Chapter 4
Research Methodology

4. Research Methodology

4.1 About the study

In the recent decade, significant initiatives have been taken by policymakers for development of inland waterway network across the nation. With an increased emphasis on reducing logistics cost and increasing the modal share of waterways in the freight transport domain, substantial investments have been envisioned for the inland waterways across the country and state. The central and state governments have earmarked more than 1000 crores for the development of inland water transport infrastructure across the two key waterways NW2 Brahmaputra and NW16 Barak. In context of significant investments, it becomes pertinent to have prioritization for the investment decisions. The study carries out an exploratory study of the inland water transport infrastructure system across the key waterways and provides inputs for decision support and optimization of the inland water transport network.

4.2 Research Methodology

The methodology for the research study comprises of the Analytic Hierarchy Process (AHP) which has been adapted to rank the inland water ports in Assam. The criteria and sub-criteria for the model has been identified based on extensive literature review and validated through expert opinion. A mix of primary and secondary data has been used to arrive at the weights of the criteria and sub-criteria. A hub and spoke model has been proposed for the inland water port and dry port network system and a location allocation model based on distance has been used for optimizing the network for the best case scenarios.

4.2.1 Inland Water Port Ranking Exercise

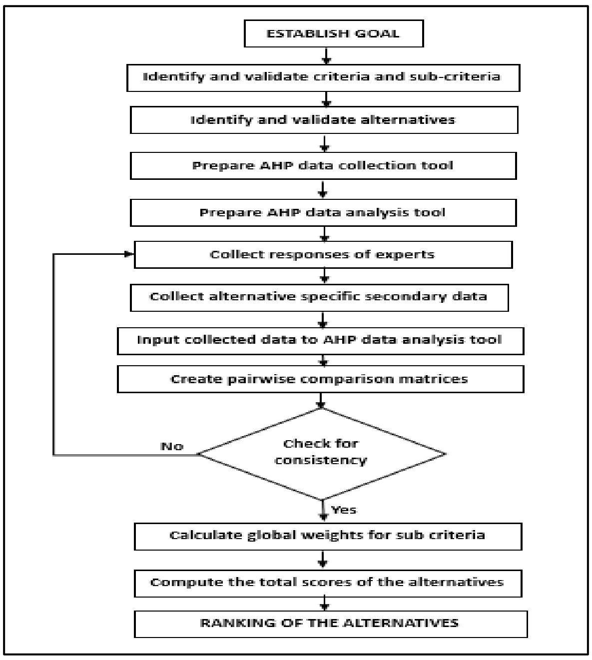
Georgoulaset. al. (2023) finds that analytic hierarchy process is a robust technique for ranking options and providing decision support for shipping operators and other stakeholders. Ugboma et al. (2006) adapted the AHP methodology to rank key Nigerian Ports. In this study, the inland water port ranking exercise for rivers Brahmaputra and Barak has been carried out using an adaption of AHP. The ranking exercise is aimed at identifying the key inland water infrastructure for investment and operations decision making.

4.2.1.1 Analytic Hierarchy Process (AHP) for port ranking

For the purpose of ranking, Analytic Hierarchy Process (AHP), introduced in Saaty (1977), has been used for evaluating the identified ports based on criteria and sub criteria identified from pertinent literature and validated by experts/stakeholders. Lirnet. al (2004), Song and Yeo (2004), Ugboma et. al (2006), Dyck and Ismael (2015) have used multi criteria evaluation for port selection in their respective geographies and since the study involves similar exercise of inland water port ranking, the AHP model is expected to serve intended purpose. Zahedi (1986) puts forward five steps in using AHP methodology as listed below:

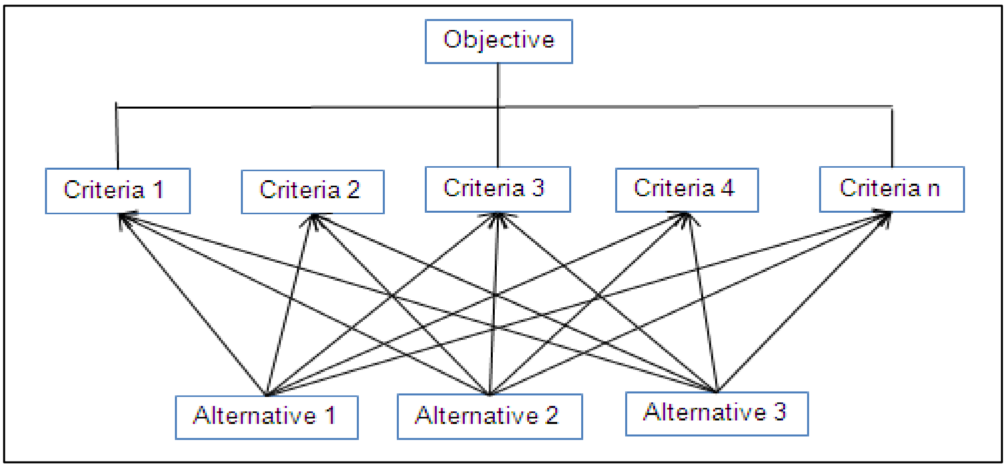
1. Drilldown of the decision problem into a hierarchy of interrelated criteria and decision alternatives: In this case, it will be the criteria (based on literature review and validated by expert opinion) for choosing a particular inland water port
2. Collecting input data from expert groups involving a fixed number of stakeholders from each decision alternative (in this case, inland water ports) for the matrices of pairwise comparisons
3. Estimating relative weights of decision elements using eigenvalue calculation
4. Calculating and checking the consistency ratio for each pairwise comparison
5. The relative weights of the decision elements are then aggregated to arrive at a set of rankings

