THE IMPACT OF LOGISTICS PERFORMANCE INDEX ON PORT INFRASTRUCTURE QUALITY: COMPARATIVE STUDY TUNISIA MOROCCO

Rihab BEN HAJ AHMED[1], Aida BOUZIR[2], Mohamed Hédi BENHADJ MBAREK[3], Saloua BENAMMOU[4]

[1, 4] *Faculty of Economics and Management of Sousse, Sousse, Tunisia*

[2, 3] *Higher Institute of Transport and Logistics, Sousse, Tunisia*

Abstract:

This scientific article examines the relationship between logistics performance indices and port infrastructure quality in Tunisia and Morocco. The quality of port infrastructure (QPI) is an important component of the competitiveness port. It represents a driving force for the economic dynamics. This quality of port infrastructure is a complex subject on which a great deal of research has emerged in the last decade. The logistics performance index (LPI) serves as a crucial indicator to assess the efficiency and effectiveness of a country's logistics system. Accordingly, this paper aims to develop a model for assessing the quality of port infrastructure. The objective is to evaluate the development of port infrastructure to improve the competitiveness of port systems in two North African countries according to nine competitiveness criteria. The analysis involves statistical techniques such as regression modeling to establish relationships. The partial least squares (PLS) regression method is adopted to obtain a reliable estimate, using nine explanatory variables :(performance indicators) (overall, the frequency with which shipments reach their recipient within the set deadlines, The efficiency of customs clearance process, ease of arranging competitively priced shipments, Lead time to import, Lead time to export, competence and quality of logistics services, Liner Shipping Connectivity Index, Container port traffic) and quality of the port infrastructure (QPI) as dependent variable. The results of the analysis highlight the influence of logistics performance indices on port infrastructure quality in Tunisia and Morocco. The results of the test the model using the partial least squares, confirm a significant influence of the identified factors on the quality of port infrastructure. It found show that it is vital to improve logistics performance, which contributes to improving the quality of port infrastructure and increasing maritime trade; which promotes economic growth. Based on the results concerning the importance of port infrastructures, the quality of the latter is empirically examined. Our results show that Morocco tends to improve the quality of its infrastructure in order to improve its competitiveness. The originality of this research work consists in using the PLS (the partial least squares) regression method, which is contrary to previous studies, which have used other econometric methods in the same study field.

Keywords: port infrastructure, logistics performance, economic growth, PLS regression

Contact:
1) belhajahmed.rihab11@yahoo.com [https://orcid.org/0000-0001-9776-6990] – corresponding author; 2) aidabouzir2020@gmail.com [https://orcid.org/0000-0002-6839-1250]; 3) benmbarekmhedi@yahoo.fr [https://orcid.org/0000-0002-9406-6355]; 4) saloua.benammou@yahoo.fr [https://orcid.org/0000-0001-5914-2722]

1. Introduction

The development of efficient port infrastructure is crucial for economic growth and international trade. The improvement of the port infrastructure is essential for an open and integrated competitiveness, since it intervenes in various fields such as economic, social or political.

This study focuses on the specific relationship between logistics performance and port infrastructure quality in Tunisia and Morocco, providing valuable insights for policymakers, port authorities, and relevant stakeholders.

The quality of Tunisian port infrastructures is compared here with that of Morocco according to nine variables, which are: the index of connectivity, competence and quality, delays before export, delays before import, efficiency, frequency, comfort, overall performance and traffic per container.

The (PLS) method is proposed as it seems to be the most efficient method adapted to the case of time series (Preda and Saporta, 2002). PLS approach can be applied even with a limited sample size (under certain conditions) and a structural model (Peng and Lai, 2012). Moreover, a considerable flexibility in assessing models with formative and reflective latent variables is offered.

PLS regression has the advantage of remedying the problems of heterogeneity of the sample of the countries in question, the problem of multi-collinearity between variables within the same country as well as the problem of missing data.

First, a brief overview of the port infrastructure literature will be given. Thereafter, the places of the study (Tunisia and Morocco) will be described. The choice of variables and the PLS method will also be justified. Finally, the main results of the study will be given and we will conclude.

2. Literature overview on port infrastructure

A brief literature review related to port infrastructure such as port infrastructure quality, logistics performance indices, efficiency, frequency, connectivity index, deadline for export and deadline for import is presented below.

2.1. The quality of port infrastructure

According to Toy et al. (2000) an approach was described to assess the impact of these developments on the choice of shippers and the impact on the choice of routes and modes of investment in the links between ports and road infrastructure. The focus is on a stated preference approach to assessing sender choice and present a detailed examination of the advantages, disadvantages and characteristics of the technique in the context of the transition economies of Poland, Lithuania, Latvia and Estonia. According to Memedovic et al. (2008) innovations in containerization and intermodal transport have contributed to major changes in global logistics. The link between the quality of port infrastructure, logistics indicators and their impact on the national economy has been studied by Komoračec (2016). It can therefore be seen that improving the quality of port infrastructure and logistical efficiency could bring great benefit to the country's economy.

It has been shown that the quality of port infrastructure has a positive and significant effect on the national economy (see for example: Ferrari et al; 2010; Bottasso et al., 2014; Park and Seo, 2016). Similarly, the positive impact of seaports on the economy has been observed. According to Hausman et al. (2013), the quality of port infrastructure significantly affects the logistics of the country. It is argued that ports, which retain the direct jobs associated with them, lose their ability to compete for freight; Helling and Poister (2000). This, in the long-term, leads to a reduction in the number of jobs. In many cases, economic development is linked to the port's long-term ability to attract more customers, while creating and maintaining jobs and income. Therefore, if the quality of the port infrastructure does not continuously improve, its negative impact on the economy of the country can be significant. 91 countries have been empically studied with seaports, using a survey of the economic contribution of maritime trade, from the point of view of port infrastructure's quality and logistics performance; Munim and Schlamm (2018). It was found that the investment in improving the quality of port infrastructure and its contribution to the economy is often questioned by politicians, investors and the general public. A structural equation model (SEM) is used to empirically show the importance of the economic impacts of port infrastructure's quality and logistics performance. An analysis of a multi-group MES is carried out by separating the developed countries from the developing countries.

