Application of fuzzy logic at the Port of Cotonou (Benin / West Africa) in analysis of port logistics viability

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Abstract

The Autonomous Port of Cotonou (PAC) located in West Africa has an access channel 15m deep, 11 berths, and an internal draft of 15m (maximum), and is connected with a road to serve continental countries such as Burkina-Faso, Chad, Mali, Niger and Nigeria. The PAC presents low productivity (average of 10,000,000 tons / year, 24.40% of the movement from the port of Lagos / Nigeria) in West Africa. This article aims to evaluate the application of fuzzy logic in the Autonomous Port of Cotonou (Benin) in the analysis of logistic viability. The methodology followed the fuzzy logic that is a support method for logistic decision-making, based on fuzzy rules (SBRF). It was used characteristic of Mamdani Matlab Toolbox with three membership functions (triangular, trapezoidal and Gaussian) to model the quality variables of infrastructures and services, equipment productivity, seeking a long-term way out of logistic viability. The result of logistic viability was medium term, equivalent to 13 years / 25 years; as far as the outcome of the future PAC is concerned. The logistic viability of the PAC depends on its input variables. The projection of this application was long term, at least 19 years / 25 years when the infrastructures are of good quality and the equipment is more modern and consistent with the current realities to satisfy the expectations of the customers.

Keywords: Fuzzy logic. Logistic Viability. Autonomous Port of Cotonou (PAC). Benin. West Africa.

Introduction

Port logistics can be defined as the set of strategic and operational means to optimize intermodal functions in the port chain, that is, an approach that makes the various operations of a port faster and more efficient. According to the various definitions, four (4) strategic elements (waiting and mooring time, the quality of port services, the productivity of port infrastructures and equipment, port costs and the port's attractiveness indexes) are indispensable and summarize the concept of port logistics.

In Africa, the port sector's main objective is to improve commercial competitiveness and reduce government spending. However, most ports in West Africa (Ivory Coast, Ghana, Benin, Nigeria, Senegal, Togo, Guinea, Guinea-Bissau, Sierra Leone, Gambia, Liberia, Cape Verde) still have obsolete and insufficient infrastructure and handling installations. Significant growth in container cargo demand requires well-equipped container ports (Chen, Xu and Haralambides 2020). According Lourdes, María and Juan(2013), ports in West Africa have difficulties in receiving ships with a capacity of 8,000 TEUs. Chen, Xu and Haralambides (2020) affirm that despite this growth, current conditions in West Africa are far from ideal, both in terms of quantity and quality of port installations. The same authors emphasize that the reform process in African ports is complex because of certain factors that negatively influence their development capacity and affect port efficiency. For the same authors, other factors such as low port density, outdated cargo handling equipment and inept management have become real obstacles in West African trade.

Located in the central part of the West African coast, the Autonomous Port of Cotonou (PAC) is one of the most important ports in West Africa (Abidjan, Cotonou and Lomé) to serve the China-West Africa container transport system and can potentially be selected as the central port (Chen, Xu and Haralambides 2020). A central port can be developed both by expanding existing port installations and by building new installations. But investments in port capacity are large, expensive and uncertain. They also involve long construction times. Therefore, it is important to choose the timing and size of port investments appropriately to respond the growth of trade (Balliauw, 2020). Supporting this idea, Lourdes, María and Juan (2013) emphasize that the expansion of container movement, in increasingly larger ships, requires port installations to deal with large ships quickly and efficiently.

International maritime trade is still expected to expand at an average annual growth rate of 3.4% between 2019 and 2024, being driven, in particular, by the growth of cargo in containers, bulk and gas (Unctad 2018). With the significant growth of maritime trade, all ports in the world are increasingly in the process of reorganization and reconstruction with the single objective of becoming the hub to face competition from their region, like the PAC. Various modifications and extensions were made to the PAC in 1983, 1998 and 2012 to adapt to current realities. However, there are still other factors (absence of private sectors in financing and computerization of administrative procedures, high port fees), thus hampering efficiency, productivity and development. Fuzzy logic has been used in several areas in decision making. According to Von Altrock (1995); Jamshidi (1997); Cury (1999); Komarova (2000) and Goudard (2001); Maria and Gleicy (2007), the fuzzy logic is found in:

> "Project management, product pricing, medical diagnostics, sales forecasting, market analysis, criminal identification, capital budgeting, business acquisition assessment, information processing, quality control and other matters involving the taking decision-making, such as movement control, production systems, environmental assessment of alternative urban and road transport projects and others "

In port areas, Rahmawati and Sarno (2018) used fuzzy logic to detect anomalies in the handling of port containers, Wanke and Falcão (2017) analyzed the allocation of cargo in Brazilian ports using fuzzy logic. Akyuz et al. (2020) applied for analysis of the fault tree and event tree of the risk of cargo liquefaction on board the ship. Optimizing investment in port development (Allahviranloo and Afandizadeh 2008), the selection of the container port by (Onut et al., 2011), the central supply chain of the port (Loh et al., 2017), and others, fuzzy logic was applied. This article assesses the application of fuzzy logic in the Port of Cotonou (Benin / West Africa) in the analysis of logistic viability.

Study area location

The study area is located in Benin, a country in west Africa, in the extreme south of Cotonou (6 ° 23′48 ″ S / 2 ° 25′33 ″ W, Benin). The port of Cotonou is at the same distance with the ports of Lagos (115 km) and Lomé (135 km).