Figure 4.1: AHP Methodology



Source: Researcher’s own compilation based on Saaty (1977)

Figure 4.2: AHP Fundamental Framework



Source: Saaty (1980)

The 9-point AHP questionnaire (Saaty, 1977) was administered to experts from the different stakeholder groups in the standard interview format and a total of 64 responses was received which is a reasonable number for the AHP model as well as considering the dearth of experts in the niche domain of inland water transportation; AHP is suitable for small sample size to get reliable results (Ghazaleh, Abu and Zabadi, 2019) and previous studies have applied AHP with just 10 or less responses (Zelko et. al 2017, Waris et. al, 2019). Geometric mean which is a better estimator has been used to consolidate the responses. Apostolopoulos and Liargovas (2016) have vouched for a purposive sampling approach in their AHP model for ranking regional parameters related to solar energy enterprises and considering the benefits of the sampling method, the same has been adapted for the study. The calculations for developing the AHP model have been carried out with a self-developed tool on Microsoft Excel. The questionnaire for the study included five dimensions with a total of twenty sub-criteria. As per the standard AHP questionnaire, the items of the questionnaire comprised of the pairwise comparison of the criteria and sub-criteria. The questionnaire was pretested by three managerial cadre employees of IWAI at Pandu office and two managers of shipping organisations operating at the Pandu port. The feedback from the pretesting exercises yielded no significant changes and thus, the original form was retained for the data collection process.

4.2.1.2 Selection of inland water ports for study

Secondary data extracted from government databases, policy documents particularly the Indo-Bangladesh protocol (Article VIII of Trade Agreement signed on 06/06/2015) and departmental records of the inland water department (both IWAI and IWT), have been used for short listing the waterways and the inland water ports. The major inland water ports along the two major waterways- Brahmaputra and Barak have been included in the study. Along with other significant ports from freight perspective, the ports of call from the trade protocol have been shortlisted for the AHP ranking exercise.

4.2.1.3 Criteria and Sub-criteria identification

Based on a systematic literature review, 5 criteria and 20 sub criteria have been identified for the port ranking exercise. The same has been validated during the primary data collection phase with the stakeholders.

Table 4.1: AHP criteria and sub criteria

Criteria	Sub Criteria	Literature evidence
Port Geographical Location (PG)	Proximity to import/export (IE)	Lirn et. al (2004), Frankel (2001)
	Closeness to highways/railroads (HR)	Chao (2010), Dyck et. al (2015)
	Proximity to dry ports (DP)	Chao (2010)
	Proximity to carriers (PC)	Brooks (2000)
Port Physical Conditions (PP)	Water Depth (WD)	Dyck and Ismael (2015), Chao
	Operating Weather Conditions (WC)	Stanivuk and Tokic (2012)
	Port Total Area (TA)	Ugboma et. al (2006)
Port Infrastructure (PI)	Terminal Size (TS)	Lirn et. al (2004)
	Port Equipment (PE)	Chao (2010)
	Port Docking Size (PD)	Chao (2010)
	Port Management IT Systems (PM)	Park and De (2004)
	Safety Mechanisms (SM)	Lirn et. al (2004)
Port Costs (PC)	Docking Cost (DC)	Ugboma et. al(2006), Lirn et. al
	Hauling Cost (HC)	Park and De (2004)
	Loading/Unloading Cost (LU)	Lirn et. al (2004), Ugboma et. al
	Applicable Tax Structure (TX)	Chao (2010)
Port Efficiency and Performance (EP)	Loading/Unloading efficiency (LE)	Chao (2010)
	Barge waiting time (BW)	Ugboma et. al (2006)
	Barge Turnaround time (TT)	Brooks (2000)
	Customs Efficiency (CE)	Chao (2010)