The results reveal that it is vital for developing countries to continuously improve the quality of port infrastructure as it contributes to improve logistics

performance. This leads to increased maritime trade and stronger economic growth. This association becomes weak as developing countries become richer. Port infrastructure development and service quality in Nigerian ports were examined from 2000 to 2001;Olufemi et al (2021). The objective of their study is to examine the relationship between the index of the quality of port infrastructure and the quality of service vis-à-vis the turnaround time of ships and the average time spent at quay. The Ordinary Least Square (OLS) regression analysis method was used based on secondary data on port infrastructure index quality, ship turnaround time, and average time spent at berth, obtained from the Nigerian Ports Authority Abstract Statistic and the World Economic Forum. Prior to Ordinary Least Square (OLS) regression estimation, variables were subjected to the Augmented Dickey Fuller (ADF) unit root test to stabilize the data; and the result showed that all variables were stationary to avoid a false regression result. The estimated results of the OLS showed that the quality of port infrastructure has a negative and significant relationship with ship turnaround time and average time spent at berth (quality of service in Nigerian ports). Based on the findings, they recommended, among other things, that Nigerian ports increase their investments in port infrastructure development to provide quality and efficient service to port users.

According to Sénquiz-Díaz (2021), the quality of transport infrastructure and the efficiency of logistics services promote economic development. furthermore, this study measures the effects of common transport and freight modes and logistics performance on exports of goods in 29 developing economies based on fixed-effect panel microdata for the period 2012-2018.

The endogenous model proved a positive relationship with the outward orientation of countries, highlighting the importance of transport infrastructure and logistical resources. The results revealed that the quality of roads and ports contributes significantly to increased exports in developing economies. However, the quality of airport infrastructure and logistics shows a detrimental effect. In particular, the level of logistics services is a detrimental factor in the export of goods in developing economies. These findings may negatively impact the potential contributions of other transport assets based on intermodal

transport functionality and global market participation. Therefore, governments should prioritize the formulation of innovative policies and integration strategies with the private sector to improve the performance of logistics providers and make full use of current transport assets, especially airports. These plans will facilitate increased exports, foster better development and improve economic competitiveness while expanding opportunities for export product diversification.

An empirical study covering 37 landlocked countries was carried out by Duzbaievna Sharapiyeva et al (2019). This study has a wider economic impact on the national economy, on the quality of port infrastructure and logistics efficiency has been considered as well as investments in the creation of high quality port infrastructure and its contribution to the economy, often questioned by politicians, investors and the general public. The Structural Equation Model (SEM) was used to provide empirical evidence of significant economic impact on port infrastructure quality and logistics efficiency. However, some landlocked countries are not, according to international agreements, inferior to other countries in terms of economic growth.

The impact of quality infrastructure, development and corruption on natural disaster damage using panel data from 14 countries in Asia and the Pacific for 2007-2017 was assessed; Taghizadeh-Hesary et al (2021). Using the generalized method of moments and the vector error correction model, the main contribution of this study to the literature lies in quantifying the role of quality infrastructure in mitigating the impact of disasters. The empirical results prove that even if the intensity of the catastrophes remains the most important factor to explain the damages, this effect is of short duration. In the same context, quality infrastructure significantly reduces long-term damage and is the most important variable. A higher level of development indicators, measured by the gross domestic product per capita, and the control of corruption, also make it possible to reduce the damage linked to natural disasters. It was suggested that improving the quality of infrastructure can be effective in mitigating the impact of disasters. Financial mechanisms such as public-private cooperation and innovative mechanisms to promote the construction of quality infrastructure were proposed.

2.2. Logistics performance indices

 A quantitative approach is adopted in the research, utilizing data from various sources, including the World Bank's LPI database and other relevant statistical resources. From 2007, the World Bank publishes a report in English every two years entitled "Connecting to Compete: Trade Logistics in the Global Economy". This report determines the logistics performance index of each country and its ranking to assess the logistics performance of 160 countries worldwide in their trade with the rest of the world, using several performance indicators. Similarly, it defines the overall Logistics Performance Index (LPI) which ranges from 1 to 5 (from lowest to highest performance).

2.2.1. The efficiency of customs procedures and security measures

Customs clearance procedures form the backbone of international trade and the supply chain. But, if the process is not well- administered, these procedures are a bottleneck for import and export businesses.

According Tongzon (2009), port efficiency is characterized by the speed and reliability of port services.

Ugboma et al. (2006) used the "analytic hierarchy process" (AHP) method based on seven selection criteria which are: port efficiency, infrastructure adequacy, frequency of vessel visits, rapid response to port user needs, location, port charges and port reputation for cargo security. In West Africa, they considered as alternatives of decisions the four Nigerian ports which are: the port complexes of Lagos (LPC), Tincan Island (TCIPC), RO-RO port (RRP) and Port Harcourt (PHPC). They show that efficiency comes first, second frequency of vessel visits and third adequate infrastructure.

According to Onut et al. (2011), port efficiency corresponds to container handling efficiency, port berthing time, customs clearance efficiency and container terminal efficiency.

Al-Haddad et al (2021) determined the factors affecting the performance of the supply chain of importing or exporting companies through the port of Jeddah. This process may change over time in order to follow changes in the global economy.

They found that failure to clear goods over a period of time affects directly the business with longer delivery times and product availability. Consequently,

the service quality level provided to customers is degraded. Traders and government clearance officials have also contributed to longer clearance times.

2.2.2. Frequency

In the articles, various researchers are interested in the frequency indicator such as (Sanchez et al, 2003; De Langen, 2007).

According to Tongzon (2009), freight forwarders choose ports that have the highest frequency of ship calls; and that an attractive port must have greater flexibility and transit time and costs.

These advantages occur following a high frequency, the relevant indicator of port performance is then being the number of ship calls.

2.2.3. Maritime Connectivity Index

Beatriz et al (2022) examined the empirical relationship between maritime connectivity and port efficiency. They used a stochastic exit distance function for a sample of 16 Spanish ports during the period 2006-2016. They found a positive relationship between connectivity and port efficiency.