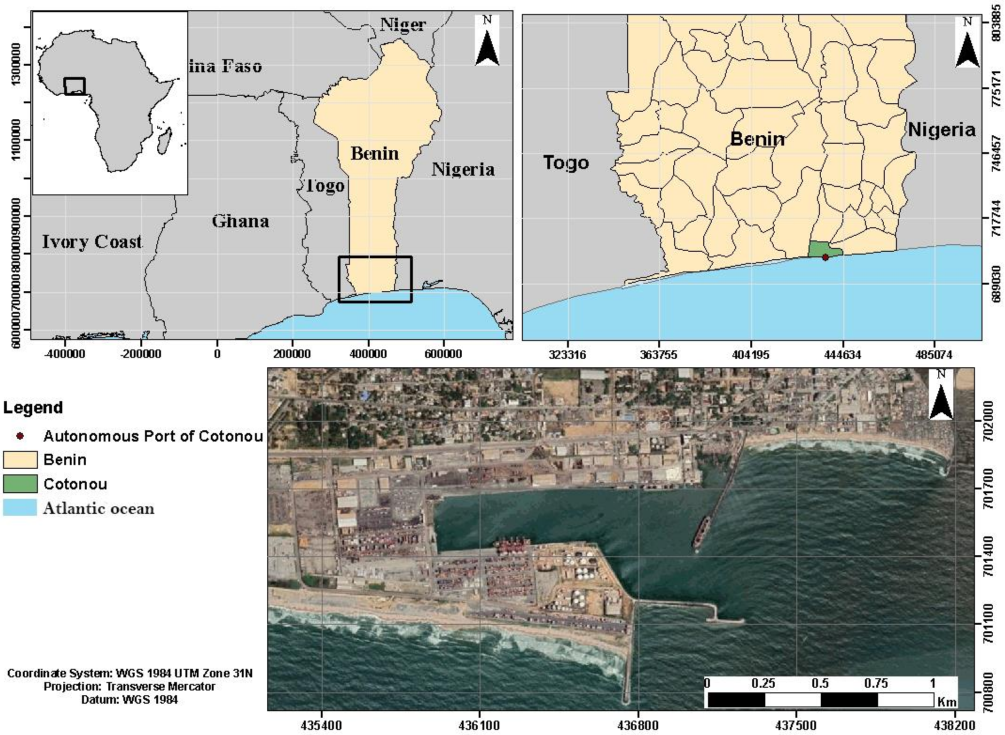


Figure 1 PAC location map, image extracted from google earth

Characteristics of the study area

The climate is tropical Aw type (warm temperate climate with dry winter), the average temperature is 26,8 °C/year, with average rainfall of 1244 mm/year, and average wind of 19 km/h. The waves reach a maximum height of 2.2m (MARÉPECHE, 2020). The PAC is built on the barrier island, which separates Lake Nokoué from the Atlantic Ocean, representing a flat topography not exceeding 10 m in altitude.

Port situation

The Autonomous Port of Cotonou, opened in 1965, was expanded in the years 1982, 1992, 2012 and is in continuous process expansion since 2019. PAC is characterized by being a sea port and a public, industrial and commercial entity with legal entity and financial autonomy. Like other ports in the world, PAC is in the process of maintaining its financial autonomy, its logistic viability in order to satisfy the expectations of its customers. This port has a road to serve the north of landlocked countries, such as Burkina Faso, Mali, Niger and Chad. It also represents the closest transshipment port to Nigeria and Togo. This representativeness is decreasing annually, that is, the port of Lomé exceeds the PAC's performance.

According to data from Port of Lomé (Togo), Benin, Ghana and Nigeria are today countries of relay and transshipment closest to the PAC.

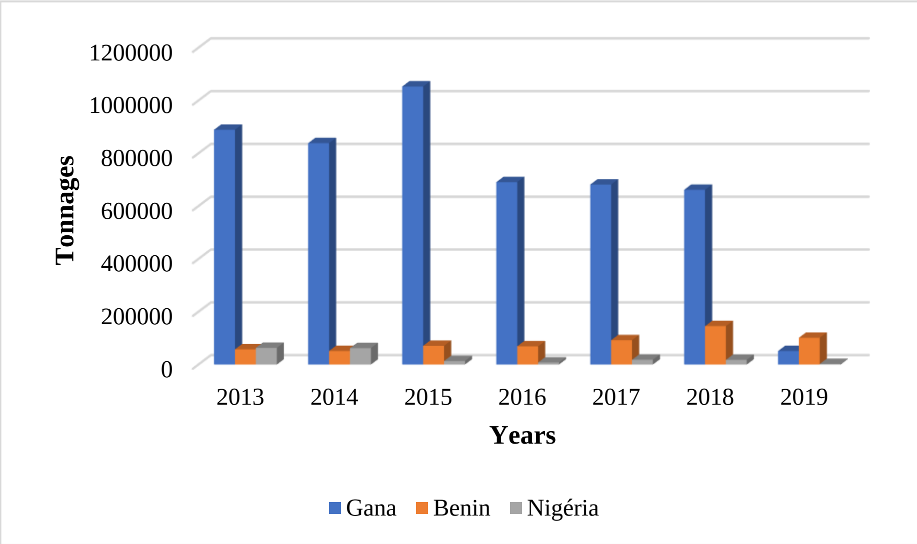


Figure 2 Transfer and transshipment from the Port of Lomé, Source: Port of Lomé (2020)

There is a significant drop compared to Ghana and an increase compared to Benin in 2019 (Fig 2). Between 2017 and 2019, the port of Lomé handled more cargo destined for Benin and in 2019, Benin was the country with a port that received the largest cargo from Togo (101,417 tons).

Figure 3 Total movement of imports, exports and transshipment in the PAC in the period from 2000 to 2019 (Source: Port of Cotonou, 2020)

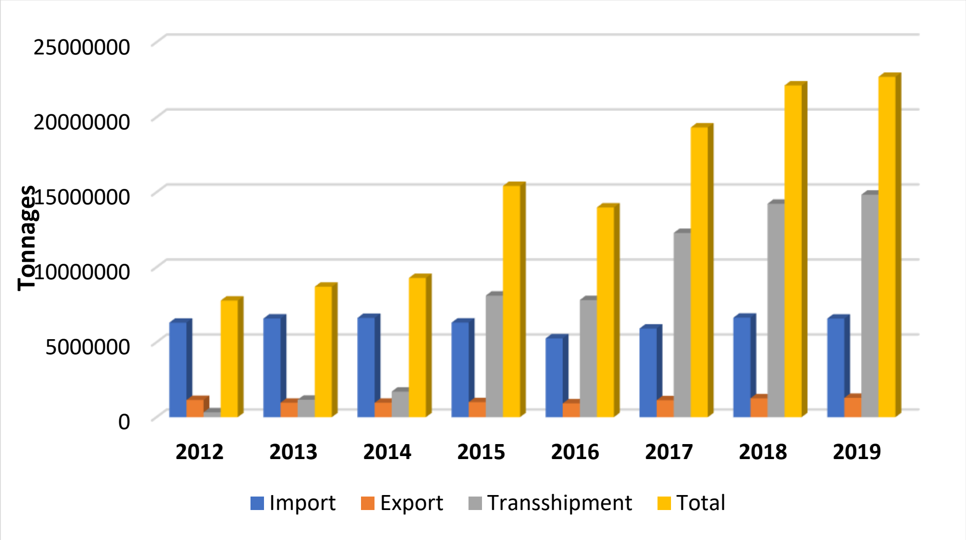


Figure 4 Total movement of imports, exports and transshipments at the Port of Lomé, in the period of 2012 and 2019