Source: Researcher's own compilation

Port Geographical Location reflects the ease of accessibility of a water port. The criteria can be measured in terms of proximity to import/export, closeness to highways/railroads, accessibility to dry ports and carriers. Lin et. al (2004) in their study involving transshipment decision making for global port network system identified this criterion and used the same for AHP ranking of the ports. Undoubtedly, exports are precursor to a Nation's economic prowess and thus, while ranking inland water ports, the proximity to export ports becomes an important factor. In context of the present study, Northeast India has been envisioned as a gateway for the southeast Asian countries and thus, significant impetus needs to be given for proximity to import/export so that trade between neighboring countries can be facilitated to a larger extent. Chao's (2010) research which was carried out in a Southeast Asian Country establishes the importance of the geographical location of a port in terms of proximity to highways and dry ports. This sub criteria becomes extremely important to facilitate intermodal and multimodal transport which enables end to end connectivity for shipments. Considering the state of Assam, the Asian Highway project by virtue of the Look East Policy is establishing regional connectivity and thus, proximity to inland water ports shall further enhance this connectivity. Finally, proximity to carriers is another important aspect to foster business prospect at that inland water port and carriers whose offices are located in the near vicinity can lead to easy facilitation between the different stakeholders.

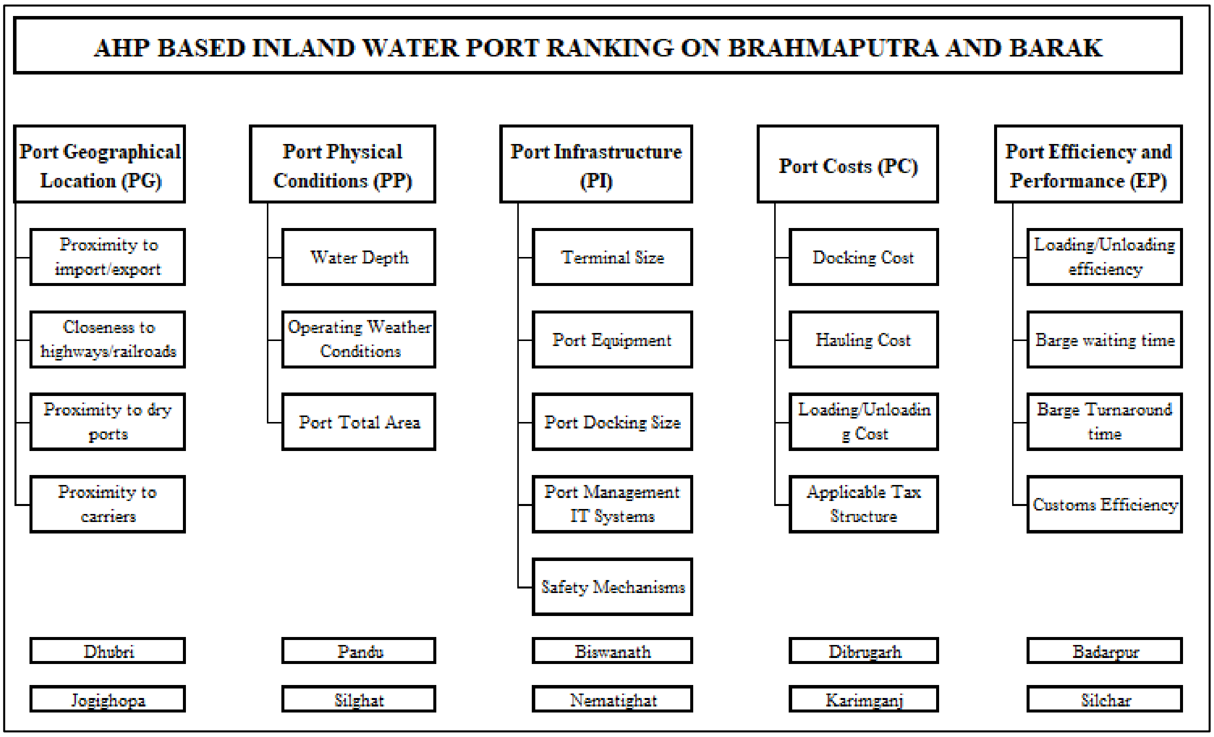
Port Physical Conditions describe the operating characteristics of that port and thus, act as guidance for route planners, fleet managers and navigators. Dyck and Ismael (2015) in their evaluation of West African ports have considered water depth as an important criterion in their port ranking exercise. This factor is particularly important for a country like India and more so for a region like Northeast which experiences a subtropical climate; water depth becomes a hindrance to the movement of ships which requires a larger draught. Water depth at inland water ports also dictates the accessibility of vessels and limits the operating capabilities of an inland water port. Stanivuk and Tokic (2012) in their work emphasized on the weather conditions as well for describing the physical parameters controlling port operations and in a state like Assam, this factor becomes pretty important with incessant rains, storms and floods. Another significant factor is the Port Total Area which limits the operational capacity of a water port; In Assam, some of the ports like Pandu port are within located within cities/towns and the physical boundaries limits port capacity to a certain extent.