The determinants of liner shipping connectivity for a sample of 100 maritime countries from 2007 to 2014 were analysed ; Jouili (2019). Two types of estimators were used to detect the determinants of liner shipping connectivity. First, a global analysis was conducted, Then, an analysis based on a geographical breakdown. It was concluded that all explanatory variables have a positive effect on liner shipping connectivity, but with clear differences in the maritime regions studied around the world.

2.2.4. Lead times before export and lead time before import

The main factors explaining the long dwell times of containers in the port of Douala were examined; Aminatou et al. (2018). The main determinants of long cargo dwell times and the impact of shipment characteristics were determined. External factors, such as the performance of clearing and forwarding agents, shippers and shipping company strategies, also play an important role in determining long dwell times.

The relationship of governance and their action on the port sector involving private companies and public organizations was examined; Claudia et al. (2018). It was concluded that sources of strategic in-

efficiency affect competitiveness. The critical factors which have affected the inefficiencies of the export and import logistics chains are also the inefficiencies related to the waiting time (turnaround time) and the delays caused by the actors of the port activity.

A predictive model was developed by Saraswathi et al. (2020) to estimate import lead-time using machine learning methods for ocean import freight while taking into account the interests of different stakeholders. The proposed model has the significant potential to benefit different parts of the supply chain by providing better visibility and forecasting of shipping times.

3. Study locations

Tunisia and Morocco were chosen to carry out a comparative study.

3.1. Tunisia

Tunisia, with its position at the crossroads of the Mediterranean has been a country with a maritime vocation since antiquity. The maritime transport of goods is a vital sector in Tunisia. It is one of the main factors for the functioning and economic growth of the country. It is therefore necessary to take measures for the development and restoration of the maritime trade fleet and ports. Maritime transport also makes it possible to meet the country's trade development needs. So, it is necessary to follow the dynamics of rapid development of maritime and port infrastructures in the Mediterranean. (figure 1)

3.2. Morocco

Morocco is the crossroads of the main trade routes between the African, European, American and Middle Eastern continents. It has 38 international trade ports including 6 marinas and 19 fishing ports. It occupies an advantageous geostrategic position due to its location on two seaboards, the Atlantic and the Mediterranean.(figure 2)

4. Choice of variables and presentation of the PLS method

In this section, the variables and the PLS method are presented.

4.1. Choice of the variables

Our study deals with observations on the quality of port infrastructure with 9 variables; where the quality of the port infrastructure represents the variable

to be explained and the performance indicators are the explanatory variables. (Table 1).

4.2. PLS regression

We start by presenting the choice of the PLS method.

Fig. 1. Geographical map of Tunisia

Fig. 2. Geographical map of Morocco

4.2.1. Choice of the PLS method

As part of our work, the relationship between the quality of infrastructure and the explanatory variables (Table 1) in the group of countries (Morocco and Tunisia) is studied. Our study is based on the method of partial least squares (PLS).

The PLS outperforms in practical scenarios due to the imperfect and often highly correlated nature of real-world data utilized in modeling (Kaufmann and Gaeckler, 2015). By selecting the most optimal linear combination to predict dependent variables.

We chose the latter because of the existence of a multicollinearity problem (see Table 2 and 3 representing the correlation matrices for Tunisia and Morocco) between the explanatory variables and the presence of missing data in our database.

4.1.1. The NIPALS algorithm in the case of missing data

In case of missing data, the steps of the NIPALS algorithm are as follows:

The first step:

−   Step 0: the starting tables X and Y
−   Step 1: build the two main components u_1 and t_1 While maximizing the covariance between these two components:

$$Cov(u_1, t_1) = cor(u_1, t_1). \sqrt{var(u_1).var(t_1)} \quad (1)$$

Construct the two regressions X and Y of which X_1 and Y_1 are the residuals:

$$X = t_1 p_1' + X_1 \quad (2)$$

$$Y = t_1 r_1' + Y_1 \quad (3)$$

The second step:

−   Replace the starting tables X and Y by the residues X_1 and Y_1.
−   Obtain two new components u_2 and t_2
−   Obtain the regressions Y and X on the first two PLS components t_1 and t_2:

$$X = t_1 p_1' + t_2 p_2' + X_2 \quad (4)$$

$$Y = t_1 r_1' + t_2 r_2' + Y_2 \quad (5)$$

Y is satisfactory, so the algorithm stops. In this case;

$$X = t_1 p_1' + t_2 p_2' + \ldots + t_A p_A' + X_A \quad (6)$$

$$Y = t_1 r_1' + t_2 r_2' + \ldots + t_A r_A' + Y_A \quad (7)$$

5. Interpreting PLS model results

Recall that our objective is to study the relationship between certain indicators relating to the quality of port infrastructure, for neighboring Mediterranean countries (Tunisia, Morocco) during the period (2007-2021).

5.1. 1st case: comparison of the quality of port infrastructure between Tunisia and Morocco

5.1.1. Number of components

For Tunisia, the coefficient of determination ($R^2Y=0.88$) is greater than 50%. Therefore, the model is globally significant. Moreover, the results provided by the SIMCA-P software show that only the first two components are significant.

$$\begin{aligned} QPI = 6{,}374 &+ 0{,}404 EACPS + \\ &0{,}173 overall + 0{,}185 EFFI - \\ &0{,}164 CQ - 0{,}018 FREQ + \\ &0{,}107 LSCI + 0{,}138 LTE + 0{,}383 LTI \end{aligned} \quad (8)$$

Equation (8) gives the regression coefficients which measure the contribution of each variable to the construction of the QPI variable. We deduce from this equation that the majority of the variables have a good contribution for the improvement of the quality of the port infrastructure.

The coefficients for two variables is found in the logistics performance category (ease « EACPS », overall performance « overall », efficiency of the customs clearance process and the competence « EFFI » and quality of logistics services « CQ ») as well as the delays (times before export and times before import) are quite high and have a good contribution for the improvement of the quality of the infrastructure. On the contrary, the Frequency variable has a very low coefficient (0.018).