Source: Port of Lomé, 2020.

The total movement (import, export and transshipment) of the PAC in the period from 2000 to 2019 presents an import rate always higher than the exports, such as the other ports in West Africa, justifying a negative trade balance (fig 3). In the period of 2017 and 2019, the Port of Lomé recorded a high amount of transshipment and a low amount of import and export compared to the PAC (fig 4). The high amount of transshipment at the Port of Lomé can be justified by its depth (17m), the largest in the region, by the quality of its services and its competitive port fees.

PAC, with aging infrastructure, deficient equipment and slow port services, has difficulties in responding the demands of the hinterland. The PAC is no longer competitive with the ports of West Africa because of the high competition that exists, being cited among the latter in the list of ports in the central and west regions, and is still not attractive because of its current organizational characteristics.

Table1 Characteristics of the Port of Cotonou and West Africa

Countries	Ports	Depth (m)	Access Channel (m)	Number of cribs	Length of stay cargo (days)	Average number / month of ships	Average tonnage handled / year
Benin	Cotonou	10 to 15	15	11	-	85	10,000,000
Ivory Coast	Abidjan	13.5 to 16	18	21	15.70	160	22,500,000
Ghana	Tema	9; 11.50 to 16	18.2 to 19	18	18	129	22,000,000
Nigeria	Lagos	15	-	-	25	95	41,000,000
Togo	Lome	16.50 to 17	18	13	-	115	30,000,000

Source: Ports of Benin, Ivory Coast, Ghana, Nigeria and Togo

The PAC received a smaller number of ships in the last four years and has the lowest number of berths (11) and the lowest depth (10m to 15m) compared to the Port of Lomé (16.50m to 17m) and the lowest tonnage (10,000,000 tons) movimented. Thus, this port is no longer viable and can have a direct impact on the country's economy, since it generates up to 60% of the Gross Domestic Product (GDP) and contributes 80% to the mobilization of customs revenue and 45% of tax revenue (PAC , 2020).

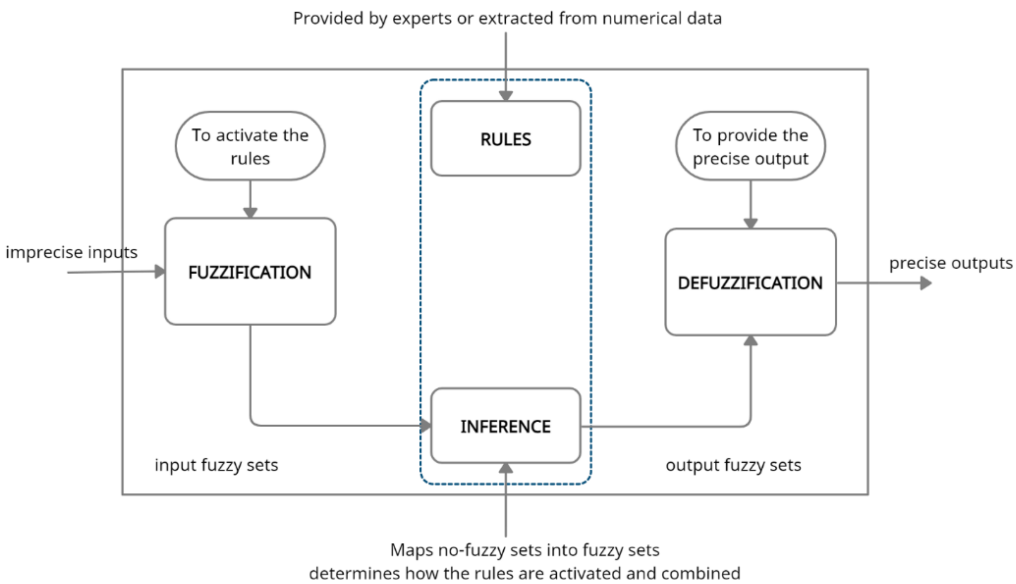
PAC has an expansion project in progress (2019 - 2023) and is subdivided into three subprojects: 1- Pier; 2- Capacity in the berths of container ships, 3- Extension of the hydrocarbon (fuel) zone and port access. After the works, the new PAC will have as main characteristics: (1) Old infrastructure replaced, access of ships adapted to market demands, depth of 15m and length per berth of 340m; (2) Container cargo, 340m vessels and 14m draft, 2 equivalent operators / competition, annual handling capacity of 1.8 to 2.0 million TEUs; (3) General cargo: modern terminals adapted to demand / dedicated and an increase in capacity; (4) Hydrocarbons: Increase in vessel capacity and storage capacity; (5) The dedicated Ro-Ro berth.

Materials and Methods

Fuzzy system

A system-based on fuzzy rules is a system that uses fuzzy logic to make decisions, generating one output for each system input. An System Based on Fuzzy Rules (SBRF) has four components or fuzzy controllers: an input processor (fuzzification), a collection of language rules, called a rule base, a fuzzy inference method and in the last phase of the process, an output processor (defuzzification), the defuzzifier converts the fuzzy output value to a value clear (fig 4) (Freitas, Peixoto and Vieira, 2013; Cabezaliand Santos, 2020).

Figure 5 *Fuzzy* system.



