Hub Network Design for Sparse Travel Demand within the African Aviation Industry

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ABSTRACT

The African aviation industry has a pressing need to build an extensive global network within the region and is undertaking various steps through the liberalisation process provided for in the Yamoussoukro Decision to expand regionally and to improve Intra- Africa air travel.

This paper analyses a study aimed at testing the cost effectiveness of designing a hub and spoke network (H&S network") for Africa that allows airlines to reduce the costs of travel and increase connectivity.

Various hub networks are designed using hub location methodologies which work on the transport economics principle that the operating costs in a network are minimised through the economies of scale achieved when flow is consolidated on routes. Different hub networks are then designed, costed and analysed to reveal that the best option for a hub network is the so-called geo-political network. A geo-political network is where hubs are created in the North, South, East and West of Africa, at airports with strong political influence, high passenger demand, modern technology and infrastructure. This result furthermore highlights the need for the various geographical regions on the Continent to work together to implement the Yamoussoukro Decision at a regional level and thereby, through the creation of hubs, increase accessibility and affordability of air travel within Africa.

INTRODUCTION

The purpose of this research was to investigate cost effective H&S network design strategies for air travel within Africa, paying special attention to sparse travel demand in Africa, in a less dense network, where sector distances are long, thus challenging some of the typical benefits of the H&S network.

The main purpose of the network was to allow for minimisation of the cost of air transport, for both the operator and the user, in a bid to lower the costs in setting up a regional airline service. The study was conducted in two major parts, which include:

1. Designing a H&S network for a regional airline service to meet passenger demand that minimises costs.
2. Investigating whether the H&S network arrangement is a viable option for both the user and operator of the airline service, in terms of indicators like costs, service frequency and time factors.

The results of the research will contribute to a greater understanding of the H&S network arrangement relevant both to the African situation, and optimum hub network service design. On a broader perspective, other potential sparse demand markets can use this study as guidelines for assessing the feasibility of creating hub networks in airline services, where sector distances are high and passenger demand is low. The major conclusions that were derived for this study include:

OPENING UP SKIES: THE YAMOUSSOUKRO DECISION

As in many other parts of the world, by the late 20th century, the African aviation industry was being run by governments and suffered the associated problems of mismanagement, lack of technical skill due to political involvement as well as corruption leading to insufficient funds to

manage national airlines. In order to align African Aviation with policies of deregulation and liberalisation already implemented in North America and Western Europe and to prevent the collapse of some African national airlines, the African ministers responsible for civil aviation met in Yamoussoukro, Ivory Coast in October 1988. This heralded the historic Yamoussoukro Declaration (YD) of 1988. Later in July 2000, the different African ministers responsible for civil aviation and the Heads of State and the Government of the Organisation of African Unity (OAU) [now called the African Union (AU)], adopted the Yamoussoukro Declaration whose name later changed to the Yamoussoukro Decision (the **"YD"**), which made it binding in law, to be adopted by all Member states of the African Union (AU).

In order for any regional expansion of airlines within the African Continent to take place , a faster implementation of the YD is required , such that open skies, free competition rules and fifth freedom rights will be granted. The most practical thing to do would be for airlines to join alliances, or unify on a regional basis, such that even though the expansion of the airline industry is political, the government involvement should be limited to trying to negotiate routes and airline service agreements.

HUB NETWORK DESIGN METHODOLOGY

The methodology of designing a hub and spoke (H&S) network for the African region was as follows:

- The hub location was as per the ρ-hub median problem, where a fixed number of hubs (ρ) are chosen from n nodes that are the airports locations. The hubs were chosen using various methodologies using cost justifications.
- The nodes allocation was to be solved as the uncapacitated single allocations ρ- hub median problem, which implies that each node will be assigned to only one hub and all nodes were routed to the closest hub.

- The network was costed using the equation under network costs shown in Figure 2 derived from Klincewicz (1991) , which calculates the cost of routing all passengers from each node to the closest hub and then to their final destination. The costs and flows needed for the calculation were derived from a cost model that calculates route-operating costs for Africa specific data. Node–Hub links had sector limitations such that the longest route would be a Node-Hub-Hub-Node route for passengers whose origin and/or destination node was greater than 3500km to the closest hub.