For Morocco, we see from Table 4 that the cross-validation retains the first three (significant) components. Moreover, the R^2Y is equal to 94%. Therefore, the model is globally significant.

$$\begin{aligned} QPI = 13{,}260 &+ 0{,}493 EACPS + \\ &0{,}063 overall - 0{,}128 EFFI + \\ &0{,}068 CQ + 0{,}157 FREQ + \\ &0{,}273 LSCI + 0{,}083 LTE - 0{,}219 LTI \end{aligned} \quad (9)$$

Equation (9) shows that the variables (EFFI-CIENCY and LTI) have negative effects on the quality of port infrastructure in Morocco. Similarly, the indicator of ease of obtaining competitive prices on shipments (EACPS) positively affects the QPI variable with a rate of 49%.

5.1.2. Importance of variables

In Tunisia, as (figure 3) shows, the first two variables (LTI and Facility « EACPS ») are the most important used to explain the quality of port infrastructure (QPI) since their VIPs are greater than 1. The importance of the other variables are small. Frequency is the least important of all the variables and therefore does not have a great influence on our explanatory variable.

For Morocco, the frequency has great importance with the other three variables: (EACPS, CQ and overall) which are the most important to explain the quality of the port infrastructure (QPI), since their VIPs are greater than 1. Concerning the Ease index (EACPS), the situation varies according to the country. Therefore, it represents an obstacle for the development of business in Africa and it has a negative impact on trade between African countries. (figure 4).

5.1.3. Map observations

Unfortunately, the poor logistics performance of the country, particularly the management of the port of Radés, could weaken these advantages. Like some other countries, Tunisia is in a weak economic situation due to the Covid-19 crisis.

Although the port of Radés carries more than 80% of container traffic and remains the decisive link for the integration of Tunisia into value chains at the regional and global levels. Port performance indicators have been falling for a decade. On average, containers must complete customs operations within seven days, but at the port of Radés these tasks take between 25 and 30 days. This leads to a total of about 1 billion dinars of losses per year. Hummels (2006) showed that reducing export clearance times by one day increases GDP by 1%. The improvement in the operational performance of the port of Radés deteriorated again in 2015.

Table 2. Correlation matrix of Tunisia

	QPI	overall	FREQ	EFFI	FACPS	LTI	LTE	CQ	LSCI	CPT
QPI	1	-	-	-	-	-	-	-	-	-
Overall	0.143	1	-	-	-	-	-	-	-	-
FREQ	-0.124	0.711	1	-	-	-	-	-	-	-
EFFI	0.168	**0.886**	0.399	1	-	-	-	-	-	-
FACPS	**0.742**	0.518	0.476	0.330	1	-	-	-	-	-
LTI	**0.805**	-0.090	-0.473	0.191	0.283	1	-	-	-	-
LTE	0.213	-0.129	**-0.644**	0.308	-0.352	**0.720**	1	-	-	-
CQ	-0.427	**0.738**	0.529	0.577	-0.0471	**-0.582**	-0.248	1	-	-
LSCI	**0.537**	-0.100	-0.059	-0.219	**0.681**	0.147	-0.387	-0.372	1	-
CPT	-0.313	**-0.589**	-0.438	-0.260	**-0.631**	0.233	0.547	**-0.540**	-0.439	1

Table 3. Correlation matrix of Morocco

	QPI	overall	FREQ	EFFI	FACPS	LTI	LTE	CQ	LSCI	CPT
QPI	1	-	-	-	-	-	-	-	-	-
Overall	**0.705**	1	-	-	-	-	-	-	-	-
FREQ	**0.870**	**0.962**	1	-	-	-	-	-	-	-
EFFI	0.265	**0.870**	**0.705**	1	-	-	-	-	-	-
FACPS	**0.989**	**0.594**	**0.789**	0.121	1	-	-	-	-	-
LTI	0.499	-0.261	0.009	**-0.702**	**0.620**	1	-	-	-	-
LTE	**0.866**	0.256	**0.507**	-0.252	**0.929**	**0.866**	1	-	-	-
CQ	**0.693**	**0.999**	**0.958**	**0.878**	**0.580**	-0.277	0.240	1	-	-
LSCI	**-0.672**	**-0.999**	**-0.949**	**-0.891**	**-0.557**	0.304	-0.212	**-0.999**	1	-
CPT	**-0.815**	**-0.985**	**-0.994**	**-0.773**	**-0.722**	0.092	-0.417	**-0.982**	0.976	1

Table 4 . Number of components (1st case)

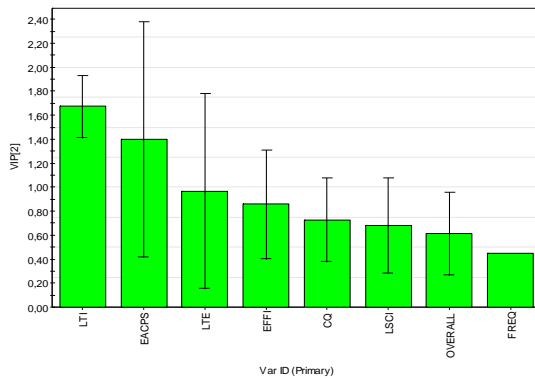| Tunisia			Morocco		
$R^2Y=0.88$			$R^2Y=0.936$		
Number of components	Q_h^2	Limit	Number of components	Q_h^2	Limit
1	0,563	0,05	1	0,75	0,05
2	0,602	0,05	2	0,833	0,05
-	-	-	3	0,869	0,05

Fig. 3. Importance of variables (1st case) : Tunisia
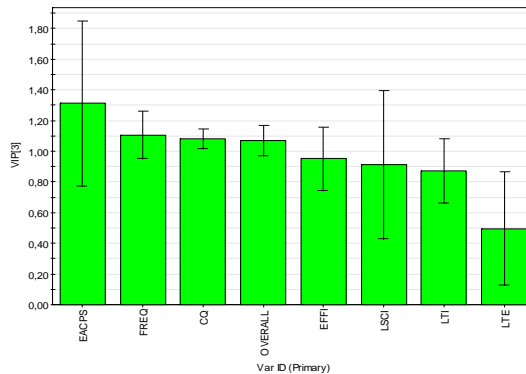
Fig. 4. Importance of variables (1st case) : Morocco

At the beginning of this year, operational performance declined because of the waiting times for ships in the harbor of 3 to 4 days in March 2015 and the duration of operations at the quay which are very high due to low productivity (9 containers per hour and per machine did not reach the target set at 13 containers per hour between 2016 and 2018 in the concession signed between OMMP and STAM). Unlike most container terminals in the world; which operate 24 hours a day, the port of Radés is organized into 3 shifts of 6 hours each; i.e. 18 hours of effective work per day. The container dwell time in the port of Radés is on average of 18 days per year compared to 6 to 8 days in 2010. However, the time in Morocco is between 6 and 7 days. (Figure 5)

Reducing import times by 10 days would be equivalent to a 1.25% drop in GDP, or even more. This would help countries to be more competitive. Improving the efficiency of seaports also reduces export times.