Source: Dos Santos (2011).

The input to the system can be an accurate value (when derived from a measurement process) or a fuzzy set (when it comes from a human observer or in the form of a database, such as the questionnaires, Maria and Gleicy, 2007). To adapt the input to the fuzzy system, the fuzzification component, which is the process of transforming the input variables into degrees of relevance or certainty, performs an interpretation or qualification of the same variables (fig 5). This fuzzification process allows associating a linguistic vector to the possible values of the input parameters to assemble a fuzzy set that portrays the imprecision of the problem under analysis, that is, to perform a mapping of the input data. In the fuzzification stage there is also the activation (or combination) of the inference rules.

The fuzzy inference process consists of the integration of parameters by means of **If-Then** rules, defined according to the parameters to be used. In this module each fuzzy proposition is mathematically transformed through the techniques of fuzzy logic. Thus, the success of the fuzzy controller depends on the inference method, because the method will provide the output to be adopted by the controller from the input. The linguistic interpretation of the result is sufficient in some applications, but in others, the numerical value as an output variable is requested. In cases where numerical results are necessary, the defuzzification process must occur after the fuzzy inference. Output variables are generated inference blocks in the form of linguistic variables (fig 5).

Rules Base

The rules are defined according to the parameters of ports characteristiques, and what normally matches the current realities.

- **Rule 1**: IF the quality of the infrastructures is Good AND the productivity of the equipment is High AND the quality of the services is Excellent THEN the logistic viability will be for Long Term;
- **Rule 2**: IF the quality of the infrastructures is good AND the productivity of the equipment is Medium AND the quality of the services is Acceptable THEN the logistic viability will be for Medium Term;
- **Rule 3**: IF the quality of the infrastructures is Practicable And the productivity of the equipment is Medium AND the quality of the services is Acceptable THEN the logistic viability will be for Medium Term;
- **Rule 4**: IF the quality of the infrastructures is Practicable AND the productivity of the equipment is Low AND the quality of the services is Acceptable THEN the logistic viability will be for Short Term.

Fuzzy membership functions

The first step in developing the logistic viability assessment system is the selection of the fuzzy inference system. Matlab Toolbox offers two types of inference systems: Mamdani and Sugeno. For a good consequence of the analysis rules, the first was chosen. Mamdani is used more often, mainly because it provides reasonable results with a relatively simple structure, and because of the intuitive and interpretable nature of the rule base (Jassbi et al., 2006).

The basic differences between Sugeno's inference method, called TSK and Mamdani's, are in the way of writing the consequent of each rule and in the defuzzification procedure to obtain the general output of the system (Barros and Bassanezi, 2010).
Matlab Toolbox offers different types of association functions that can be used in logic-based models such as triangular, trapezoidal and Gaussian etc. For this analysis, the three functions (triangular, trapezoidal and Gaussian) were chosen to facilitate decision making of port logistics viability.

Application

Fuzzification

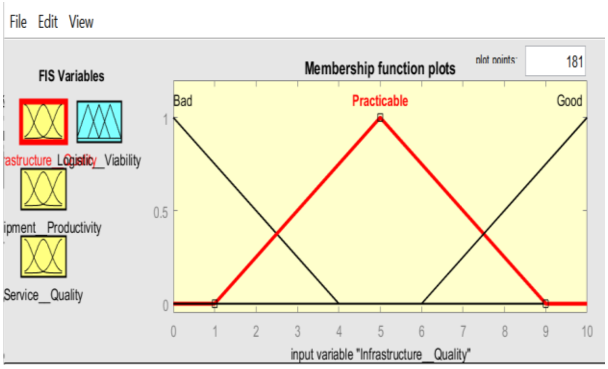
The fuzzy rule, SBRF was used to analyze the PAC's logistic viability, applying the Mamdani characteristic to model the quality of infrastructures and services, equipment productivity.
Oliveira Junior et al. (2007) present an interesting way of representing controllers based on fuzzy logic by means of Matlab, a very suitable tool for the construction of mathematical systems and simulations of computational concepts. The development of a system based on fuzzy logic enters with three variables and left with one variable, started in the fuzzy environment in the Matlab tool (through the fuzzy logic in the command window).

Table 2 Linguistic variables, Evaluation universe, fuzzy sets

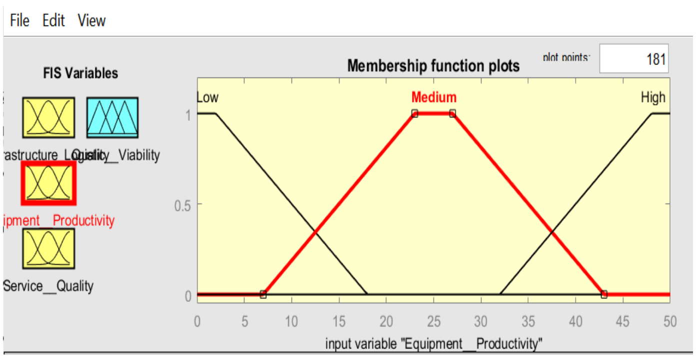
Situation	Linguistic variables	Evaluation universe	Fuzzy sets
Inputs (background)	Infrastructure Quality (IQ)	[0; 10]	[Good, Practicable, Bad]
	Productivity Equipment per hour (MPH)	[0; 50]	[High, Medium, Low]
	Quality of services (QS)	[0; 10]	[Excellent, Acceptable, Bad]
Output (consequent)	Logistic Viability (VL)	[1, 25]	[Long Term, Medium Term, Short Term]

The universe of evaluation of the variable IQ [0 to 10] is considered as a grade to evaluate the quality of port infrastructure (Table 2). The quality of the infrastructures is considered bad, when the universe of evaluation is between [0, 4], that is, when the value is zero, the degree of relevance is 1 (maximum), 100% bad and when the value increases for 4, the degree of pertinence decreases to 0 (Fig 6a). When the universe of evaluation is at 2.5; it means that the degree of pertinence is at the point of maximum cloudiness between the diffuse sets bad and practicable, just as practicable and good when the universe of evaluation is at 7.5. The infrastructure is considered practicable when the universe of evaluation is between [1, 9], its maximum relevance is 5 and the good qualification starts at 6 and ends at 10 (Fig 6a).