Port Infrastructure comprising of the available terminal size, equipment, docking size, port management IT systems and safety mechanisms can help in evaluating the extent of investments required for developing that selected port. Lirnet. al (2004) in their study considers the existing infrastructure as an important criterion in their ranking exercise as it reflects the ability of the ports to handle port traffic. The terminal size is to a certain extent dependent on the port total area from the previous mentioned criteria of Port Physical Condition. Port equipments are a pivotal part to loading/unloading and in the absence of proper equipment, the related costs go up and this emerges as a major hindrance to port traffic. Docking size becomes significant in order to facilitate multiple vessels at a single time and a larger docking size leads to an efficient utilization of port resources. In the age of digitization and point to point tracking, it becomes pertinent to have efficient port management IT systems in place to capture and track shipments and vessels. In order to fulfill International Maritime compliances, ports necessarily need to have the safety mechanisms in place to ensure that all vessels can dock.

Docking, hauling, loading, unloading costs along with the applicable tax structure are the key considerations in the criterion of **Port Costs**. Ugbomaet. al (2006) in their research found that docking cost is an important port selection criterion for carriers and vessels. The ultimate goal of any service provider is the bottom line and thus. a high docking cost shall lead to transport providers shunning the ports with high docking costs and may lead them to alternate ports elsewhere in the near vicinity. Infact, this port cost factor has been used by countries to divert sea port traffic from other countries to their own ports. Loading and Unloading costs is a reflection of the labour availability and reflects the ability of the port to go for a capacity increase. Sophisticated loading/unloading equipment can however decrease the impact of labor to a certain extent but in that case, skilled labor shall be a factor for determining the cost. Tax structure in a particular state is likely to be fairly the same but if it is concerning different states, this can also emerge as a major factor in overall cost determination. Service providers/ carriers would be more inclined to prefer a port which gives them a higher bottom line by virtue of optimizing the overall port costs.

Port Efficiency and Performance consisting of key matrices such as loading/unloading efficiency, barge waiting time, barge turnaround time and customs efficiency is a parameter which reflects the overall health of the present facilities in the port. Historical records in terms of loading unloading times presents the ease of a vessel in getting ready for the next voyage. Chao (2010) considered this as a significant criterion to evaluate port selection preferences by service providers. Barge waiting and turnaround time help in understanding the overall effectiveness of port operations and associated costs such as rent, demurrages etc can be controlled considering these criteria.In recent times, Ease of doing Business has been given significance and this can be estimated through the ease of accomplishing compliance processes. Considering export/import trade, one of the major bottlenecks in terms of time taken is the customs clearance process and this acts as a major determinant of export/import port selection. Every port does not have custom clearance facilities and this in turn leads to the need of dry ports. However, in this context, ports having easy access to customs offices shall have to be given priority in terms of investment decisions as such ports have a greater probability of getting transformed into preferred export/import destinations for global shippers.

Figure 4.3: AHP Conceptual Framework for inland water port ranking



Source: Researcher's own compilation

4.2.1.4 Sources of data

The study has been conducted by collecting primary data as well as secondary data. The primary data component has been used for Objective 1 in establishing the criteria and sub criteria scores of AHP technique for inland water port ranking. The variables have been retrieved through a systematic literature review and the same has been validated by means of personal interviews with expert from the different stakeholders (shipping companies, fleet providers, transporters), government (ministry of shipping, inland water department officials IWAI, IWT, AIWTDS) and academia (IIT Bombay, IIT Delhi, IIFT Kolkata, IIT Guwahati, NERIWALM). For Objectives 2 and 3, analysis has been carried out using data of secondary nature consisting of geographic and topological data, GIS data, and minor primary data in terms of carrier rates etc.

For any public infrastructure decision, policymakers and key functionaries of government organizations play a pivotal role. In context of inland water transportation, service providers and users have a major stake in inland water port operational decisions. In Assam, the service providers from inland water port perspective are the tactical functionaries of the inland water transport departments while port users are the shippers/shipping agents. Previous AHP studies on port competitiveness have included experts from academia to factor in their experience in water transport projects. The recruitment process of the experts from practice involved detailed discussions with Director of IWAI and Deputy Director of IWT at their respective regional head offices after considering factors such as experience and staff deputed at the inland water port locations while representation from Academia were identified from the research work done in the domain. As such, the expert panel mix for the AHP exercise comprising of key functionaries at government agencies, supervisory level tactical staff at the inland water ports, shippers and researchers from academia ensured that perspectives from different professional backgrounds were captured.