For the connectivity index, Morocco went from the 84th place to the16th place. It increased from 64.28 in 2014 to 68.28 in 2015. However, this index fell to 64.72 in 2016. Overall, according to the ease index, Morocco ranks the 86th in the world in 2017, while it was in the 128th place in 2010. At the African level, from the 12th place in 2010, Morocco rose to the 2nd place in 2017.

Morocco's port performance rose from 3.03 in 2012 to 2.54 in 2018; moving from the 50th to the109th place. This situation is explained by the weakness of customs services and the ability to track and trace shipments. Morocco has many logistics operators that provide poor quality and fragmented services and the number of logistics operators remains low to meet international standards (Chauffour, 2018).

Indeed, Moroccan seaports achieved, in 2019, maritime connectivity score of 58.19. The latter is very high compared to countries with a comparable economy. Likewise, they obtained a score of 5 out of 7 in terms of the quality of port infrastructure. These performances are supported by an important policy aimed at the creation and extension of port infrastructures, and a national strategy for the development of logistics competitiveness (SNDCL) to meet maritime logistics needs and a port strategy to improve this sector. (Figure 6)

Maritime commercial traffic has declined since 2017 and has worsened with the onset of the COVID-19 health crisis. Likewise, they fell by 4.1% in 2020.

According to the monthly plan, the statistics for the first four months of the year 2020 (ANP, 2020) show that the traffic denoted a gradual evolution to reach its maximum in April, and that the year 2020 recorded a sustained increase compared to 2019 for the four months indicated.

The Tanger-Med port is committed to the development and implementation of an action plan aimed at maintaining strategic international and national supply flows. But, it has a lot of requirements for health protection. An information system called PorNet was put into operation, functioning as a one-stop shop integrating the entire port community and all foreign trade operators (El-Mahdad, 2016). The system has been deployed in all national port areas since 2012 and has proven its effectiveness during the Covid-19 pandemic crisis. The latter stipulates physical distancing measures for people and avoids any manipulation of paper documents.

In 2021, the achievements affirmed the position of the "Tangier Med" port complex as an essential strategic hub. Similarly, this "Tangier-Med" logistics platform facilitates national logistics competitiveness.

5.1.4. Map of variables

The "LTI" variable of Tunisia is very close to the dependent variable. Hence, it has an important and significant influence on the quality of the infrastructure. On the other hand, the variables (FREQ and CQ) are far from the variable (QPI). This is confirmed by the PLS regression equation. The latter showed us that these variables have very low coefficients and therefore have a poor contribution to the construction of the variable (QPI). (Figure 7).

For Morocco, the connectivity variable is very close to the dependent variable. Hence, it has an important and significant influence on the quality of the infrastructure. On the other hand, the variable LTI is far from the variable (QPI). This is confirmed by equation (9) which showed us that this variable has a very low coefficient. Therefore, it has a bad contribution for the construction of the variable (QPI). (Figure 8).

5.1.5. Comparison between Y observed and Y predicted

PLS regression provides a very powerful resolution. Indeed, the coefficient of determination R2 is almost 88% with 2 PLS components for Tunisia (figure 9). For Morocco, the R² determination rate is nearly

94% with three PLS components (figure 10). Predicted and observed results may differ. (figure 9 and 10). The European Bank for Reconstruction and Development estimated in its transition report (2017-2018) that Tunisia should devote 23.8% of its GDP to modernizing and developing its infrastructure in 2022.
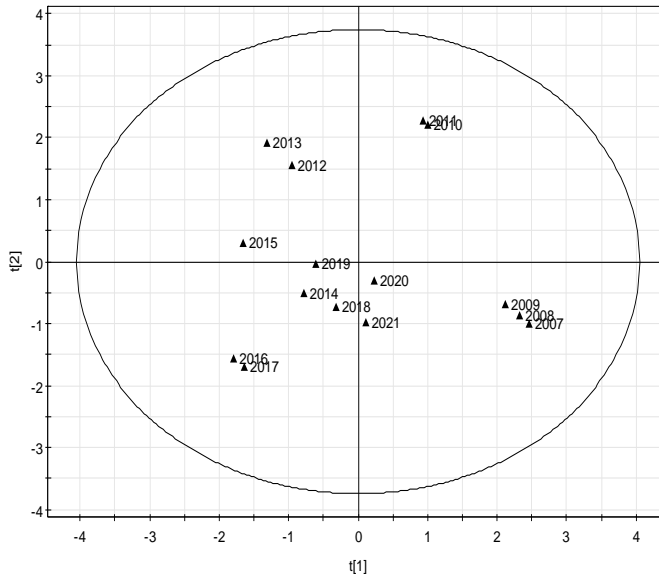