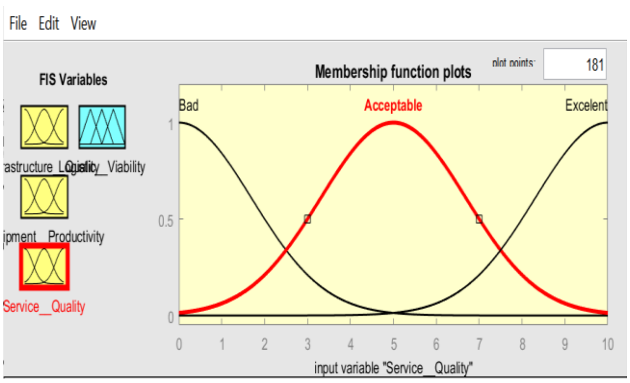
(a) Infrastructure Quality



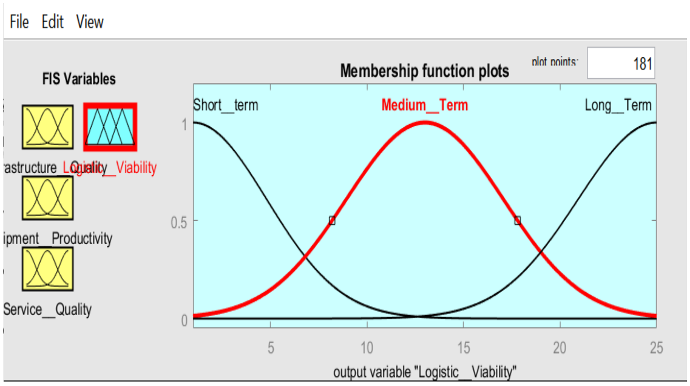
(b) Equipment Productivity



(c) Quality of Services,



(d) Logistic Viability



(e) set mapping variables fuzzy

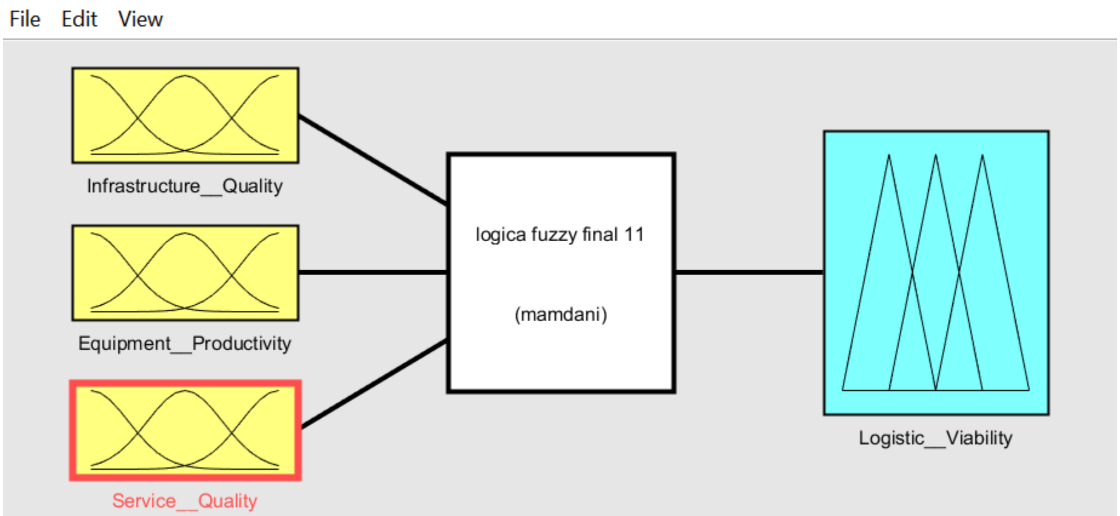


Figure 6 (a) Infrastructure Quality (b) Equipment Productivity (c) Quality of Services, (d) Logistic Viability (e) Input (yellow), output (blue) and set mapping variables fuzzy (white), (elaborated in matlab)

The universe of EP evaluation was defined according to the movement per hour MPH of port maintenance equipment of container ships in Africa, where it is difficult to reach the target of 50 MPH of equipment (crane or portaîner) (table 2). According Lourdes, María and Juan (2013), the number of container movements per hour in Africa is between 10 and 20, compared with 25 to 30 in the main world ports or even worse when they use ship equipment with only 7 and 10 movements per hour. The EP variable is considered low, when the universe of evaluation is between [2.5 12.5], medium when it is between [12.5

37.5] and from 38 it can be considered high (fig 6b). Between 23 and 27; the degree of relevance of the medium set is maximum, that is, between a maximum MPH of 50, if a device reaches an MPH of 23; 24; 25; 26; or 27; the degree of membership is 100% medium. 37.5 MPH is the point at which the maximum cloudiness between medium and high occurs, starting at 38 MPH, the degree of high relevance is higher than medium and can be qualified from there.

A universe of evaluation of the variable SQ [0, 10] was defined to evaluate port services (table 2). Like the IQ and EP, the SQ has 3 diffuse sets (Bad, Acceptable and Excellent). It's considered bad when the universe of evaluation is between 0 and 2.5; acceptable from 2.6 to 7.5 in which it changes to excellent (fig 6c).

The universe of evaluation of the output variable LV was defined in relation to the amortization time of the infrastructures and equipment. According to the "Metropole" Council of March 4, 2016, port infrastructure has an amortization period of 30 years. Therefore, equipment amortization is less than 30 years, with an interval of 1 to 25 years (table 2). The LV is considered short term when the universe of evaluation belongs to the interval from 1 to 7 years and between 7.1 to 19 years, the universe of evaluation changes to medium term and long term after 19 years (fig 6d).

Defuzzification

The fuzzy rules in the model based on fuzzy logic are translated after modeling in real numbers. When the inputs were real, you expect to have real output as well. The quality of the infrastructures is 05/10, equipment productivity 25/50, quality of services is 05/10 and the output of the variable logistic viability is 13/25 (fig 7a).