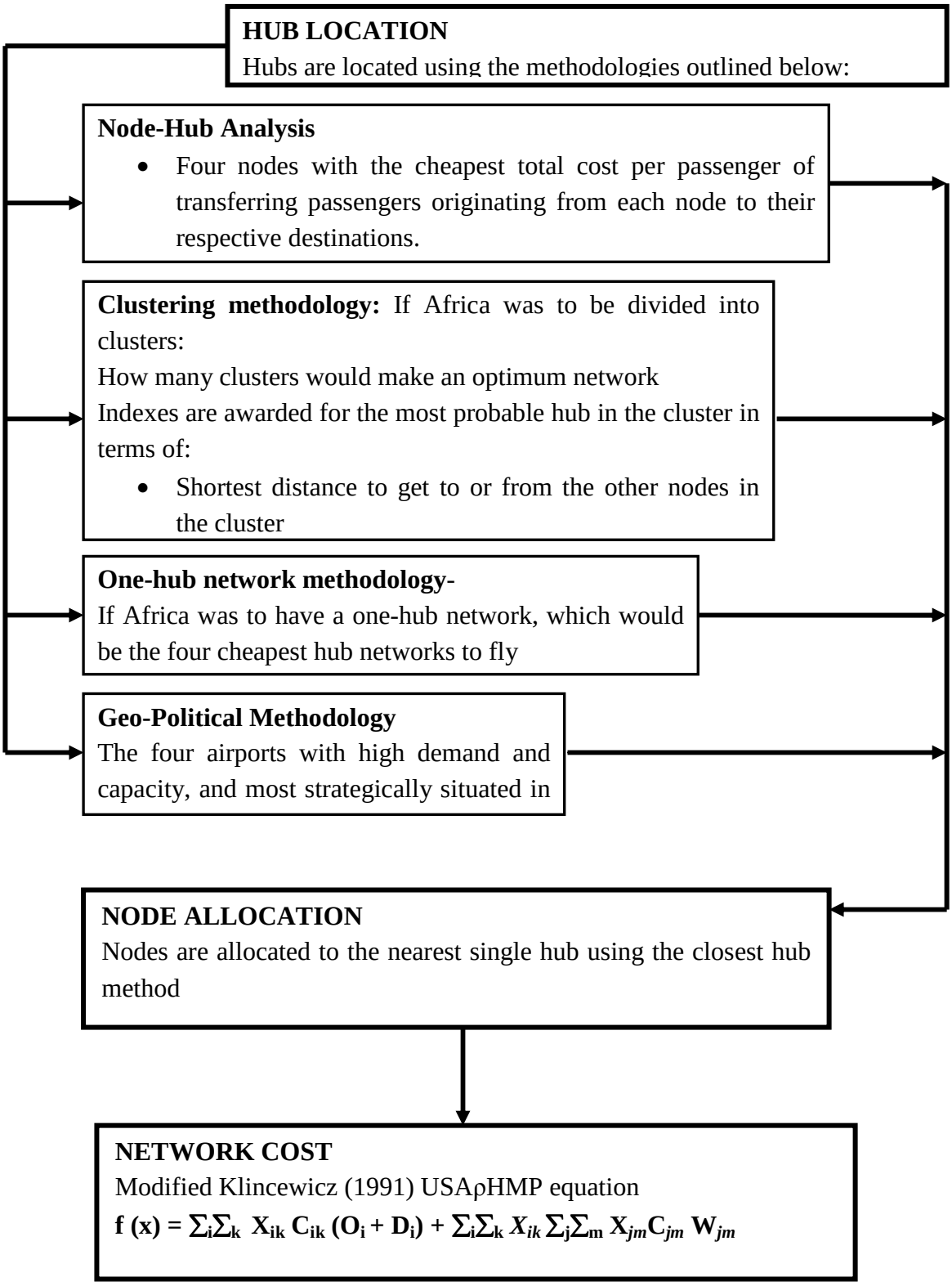

Figure 1: Network Design Process Flow Chart

HUB LOCATION METHODOLOGIES

The following are the cost effective methodologies used to identify the possible hub location options that would provide the cheapest network:

1. The nodes with the cheapest cost to fly to in terms of costs per passenger and costs per aircraft-km.
2. The nodes with the cheapest cost to fly from in terms of costs per passenger and costs per aircraft-km.
3. One-hub network methodology which analyses each node as a hub in a $\rho=1$ network, thus picking the cheapest hub option on the Continent.
4. Africa being a large continent, the methodology of clustering is used as a way to analyse hub network design especially over large areas for:
    - The optimum number of hubs;
    - The most attractive nodes in clusters in terms of distance and passenger flow indeces;
    - The most attractive nodes in a cluster in terms of costs of supply and demand indeces.

GEO-POLITICAL METHODOLOGY

The aviation industry in Africa is a highly political industry and because of this, a network design based on airports in countries with the greatest political influence on the aviation industry will have to be considered as locations for the siting of hubs. Furthermore, the problem of African airports lacking proper infrastructure has to be taken into consideration. This implies that airports with geopolitical influence in the aviation industry will be chosen as hub choices giving justifications as to why they are the suitable hub choices. After these hubs are chosen, the nodes are allocated using the same procedure as before and the network is costed. The general characteristics of the airports to be picked as hubs include the following:

1. High passenger demand so as to be able to benefit from the lower costs of transporting the passengers even after the hub is created
2. Adequate infrastructure in terms of runways, air traffic control facilities gates, aprons terminal buildings and handling facilities to accommodate the high frequency of flights, so as to reduce delays in flight schedules and slot timing which implies minimum additional investment when converted to hubs.
3. Convenient geographical location which is close to the economic heart of the region and easily accessible for passengers.
4. It is currently being used as an airline hub to consolidate passengers en route to their final destinations from different origins.

All the 50 international airports used in the database of the cost model were analysed using data from various aviation authorities. The Continent was divided into geographical regions, based on the optimum hub number as calculated using the clustering methodology (which found the optimum hub number to be 4). Furthermore, these divisions were also aligned to existing regional trade and economic organisations within which a level of trust and cooperation had already been established; for example the Open Sky policy in the European Union was enhanced after the European Union was formed. Airports were then allocated within their clusters and within an average distance of 3 500 km from the centre of the cluster, which would ensure short-haul N-H route benefits of flying smaller cheaper aircraft even for a small passenger demand node-hub route within the cluster.

The criteria followed in choosing hub options for each cluster was based on using the following factors: high passenger demand, infrastructure, technology advancement, number of flights operating, number of airlines operating, hub capabilities or function at airline or geographical level, as shown in Table 1.

Table 1: Criteria for choosing the most likely hubs

ITEM	NORTH			SOUTH	EAST		WEST	
Airport	**FEZ**	**ALG**	**CAI**	**JNB**	**NBO**	**ADD**	**KAN**	**DKR**
Country	**Morocco**	**Algeria**	**Egypt**	**South**	**Kenya**	**Ethiopia**	**Nigeria**	**Senegal**
Passenger	1 329 040	1 329 036	1 242	3 669 000	741 000	843 000	252 000	19 500
Node-hub	13 642	15 069	31 134	11 114	10 360	10 762	33 775	53093
Airlines	16	14	49	42	45	19	36	28
runways	1	2	3	3	2	1	2	2
Major function	Europe-Africa link	Europe-Africa link	Egypt air hub	SAA hub, Trans-Atlantic link	Transit hub, regional Hub	Airline Hub	Regional hub	Re-fuelling
Hub choice	**FEZ**			**JNB**	**NBO**		**KAN**	

In the north, Egypt is eliminated due to the fact that it has very long N-H distances, even though it has high passenger numbers. FEZ in Morocco is chosen because it has shortest Node-Hub distances and has more airlines serving the airport presently.

In Southern Africa, South Africa, currently acts as a hub from Asia to Africa, is a hub to a South African Airways, and is suitably located within the southern potion of the Continent.