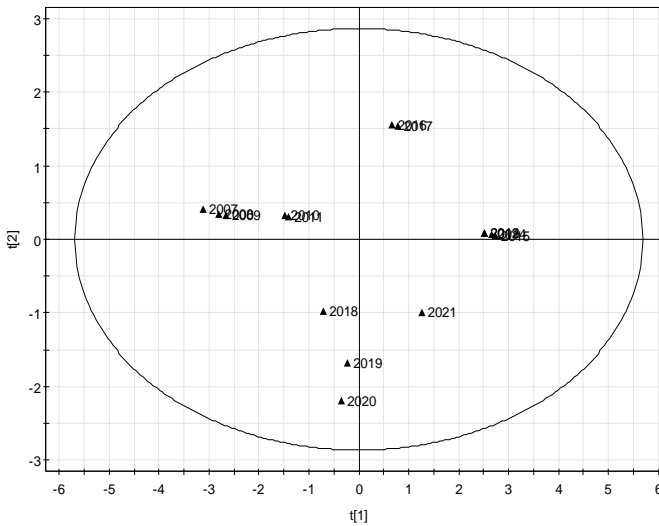Fig. 5. Map of observations (1st case) : Tunisia
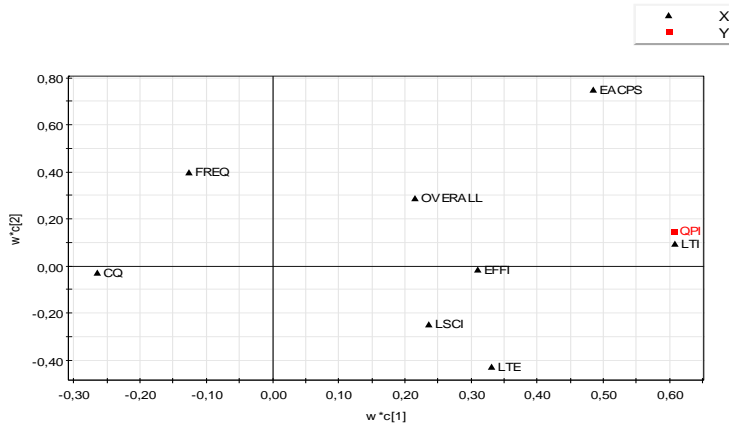

Fig. 6. Map of observations (1st case) : Morocco
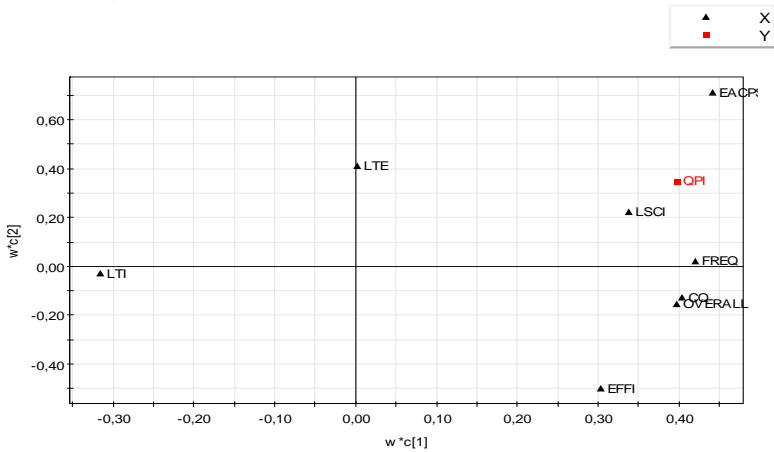
Fig. 7. Map of variables (1st case) : Tunisia

Fig. 8. Map of variables (1st case) : Morocco
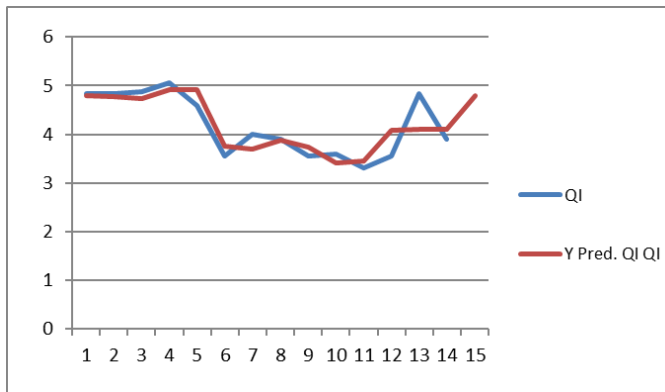
Figure 9. Comparison between Y observed and Y predicted (1st case) : Tunisia
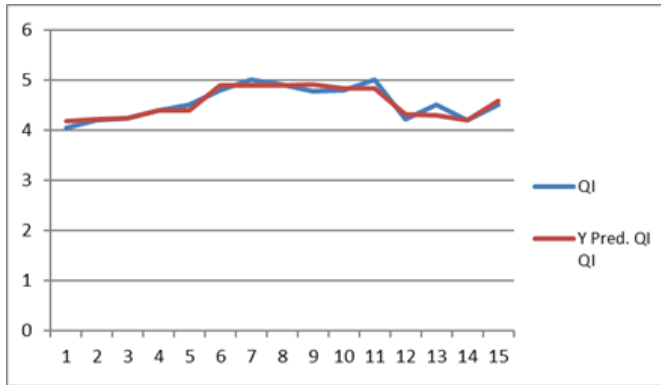
Figure 10. Comparison between Y observed and Y predicted (1st case) : Morocco

5.2. 2nd case: Tunisia-Morocco comparison[1]

In the 2nd case, "traffic" as an additional variable was added.

5.2.1. Number of components

For Tunisia, only the first two components are significant with a very high coefficient of determination R² close to 93% (table 5). This indicates the good quality of fit.

$$QPI = 6{,}374 + 0{,}362EACPS +$$
$$0{,}149overall + 0{,}179EFFI -$$
$$0{,}174CQ - 0{,}045FREQ - \qquad (10)$$
$$0{,}192CPT + 0{,}117LSCI +$$
$$0{,}166LTE + 0{,}388LTI$$

Knowing that the regression coefficients measure the contribution of each variable to explain the dependent variable, equation (10) shows that FREQUENCY has the lowest regression coefficient and therefore the latter poorly explains the quality of port infrastructure. The Facility (EACPS) and LTI variables have very high coefficients compared to the other variables; which indicates that these variables have a strong and positive influence on the dependent variable (QPI).