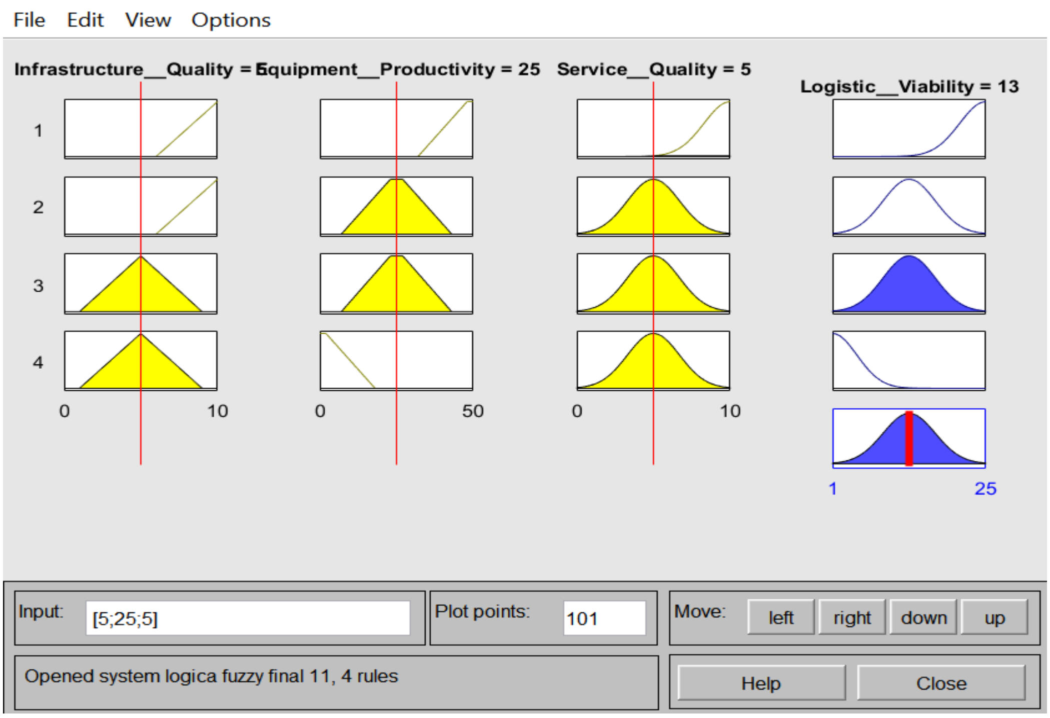


Figure 7a The Rules base and fuzzification of variables IQ, EP and SQ (yellow) and defuzzification of variable LV (Blue). Fuzzy result for IQ = 05; EP = 25; SQ = 05, (elaborated in matlab)

The first line corresponds to the first rule, the second line also corresponds to the second rule, and so on. Columns 1, 2, 3 and 4 are respectively for infrastructure quality, equipment productivity, service quality and logistic viability. The red bars show the numerical results after modeling (fig 7a). The red bar in the fifth row of the fourth column shows the result of the level of logistic viability in relation to the practicable infrastructure quality, medium equipment productivity and acceptable service quality in the Port of Cotonou. This red bar of the membership function of the output variable shows that the corresponding diffuse set is medium term with a maximum degree of membership (fig 7a).

Figure 8b Rules base and fuzzification of variables IQ, EP and SQ (yellow) and defuzzification of variable LV (Blue) b: Fuzzy result for IQ = 06; EP = 33; SQ = 07, (elaborated in matlab)

The infrastructure quality column increased from 5 to 6, meaning the presence of an expansion project. In other words, after carrying out the "future PAC" project, the quality of the infrastructure will increase (fig 7b). In the same way with the equipment productivity column, which changed from 25 to 33 and the quality of services went from 5 to 7. The only similarity is observed in the intersection of the fifth row and the fourth column. The result of the variable logistic viability is 13, it means an advance in the input variables of the system, it is not recognized as a major work carried out in the PAC since the south quay of the port is 15m deep, the project foresees 15m dredging for the north quay and an extension west of the port. Currently, only container vessels with a draft greater than 11m and less than 15m can dock and only at the berth (south quay), designed for the Bolloré Group. The perceived difference was with the degree of pertinence, which was totally medium term (fig 7a) decreased (fig 7b), the blue graphic level.

The implementation of the project will allow ships with up to 15m of draft and longer to enter the PAC. With port equipment, no project is prepared and published on the websites of logistics companies, but it is possible after carrying out this project, that handling operators will increase the efficiency of their equipment to face the competition since the PAC, it once reached MPH 33 / portainer in 2018.

The capacity of the vessels increases annually (such as the Suezmax of 17m draft, Panamax of 12.04m, Post-Panamax of 26m, Capesize with 18.91m, Chinamax 24m, Malaccamax 20m containers) and the equipment becomes more modern with the development of maritime trade. The new project should announce a dredging to 17m or 22m in depth to receive larger ships. In some ports in West Africa, there are 17m deep ports, such as the port of Lomé (Togo), Tema (Ghana) and Lagos (Nigeria). However, shipowners are looking to reduce their stopping time at ports. This reduces the vessel's operating costs and improves the profitability of its port call. The optimization of call times could in future encourage shipowners in prioritize PAC services in the rotation of larger ships that serve several ports in the region.

Specifically, if a port has the necessary extra capacity (such as good infrastructure quality, more modern and sufficient quantity handling equipment and service quality) to attract more cargo flows, as well as economies of scale as a result, this will have a price advantage over competitors and in turn attract even more cargo (Haralambides, 2002), this would converge to Long-term logistic viability (fig 8).