4.2.1.4.1 Government organization/agencies

Primary responses for the AHP standard 9-point questionnaire (Saaty, 1977) were collected from officials and staff of government departments and organizations related to inland water transportation in the state of Assam. Da Cruz et. al (2013) while using the AHP model for seaport evaluation has defined practitioners having a minimum of 5 years of experience as experts from the maritime industry. Using the same level of experience as criteria for experts, a total of 41 responses have been collected through interactions with expert groups spanning managerial (strategic) and staff (operational) levels from the Ministry of Ports, Shipping and Waterways, Inland Waterways Authority of India, Inland Water Transport- Assam and Assam Inland Water Transport Development Society. These officials are the forerunners for the developmental initiatives in the region for inland water transport and their experience in terms of operationalizing and managing the inland water freight services is significant from the perspective of the study.

4.2.1.4.2 Shippers/Shipping agents

Considering experience of shippers in the domain of sea transportation, Ugbomaet. al (2006) collected responses from managerial level executives of shipping companies to come up with an AHP based approach for port selection decisions in context of Nigerian sea ports. In the inland water sector as well, the shipping companies have been highly instrumental in supporting the sector by providing services and augmenting equipment of the state-owned departments. They play a major role in facilitating the carriage of cargo and freight across the inland water ports. From the perspective of the port users too, this group provides necessary feedback to the port operators for streamlining operation. For the study, information related to shipping companies and third-party organizations working on contractual mode was retrieved from the government departmental records. A total of 17 responses has been collected from managerial (including consultant) level employees of organizations such as Eastern Navigation Pvt. Ltd, Brahmaputra Infrastructure Ltd, Assam Bengal Navigation, South Coast to name a few. From the operational standpoint, these organizations are well versed with the inland water transportation network of the entire northeastern states.

4.2.1.4.3 Academia

Academic researchers play a poignant role in theory building by observing the physical phenomenon. Lee et al. (2014) carried out an AHP analysis for evaluating port competitiveness with the support of eight universities in five continents and academic researchers’ opinion was considered for the ranking. In the context of inland water transportation in India, research evidence has highlighted the role of the experienced researchers to this domain by virtue of projects, research papers and consultancy assignments. To leverage on the academic acumen, interactions with academia related to inland water sector were undertaken and their opinions have also been recorded in the form of responses to the questionnaire.

4.2.1.5 Data collection period

The primary data for the AHP questionnaire was collected from respondents during the year 2022-23 through the office, site and port visits. A detailed schedule of the data collection activities is provided at appendix A2. Secondary data used in the different parameters of the AHP ranking have been compiled from the secondary sources during the same period.

4.2.1.6 Extent of data collection

The primary data collection has been limited to the identified criteria and sub-criteria for the shortlisted inland water ports as per the defined scope. This was carried out during physical visits to the inland water ports and waterway infrastructure along the two major waterways- Brahmaputra and Barak.

4.2.1.7 Tools for data collection

The standard AHP 9-point scale (Saaty, 1980) has been utilised for preparing the questionnaire to quantify managerial judgement in context of the identified criteria, sub-criteria and decision alternatives. The same 9-point scale has been adapted by Lirnet. al (2004), Ugboma et al. (2006) and Chao (2010) among other researchers for developing water port prioritization AHP models in different geographies.

Table 4.2: 9-point scale for pairwise comparison in AHP

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two criteria/ sub criteria contribute equally to the objective
3	Moderate Importance	Judgement slightly favors one criterion/sub criterion over another
5	Strong Importance	Judgement strongly favors one criterion/sub criterion over another
7	Very Strong Importance	One Criterion/ sub criterion is favored strongly over the another
9	Absolute/Extreme Importance	There is evidence affirming that one criterion / sub criterion is favored over another
2,4,6,8	Intermediate values between above scale values	Absolute Judgement cannot be given and a compromise is required
Reciprocals of the above	If element i has one of the none zero numbers assignment when compared with activity j. j has the reciprocal value when compared to i	A reasonable assumption

Source: Saaty (1980)

To provide enhanced clarity for the respondents, the fundamental scale has been customized to meet the requirements of the study. The intermediate values of the original scale have been defined for the convenience of the expert groups.

Table 4.3: AHP pairwise comparison Scale (adapted)

Value	Interpretation
1	Equal Importance
2	Weak Importance
3	Moderate Importance
4	Moderate Importance plus
5	Strong Importance
6	Strong Importance plus
7	Very Strong Importance
8	Very Strong Importance plus
9	Extreme Importance

Source: Researcher's adaption from Saaty (1980)

On the basis of the adapted scale, the AHP questionnaire has been designed to capture the judgement of the experts and quantify the same in terms of the numerical values 1-9. The primary data was collected through in person surveys with the responses recorded on the developed AHP questionnaire. The questionnaire used for the purpose has been provided in Appendix A1. The questionnaire is divided broadly into three sections- A, B and C. Section A contains respondent details, section B provides a description of the adapted scale while section C contains questions corresponding to the pairwise comparisons of the criteria and sub criteria.