For Morocco, four components are significant (table 5). The coefficient of determination R2 is equal to 95%. Therefore, the model is globally significant.

$$QPI = 13{,}2601 + 0{,}645EACPS +$$
$$0{,}0475overall - 0{,}111EFFI -$$
$$0{,}058CQ + 0{,}214FREQ + \qquad (11)$$
$$0{,}008CPT + 0{,}117LSCI -$$
$$0{,}012LTE - 0{,}276LTI$$

According to the equation (11), we find that the coefficient of the variable (FACILITY) : « EACPS » is quite high therefore gives a good contribution for the improvement of the quality of the infrastructure. The other variables have low coefficients and therefore a poor contribution to the explanation of the model. Note that the "Efficacy" variable has a very low coefficient (-0.111) compared to the other variables.

5.2.2. Importance of variables

According to the Variable Importance in the Projection (VIP) ranking, Tunisia's two variables (LTI and FACILITY « EACPS ») are the most important in explaining the quality of port infrastructure since their VIPs are greater than 1, while the VIP of others are less than 1. This result means that these variables have no influence on the dependent variable QPI. (Figure 11)

For Morocco, figure 12 confirms that the four variables FACILITY, FREQUENCY, CQ and overall are the most important in the exploitation of the quality of the infrastructure.

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[1] for the case of Morocco was the subject of an IEEE 2022 proceeding, within the 14th IEEE international conference on Logistics and Supply Chain Management.

Table 5. Number of components (2nd case)

Tunisia			Morocco		
$R^2Y=0.925$			$R^2Y=0.95$		
Number of components	Q_h^2	Limit	Number of components	Q_h^2	Limit
1	0,573	0,05	1	0.747	0.05
2	0,531	0,05	2	0.772	0.05
-	-	-	3	0.806	0.05
-	-	-	4	0.836	0.05
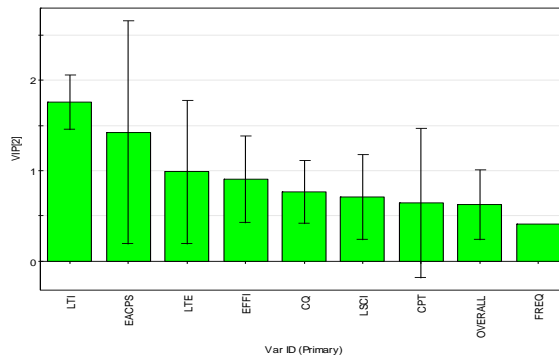
Fig. 11. Importance of variables (2nd case) : Tunisia
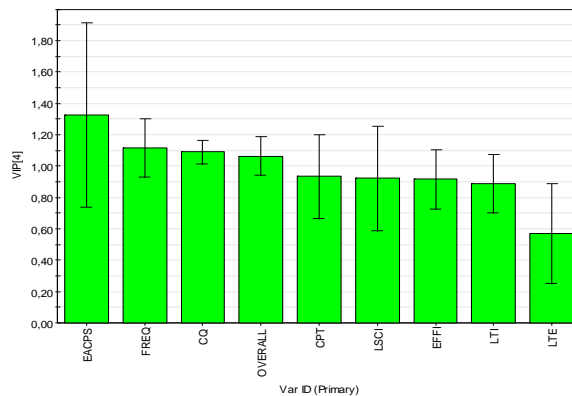
Fig. 12. Importance of variables (2nd case) : Morocco

5.2.3. Observation maps

Tunisia's foreign maritime trade amounts to approximately 30 million tons/year. They have experienced a significant drop in their activity since the events of 2011; going from more than 30 Million Tons in 2010 to around 25 Million Tons in 2011. Since that date, exchanges have gradually resumed, approaching the year 2010. As a result, according to the Merchant Marine and Ports Office (OMMP), commercial traffic in Tunisian seaports, including Skhira, showed a growth of 4% ; the volume of trade increasing from 28 million tonnes at the end of 2013 to 29 million tonnes in 2014. (Figure 13)

The numbers relating to the evolution of inflation in Tunisia during the years of the COVID-19 health crisis recorded a slight increase of 5.7% in 2021 against 5.6% in 2020. It can be said that the Covid-19 pandemic once again shows the strategic importance of maritime transport (Tourret, 2020).

Moroccan maritime traffic has been characterized for many years by a positive and sustained growth in trade in various goods. It has experienced strong fluctuations since 2007 with an annual growth of 9%. Since then, maritime traffic fell by 7% in 2008 and 12% in 2009 following the global economic crisis. A remarkable increase of 16% was achieved in 2010. This traffic decreased in 2011 by (-0.2%) and resumed its growth in 2012 (+3%) and in 2013 (+9%). This increase is mainly due to that of solid bulk goods. (Figure 14)

In a country like Morocco, where 98% of the volume of foreign trade is transported by sea (METL, 2016), the implementation of these strategies could not achieve their objectives without having a supply chain capable of transporting the flow of goods in good conditions.

According to the latest data from the Ministry of Equipment, Transport, Logistics and Water, traffic in the Moroccan port system increased by 1.9%. It went up from 134.9 million tonnes in 2017 to 137.5 million tonnes in 2018. This increase is due to the increase in both the volume of imports and transshipment, while the volume of exports fell slightly by 0.9%. The ministry in a summary of the activity of Morocco's ports in 2018.

Maritime trade traffic has been on a downward trend since 2017, this decline worsened during the COVID-19 health crisis, recording a decrease of 4.1% in 2020.

From February to November 2019, Moroccan monthly traffic recorded between 6 Mt and 9 Mt, thus following a positive trend due to a 4.8% increase in imports. On the other hand, exports of phosphate and clinker traffic decreased during this period.

The growth of port traffic in 2020, thus being part of an evolving trend, which is recorded each year by the ports with the exception of the month of October, showed a decrease compared to the year 2019, to continue the trend positive in November 2020. Indeed, this drop in traffic is explained by the new trend in Morocco to reduce imports, while encouraging the local economy.

In the UNCTAD (2020) report titled "COVID-19 and maritime transport: Impact and responses", Morocco's ports have shown strong adaptability and remarkable resilience to ensure the continued operation of Moroccan ports in the best conditions. Morocco was able to achieve these results by implementing a series of measures aimed at protecting its port infrastructure and improving the functioning of its seaports.