In East Africa, the two probable hubs are found in Ethiopia and Kenya. Even though ADD has higher passenger numbers, it has higher total N-H distances for all nodes. Nairobi serves more airlines and has greater capacity runway, as its acts as a major hub between another large carrier Kenya Airways.

In West Africa, Nigeria has higher passenger capacity than Senegal and has lower Node-Hub distances within the region and serves more airlines, and is more suitably located in the western potion of the Continent. Figure 2 shows the geographical boundaries of the geo-political network proposed above.

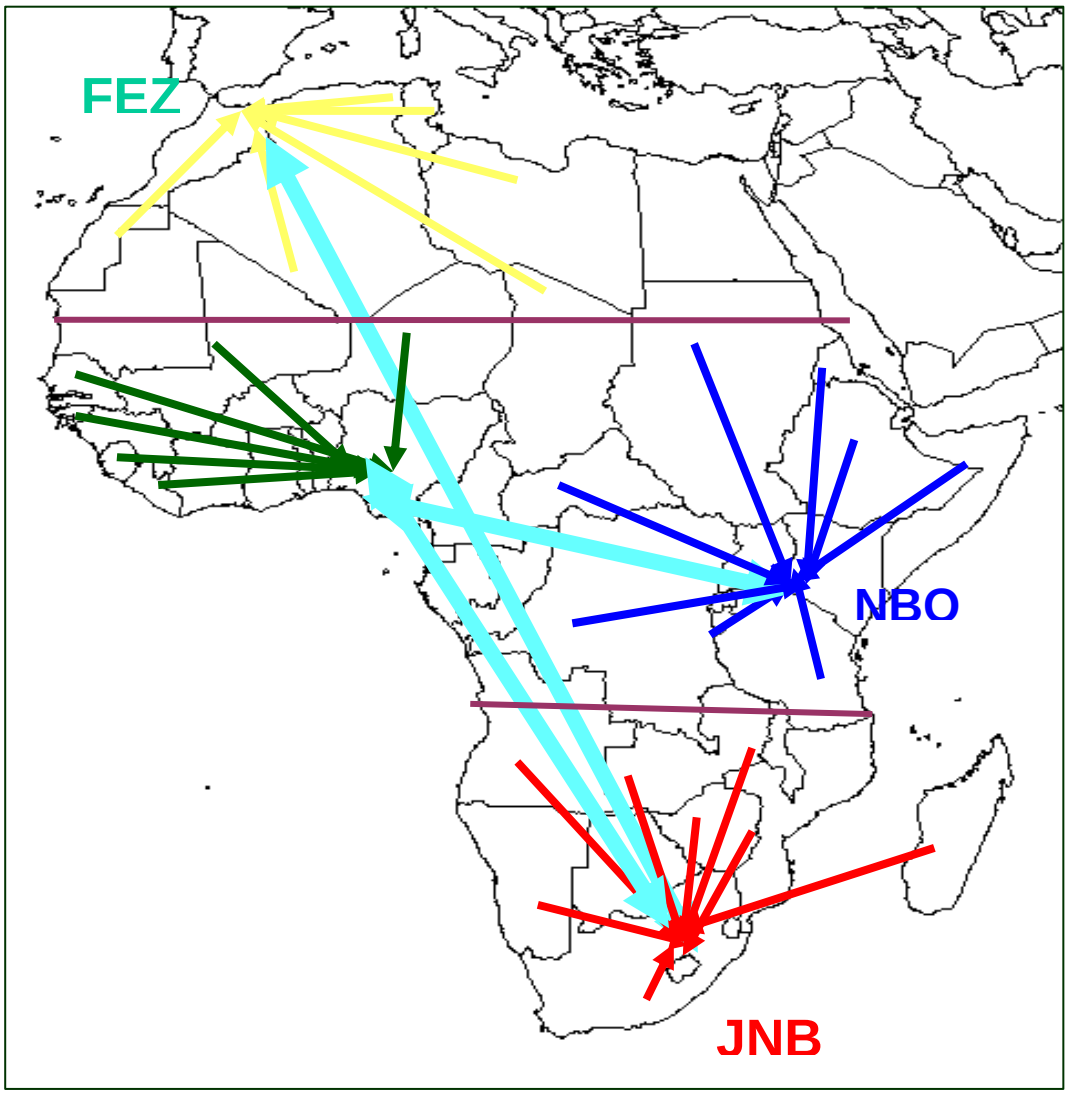

Figure 2: Geo-political network methodology

HUB NETWORK ANALYSIS

This chapter is aimed at analysing the various networks that have been costed as shown in Table 2 using the various methodologies shown in Figure 1. This analysis will be aimed at giving the necessary inferences as to what network has the most cost effective design in terms of the criteria such as Hub location: Hub-Hub movement, Node-Hub movement, so as to design a cost effective H&S network for the African Continent

Table 2: Hub network cost summary

NO	NETWORK TYPES	HUB AIRPORT LOCATIONS	NODE-HUB COST (US$)	HUB-HUB COSTS (US$)	TOTAL COSTS US$)	% from cheapest network
1	GEO-POLITICAL	FEZ-JNB-NBO-KAN	851 005	965 800 536	1 575 355 943	0,00%

The H&S networks designed are then analysed in terms of costs so as to draw inferences as to how to design a H&S network that will lower airline operating costs and network costs. The general inferences drawn from the analysis of these methods show that:

- In the short-term, cheap options for hubs can be the airports with the highest passenger demand, because they have the benefits of two sets of economies of scale realised with a high number of passengers flying a route. They also have the advantage of advanced infrastructure, which would be a general problem within African airports, so as to handle the increased passenger demand that is characterised with hubbing.
- An average percentage analysis carried out for all networks calculated show that on average, the Node-Hub costs cater for 62% of the total costs while the Hub-Hub costs cover only 48% of the network costs. This confirms O'Kelly's (1998) findings that the Hub-Hub portion of the trip, costs less than the spoke portion, so the network has an incentive to connect the nodes to the hubs as quickly as possible, to take advantage of the cheaper Hub-Hub costs.