4.2.1.8 AHP tool for data analysis

Based on the calculation principles for AHP (Saaty, 1977), a data analysis tool has been developed on Microsoft Excel software. The eigen vector and priority weight calculations including consistency check has been accomplished using the developed tool. Standard mathematical formulas available on MS Excel has been used to compute the values.

Table 4.4: Pairwise Comparison Matrix (empty) on MS Excel tool

Pairwise Comparison Matrix					
Criteria	C1	C2	C3	C4	C5
C1	1				
C2		1			
C3			1		
C4				1	
C5					1
Sum					

Source: Researcher's own compilation

Geometric mean of the pairwise comparison responses provided by the experts are entered in the corresponding shaded cells only. The other cells are computed automatically as the reciprocal of the values entered in the corresponding pairwise comparisons (reverse). The row for the sum is calculated as the summation of the values in the corresponding columns. The next step is preparation of the standardized matrix.

Table 4.5: Standardized Matrix on MS Excel Tool

Standardized Matrix							
Criteria	C1	C2	C3	C4	C5	Weight	Rank
C1	1/Sum1	Value/Sum2	Value/Sum3	Value/Sum4	Value/Sum5	Average (C1)	
C2	Value/Sum1	1/Sum2	Value/Sum3	Value/Sum4	Value/Sum5	Average (C2)	
C3	Value/Sum1	Value/Sum2	1/Sum3	Value/Sum4	Value/Sum5	Average (C3)	
C4	Value/Sum1	Value/Sum2	Value/Sum3	1/Sum4	Value/Sum5	Average (C4)	
C5	Value/Sum1	Value/Sum2	Value/Sum3	Value/Sum4	1/Sum5	Average (C5)	

Source: Researcher's own compilation

The Standardized matrix is developed by dividing the pairwise comparison cell values with the sum of each corresponding column. The weights are then calculated as the average of the row values of the standardized matrix. The ranks or priorities of the criteria are assigned in descending order of the weights and the same has been achieved using excel formulas.

To ascertain the consistency of expert opinion, the consistency ratio has been calculated using the random index (Saaty, 1977). This is important to establish the validity of the calculation.

Table 4.6: Consistency calculation on MS Excel Tool

C1	Sum Product C1 / Weight 1	No of comparisons	C
C2	Sum Product C2 / Weight 2	Average Consistency (A)	S/ C
C3	Sum Product C3 / Weight 3	Cosistency Index (CI)	(A-C)/(C-1)
C4	Sum Product C4 / Weight 4	Random Index (RI)	Value from RI Table (Saaty, 1977)
C5	Sum Product C5 / Weight 5	Consistency Ratio (CR)	CI/RI
Total	*Sum of consistency (S)*	**Consistent?**	**Yes if Consistency <0.1**

Source: Researcher's own compilation

The consistency value for each pairwise comparison is determined using adapted methodology using excel formulas extensively to model the underlying equations. In the initial step, for each criterion, the sum product of corresponding rows in pairwise and standardized matrices are calculated. This value is divided by the respective weights of the criterion and the sum of consistency calculated which is used in calculating average consistency depending on the number of comparisons. Thereafter, the consistency index is calculated as a function of average consistency and no. of comparisons. Finally, the consistency value is determined by the following formula.

$$Consistency\ Ratio\ (CR) = \frac{Consistency\ Index}{Random\ Index}$$

Malczewski (1999) found that a consistency or consistency ratio (CR) of 0.1 is a reasonable level of consistency for the pairwise comparisons. A CR value above 0.1 necessities revisiting of the pairwise comparisons for inconsistency in rating of the criteria (Pourghasemi et al., 2012).

4.2.2 Identification of dry port location

Exponential growth in international freight transport in Asian countries over this decade has resulted in substantial revenue and environmental impact and this has led to proliferation of intermodal transport for efficient freight transport operations. This has led to substantial development of intermodal interfaces such as dry ports to complement the existing operations of water ports. Ng and Gujar (2009) defined dry ports as inland transport infrastructure with cargo-handling facilities that support key logistics functions such as consolidation, distribution, temporary storage, customs clearance and thus, facilitating private public institutions for supply chain interactions. Rosoet. al (2009) gave the definition of dry port as: “an inland intermodal terminal that is directly connected to seaport(s) with high-capacity transport mean(s), where customers can leave/pick up their standardized units as if directly to a seaport.”

Hanaoka and Regmi (2011) examined the emergence of dry ports and the resulting intermodal transport opportunities in selected Asian countries. Establishing transport links, services and strategically locating nodes play key role in developing the intermodal capabilities of a region. However, in the Asian continent, twelve countries are landlocked and thus, the very development of intermodal transport requires setting up of dry ports. Rosoet. al (2009) attributes the need of dry ports to enhance rail and road connectivity with seaports so that container transport becomes efficient with utilization of energy efficient traffic modes and provide improved transportation solutions for shippers in the land locked regions of the county. In their study, emphasis was given on extending the dry port concept and defining three dry port categories namely distant, midrange and close. On the other hand, Notteboom and Rodrigue (2009) classified dry ports on the basis of satellite terminals, transmodal centers and inland load centers while Wilmsmeieret. al (2011) divided dry ports on the basis of directional development.