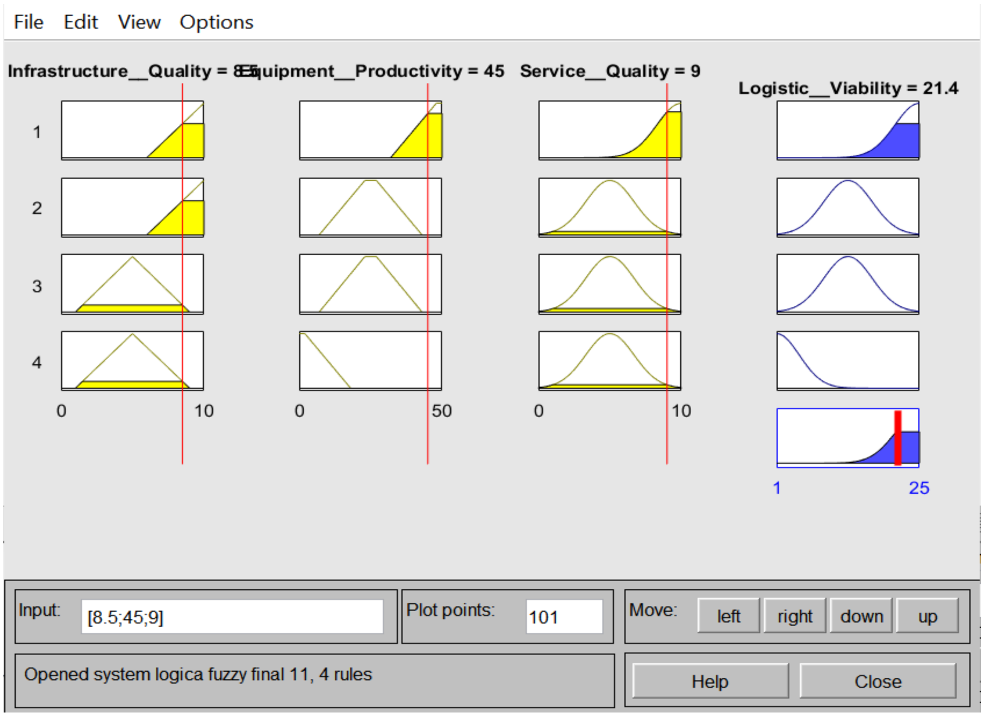


Figure 8 Fuzzy result for the evaluation universe, IQ = 08.5; EP = 45; SQ = 09,(elaborated in matlab)

The input variables are more advanced, equivalent to the numerical results of each column, 8.5 or Good for infrastructure quality, 45 or Hiht for equipment productivity, 9 or excelent for service quality and 21.4 years for exit logistic viability, represented by a red bar at the intersection of the fifth row and fourth column (fig 8). With a 17m or 22m depth dredging, good infrastructure quality and the acquisition of the most modern port equipment, the level of the variable logistic viability is expected to increase in the long term.

Discussion

Port logistics is one of the main relevant activities in the port position that indicates the position and efficiency of a port and makes it an indispensable link in the port activities chain, that is, an ideal layout of space and the coordinated development of the port. The fuzzy methodology is a good tool for analyzing and handling inaccurate decisions. Rahmawati and Sarno (2018); Wanke and Falcão (2017); Akyuz, et al. (2020); Allahviranloo and Afandizadeh (2008); Loh et al. (2017); Onut et al. (2011), among others, obtained results satisfied with the fuzzy application. The analysis of logistic viability at the port of Cotonou using fuzzy logic based on fuzzy rules and modeled on the Matlab Toolbox gave a medium term, equivalent to 13/20. This result shows that the logistic viability is linked with port IQ, SQ and EP variables.

Regarding the quality of port infrastructures, PAC is making an improvement in its infrastructures, however, the result of PAC remains the same as it is today (fig 7b). This shows that there are no major improvements in the PAC's infrastructure and logistics investment project suggestions. Obsolete port equipment and the services offered have caused a decrease in the flow of ships in the port.

The access channel of the project is the same, 15m, the same number of berths (11) and port efficiency, considering that there will be no acquisition of new port equipment, and the services will be the same. If the current movement of containers at the port is 333,000 TEUs, after the project is carried out, an increase between 10% and 20% more are expected. At the same time, neighboring ports, such as Lomé (Togo) handles 1193800 TEUs (fig 9).

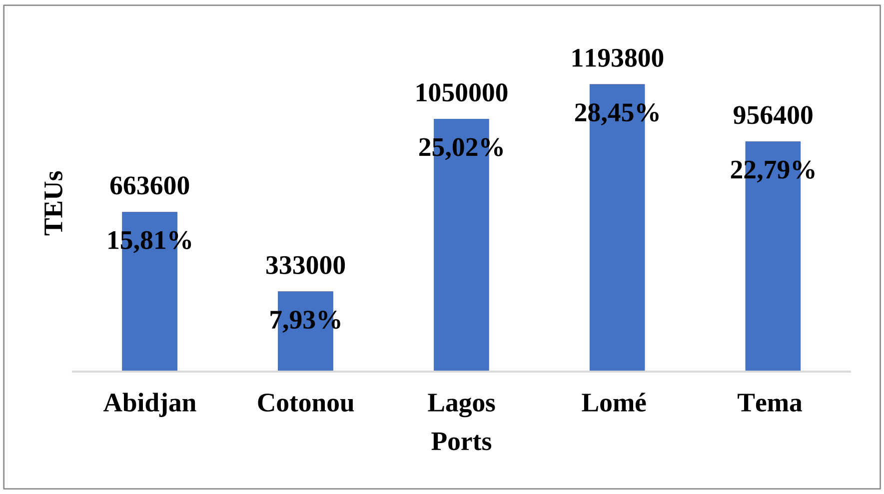


Figure 9 Container movements at TEU 2017 between neighboring ports, (Ports of Cotonou, Abidjan, Lagos, Lomé and Tema)

The Port of Lomé is the hub with 1,193,800 TEUs and Cotonou is the last with 333,000 TEUs in 2017, while the maritime trade favors the unification of cargo, for more security and ease in cargo handling (Fig 9). Among the 5 ports that serve the hinterland, PAC handles less containers, which is safer and more used by ships.