- The cheapest network from Table 2 is the geo-political network, even though it doesn't have low Hub-Hub costs, because the some long Hub-Hub links i.e. JNB-FEZ. The low Node-Hub costs derived from the economies of scale of traffic density, with the central location of the hubs within the geographic region and the high origin and destination flows of the hub; therefore play an important part in lowering the total network costs.

Recommendations

The methods, that were used to design a H&S network in this thesis, used a mechanistic model to calculate the route costs and the network costs. There is a need to design a non-

mechanistic method to identify the optimum solution for ρ-hub median problems for the Africa network. There are various hub location methodologies that have not been used in this study because they utilise a cumbersome and mechanistic method of network design.. Below are some of the methods that can be used for hub location that can be explored:

- **Heuristics** which uses the problem-solving technique in terms of which the most appropriate solution is selected at successive stages of a program for use in the next step of the program. This method would investigate features like flow-threshold, or capacity restrictions, cheapest Node-Hub costs and cheapest Hub-Hub costs.
- The **Tabu-search** and **Genetic algorithm** procedure can be used because it is an iterative procedure that moves from one feasible solution to another. This procedure would involve costing all the possible combinations of hubs, until the cheapest combination of hubs is found. This method would need the automation of the hub location, node allocation and network costing procedure
- A **Linear programme** can be used to solve the problem, especially if the variation of demand elasticity with cost can be quantified. The costs for each route as it becomes a Hub-Hub link can be calculated such that the costs don't have to be inserted manually into the network cost equation for all the possible networks.

Hubbing as an option for increasing Intra-Africa travel has been investigated, from the policies involved in opening up the skies, to the procedure that can be used in the hub location and node allocation so as to minimise transportation costs. Route analysis was carried out for typical routes so as to analyse whether or not they would benefit from hubbing. This study can be used by: airline operators, operational researchers, policy makers and aviation researchers to give an insight into the African aviation market and the way in which to profitably develop the market in the future.

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