The potential benefits of having dry ports as discussed by different researchers can be summarized as below:

- Easy extension to inland water ports capacity
- Proximity to rail and roadways
- Access to customs and other related documentation facilities
- Easy transfer, distribution, break bulk or consolidation point for freight
- By virtue of modal shifts, dry ports would help in easing traffic congestion and emissions

In case of developed nations such as Europe and North America, dry port developments are envisioned by seaport operators with the aim of easing out capacity constraints, natural barriers and other external elements at seaports for improving accessibility. However, for developing nations and regions like India and South East Asian economies, Ng & Cetin (2012) opined that dry port development is aimed at improving the inland logistics efficiency through measures of freight consolidation for the water ports. In this respect, the critical issue of dry port development is location site selection which determines the degree of efficiency. Some of the key factors in the dry port location analysis are total logistics cost, initial setup cost and qualitative location factors involving supply chain stakeholders such as operators, users and community. Despite the different location analysis models, Nguyen and Notteboom (2016) opines that dry port locations in developing economies might be more ‘cluster-oriented’ rather than ‘supply chain oriented’.

4.2.2.1 Hub and Spoke Network design

A Hub-and-Spoke (HS) network model simplifies a network of routes; the central hub connects the different ports by means of the spoke like connecting feeder services (Fakapelea, 2013). For some HS models, liner services connecting regional terminals and hubs are the spokes while at the hubs, the containerized cargo is transferred from one liner to the next one transporting the shipment to the destination. Ideally, the location of hubs are near the centre of transport demand with a motive of minimizing the trip times and distances between origin and destination. Such a system may also be designed to consolidate small loads departing and arriving from multiple directions, thereby improving upon economies of scale in the transportation domain. Effective HS systems customized to a region’s specific need improves the quotient of logistics service while ensuring operational efficiencies of resources employed (Wei et. al, 2017). In the global shipping arena, during the last decade, gateway hubs like Yantian-Shenzhen, and Shanghai, transshipment hubs like Algeciras, Malta, and TanjungPelepas, and mixed hubs like Dubai, Port Klang, and dominant hub ports like Singapore have revolutionized the Hub-and-Spoke Network designs and brought in higher efficiencies and effectiveness (Lam and Iskounen).

For the hinterland regions of the country, export and import shipments possess uncertain characteristics, owing to which, a direct transport model for the same from inland regions to inland water ports may lead to an increase in logistics costs and misallocation of resources. Wei et. al (2017) proposed a hub-and-spoke logistics network based on a two-stage logistical gravity model for the inland regions in China to cope with the disadvantage of the direct transport model.

4.2.2.2 Parameters for the Hub and Spoke (HS) Model

To be able to sustain an efficient HS system, the spokes have to keep up with the improvement of the hub. The dry ports need to keep up with the advancements in the inland water ports and cater effectively as per their throughput. In this context of developing inland water ports dry ports in a hub-and-spoke network design, studies have revealed the following considerations:

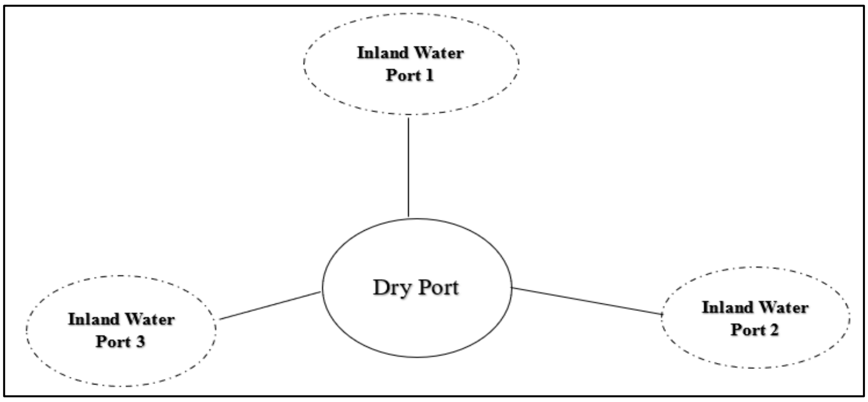
- **Distance minimization:** The relative distance between the dry ports (hubs) and the inland water ports needs to be minimal so that the time required to traverse along the spokes are minimized
- **Cost minimization:** While considering the region, overall initial setup costs need to be low for enabling a low initial investment for the hub ports.
- **Ownership:** Most of the secondary ports (dry ports) in Africa, America and parts of Asia are under government ownership model. However, such ports being operated in a non-commercial manner are not inclined towards customer service. Thus, privatizing such ports may lead to increased operational efficiencies.
- **Customs practices:** Frameworks involving customs practices to that nation are also one of the considerations concerning the design of a HS network design.
- **Equipment maintenance:** Dry ports involving transshipment traffic require robust maintenance schedule for the overhauling and container loading equipment. State owned dry ports may suffer from poor equipment maintenance while privatized ones have robust mechanisms for equipment maintenance.