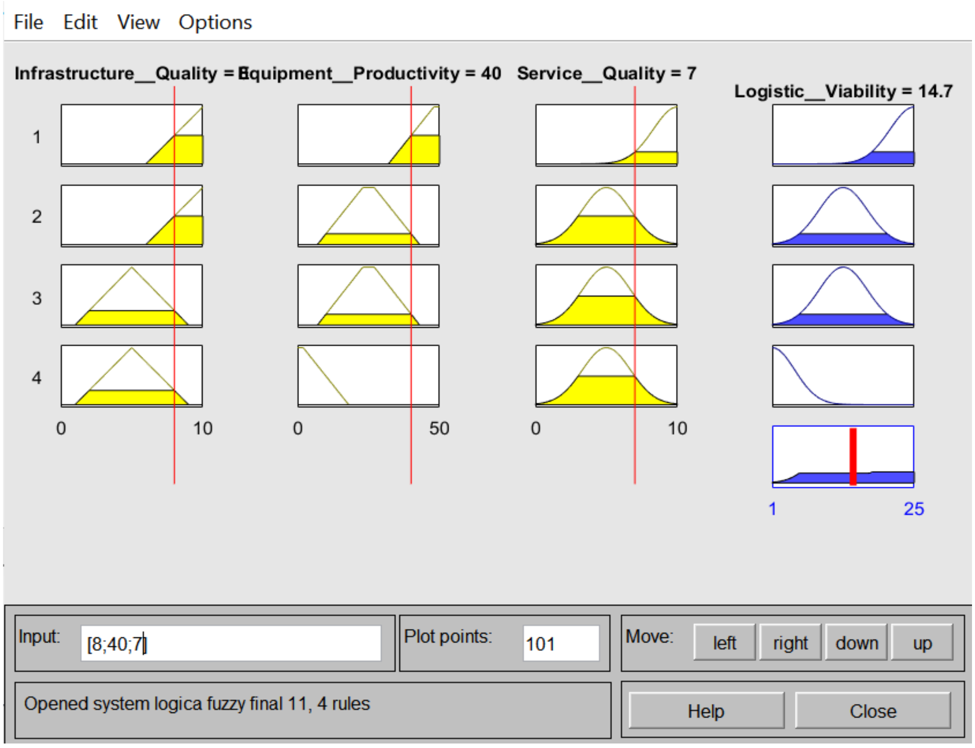


Figure 10 Result fuzzy of the current state of the port of Lomé (elaborated in matlab)

After modeling in Matlab with the current characteristics of the port of Lomé, considering the same universe of evaluation previously used with the PAC, with a quality of infrastructure 8, the productivity of equipment 40 and the quality of services 7, the result shows a viability logistics of 14.7 years close to 15 years (fig 10). This result confirms the dependence of IQ, EP and SQ on port viability. Comparing the PAC and the port of Lomé, the latter is the best in terms of characteristics.

There is innovation, adequate infrastructure of good quality, port equipment of the latest generations and excellent service in the result (fig 9). The application of the result presents a good perspective and performance in the long term of 21.4 years for logistic viability.

Needs

The PAC must invest in port infrastructure, logistics, equipment and also in advanced technologies. The access channel must be dredged to 22m, the depth of the port also to 20m or 22m, and thus, allowing access to vessels with large size and greater draft up to 22m. On the other hand, the most modern port equipment is very useful for the efficiency of the port, that is, to provide for the acquisition of the equipment, to reduce the time of stopping at the port and attracting many ships. According to Hsu, Lian and Huang (2020), in addition to distance, containing both ocean and land, the important attributes that sea carriers consider in deciding which port calls are general infrastructure, port tariffs, port efficiency, availability and berth size. The PAC must computerize its administrative procedures for customers, improve the quality of services and establish new rates to be more competitive.

When the realization of the data find difficulties because of the current infrastructure, it would be better to propose a new project for a second port, specialized for container ships (more advisable), with installation of most modern equipment. As a consequence, there is an increase in the PAC's chance to have a greater participation in the Beninese economy and in the port to establish long-term logistic viability.

Conclusion

The best ports in the world have quality port infrastructures and modern, computerized, fast, efficient and effective port equipment for all port operations, such as unloading or loading, handling and storage of products (Unctad 2018).

It was possible to perform this analysis, using the proposed methodology. The relevance of each of the variables analyzed was modeled using the fuzzy logic, in the Matlab fuzzy Toolbox. The analysis of PAC's logistic viability using the fuzzy logic method shows three possibilities of a diffuse set for the port, short, medium and long term. PAC's logistic viability is linked to institutional reforms, directly related to port services. In figures 7 and 8 after modeling, port services vary from 5 to 7 and then 9 when logistic viability is long term, that is, a relevance of one of the aspects that hinders efficiency and weakens logistic viability. Certainly, a good quality port service reduces increased service costs and down time at the port. In practice, these results prove the dependence on the variable quality of port services, infrastructure and equipment productivity.

The results show that the quality of the infrastructures is 05, the productivity of equipment in motion per hour for MPH equipment is 25 and short term logistic viability, 13 years. These results come in fact that most of the equipment and most of the infrastructure does not correspond with the current reality, this summarizes the factors that are hindering the development of the PAC (fig 7a).

With the project planned for the future PAC, there is no big difference between the current state of the PAC and 3 years from now, hence the same numerical output 13 of the variable logistic viability (fig 7b). The difference arose at the north quay where, after the project was completed, the other types of ships (general cargo, oil tankers, RO-RO) with a draft of up to 15m will enter. It would no longer be just the southern quay that container ships with a maximum draft of 15m will receive. With this level, suppose that the logistics companies grow with the evolution and acquire or improve the productivity of their equipment.

The results highlight a good performance of the PAC with a good quality of the infrastructure 8.5 / 10, a good productivity of the equipment, 45 MPH and an excellent quality of service 9/10, consequence, long term logistic viability, 21.4 years (fig 8).

The fuzzy logic as a method shows the changes and realization that the PAC needs to be efficient. In addition, fuzzy logic shows good performance and can help the PAC to achieve its goals and be the hub of the region. For it to be long term, it would be better to increase the measures and characteristics of the project in order to expect a good result from the analysis (fig 8). Other possible options for the PAC to achieve long-term logistic viability is to launch the realization of a new container terminal or a new port project.

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