios.

Acknowledgements

The author would like to sincerely thank Professor Makoto Usami from Kyoto University for his guidance, support and valuable advice. The author also thanks the Vietnam National Mekong Committee and for providing data for the research. This study was supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan through Monbukagakusho Scholarship.

Conflicts of Interest

The author declares no conflict of interest.

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Supplement Material

Appendix A. List of Abbreviations

AHP	Analytic Hierarchy Process
IWED	International Water Event Database
LMB	Lower Mekong River Basin
LWCED	Lancang-Mekong Water Cooperative Events Database
MCDA	Multi-criteria Decision Analysis
MRB	Mekong River Basin