The above considerations play key role in the hub-and-spoke model design concerning inland water and dry port networks.

4.2.2.3 Hub and Spoke Theoretical Framework

As per research evidence (Roso et. al, 2009; Ng & Cetin, 2012), prospective locations of dry ports are determined based on attributes such as easy extension to inland water ports, proximity to rail and roadways for multimodal capabilities, access to customs and ease of transfer and distribution. For the optimization model, the dry ports shall act as hubs connecting the inland water ports which shall be the spokes.

Figure 4.4: Hub and Spoke Theoretical framework



Source: Researcher's own compilation

For the identified inland water port locations, an initial assessment was carried out to identify prospective dry port locations in four major regions along the Brahmaputra and Barak valley. The dry port locations must fulfill the parameters as identified through literature review and accordingly, the following locations were identified. The dry ports shall be located at appropriate hinterland locations supporting multimodal connectivity. Even though few prospective dry ports may be in the vicinity of the inland water ports, it would be regarded as separate facility. Each of the prospective dry port locations have been classified on a scale of high, moderate, and low in terms of fulfilling the identified criteria.

Table 4.7: Dry Port attributes comparison (*region specific*)

Dry Ports Locations (*prospective*) Attributes	Jogighopa	Tezpur	Dibrugarh	Badarpur
Easy extension to inland water ports	High	Moderate	Moderate	High
Proximity to rail and roadways	Moderate	High	High	Moderate
Access to Customs	High	Moderate	Moderate	High
Ease of transfer and distribution	Moderate	High	High	Moderate
Supporting Industries	Moderate	Moderate	Moderate	Moderate
Market Accessibility	Moderate	High	High	Moderate

Source: Researcher's own compilation

Based on the consideration of relative distances between the selected inland water ports and geographical proximity to rail-road connectivity, the following hub-and-spoke network model of inland water port - dry port was initially identified.

Table 4.8: Hub-and-spoke model for the port network (*region specific*)

Dry Ports Locations (*prospective*)	**Spokes connecting the inland water ports**
Jogighopa	Pandu, Dhubri, Jogighopa
Tezpur	Silghat, Biswanathghat
Dibrugarh	Neamati, Dibrugarh
Badarpur	Karimganj, Badarpur, Silchar

Source: Researcher's own compilation

However, to identify overall best-case scenario of the hub-and-spoke network model for the state, the prospective dry port locations have been expanded. Additionally, the existing dry port at Amingaon (Guwahati) has been included in the list of dry ports (prospective) for the purpose of optimizing the network.

4.2.2.4 Data and Assumptions

Secondary data has been used for fulfilling objectives 2 and 3. Secondary data primarily in the form of locational attributes have been captured to carry out the scenario analysis. The distance between the ports have been ascertained through Google Maps and GIS data. Through the port and field visits, observational data related to the attributes of the parameters for dry ports have been recorded. A total of ten (10) inland water port locations and eleven (11) sites for prospective dry ports have been visited to capture locational attributes of required data for optimization from the perspective of distance.

4.2.3 Optimization of the port network system

The proposed hub and spoke model have been optimized based on road distance between the nodes. Using a brute force approach involving the objective of distance minimization akin to location allocation modelling, multiple scenarios have been analyzed for the best-case scenario. The following hub scenario models have been developed to identify the cost optimized case

- One Hub Scenario Model
- Two Hub Scenario Model

- Three Hub Scenario Model

Haralambides (2002) advocates for evaluation of public investment and rationalizing public infrastructure in terms of the economic development impact and recovery of investment costs. On a similar note, considering the expenditure of establishing dry ports and marginal cost pricing, a maximum of three hubs may be suitable from the perspective of cost benefit analysis. The existing dry port configuration is also evaluated in the different hub scenario models.

4.2.3.1 Location Allocation Model

Feng et al. (2013) constructed a location-allocation model for the regional seaport-dry port network optimization problem. Location Allocation models are used to determine the most suitable location for a single or group of facilities to fulfill certain requirement. The ultimate goal of a location allocation model is minimizing either the cost or the distance between demand centres and service facilities. Location allocation also helps in ascertaining the number of facilities required for serving demand using optimal resources. Rodrigue, J (2020) provides a comprehensive description of location allocation models in his textbook on transport systems.