Between 2020 and 2021, port activities in Morocco increased by 11.6%. This increase is explained by an overall growth from 172.1 million tonnes in 2020 to 192.1 million tonnes in 2021. Domestic traffic recorded a volume of 111.5 million tons, while transshipment reached a volume of 80.5 million tons.

5.2.4. Map of variables

The structure of correlations between the explanatory variables and the explained variable presented in figure 15 allows us to identify the following points;

For Tunisia:

-   All the variables are far from the origin. This explains the existence of a good quality of point cloud representation.
-   The variable (LTI) is very close to the dependent variable (QPI). This means that this variable has a significant and important influence on the quality of the infrastructure compared to the other variables chosen.
-   The two variables (Frequency and CPT) are distant from the (QPI) variable. This confirms the results of equation (10) of the PLS regression. It showed us that these two variables have

very low coefficients and thus have a bad contribution for the construction of the quality of the port infrastructure.

–   We note, for Morocco, that certain explanatory variables are far from the dependent variable (See equation 11). The latter shows us that the four variables (LTI, LTE, CQ and Efficiency) have very low coefficients and also a poor contribution for the construction of the QPI. The

main weak points for Morocco are the weakness of the transport infrastructure (the quality and the reception capacity), the deterioration of the transport services (the low efficiency and the high cost) and the weakness of the technological infrastructure. This negatively influences the efficiency and quality of customs services. (Figure 16)
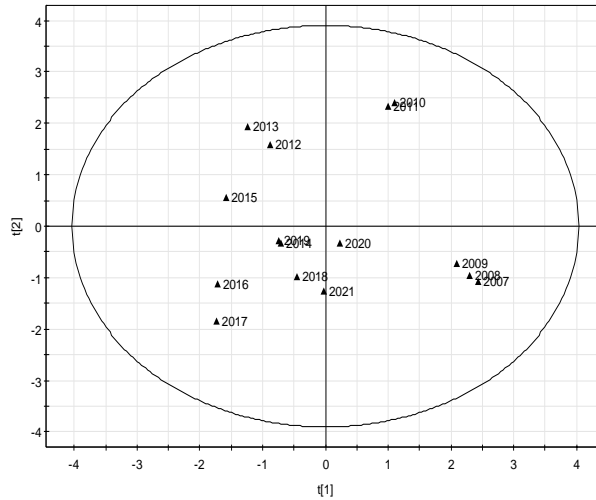

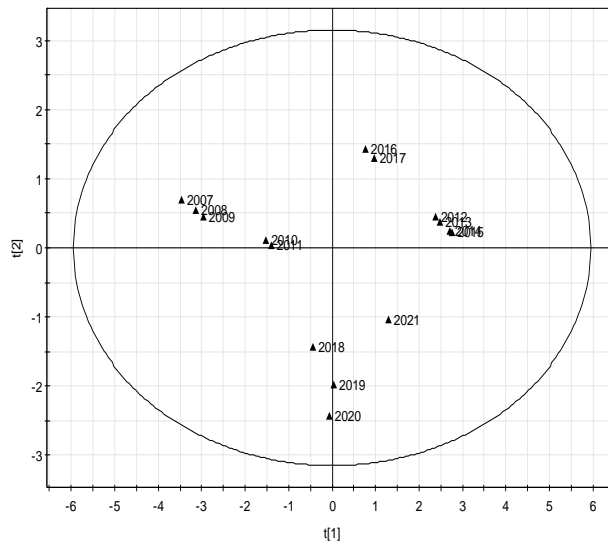Fig. 13. Maps of observations (second case) : Tunisia

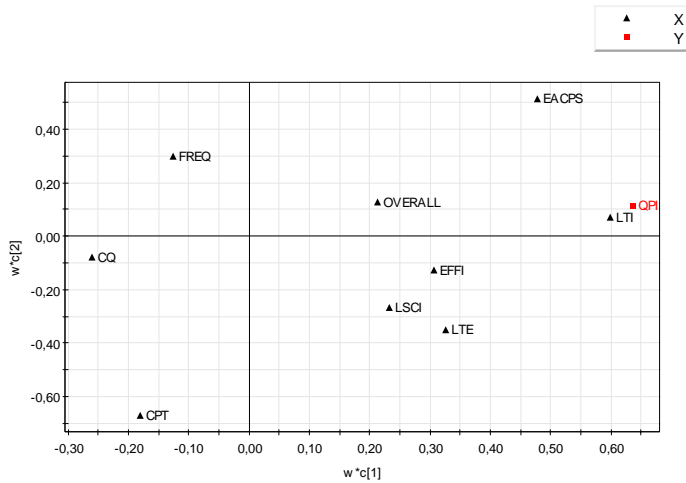Fig. 14. Maps of observations (second case) : Morocco
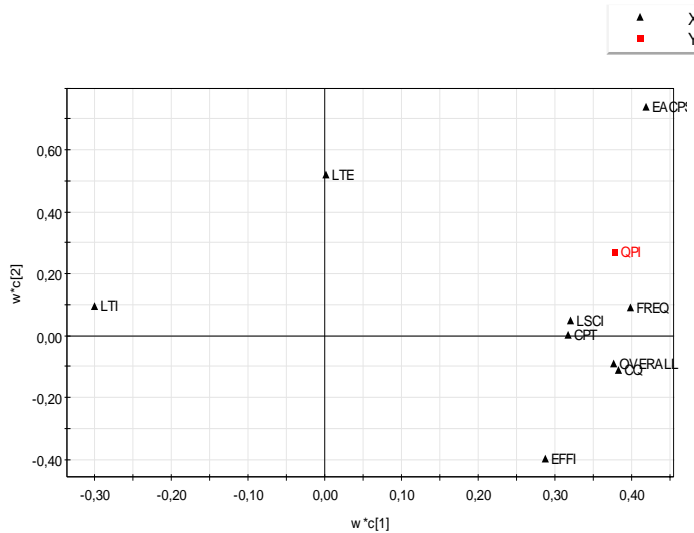
Fig. 15. Map of variables (second case) : Tunisia

Fig. 16. Map of variables (second case) : Morocco

5.2.5. Comparison between Y observed and Y predicted

The coefficient of determination R² is equal to almost 93%. This confirms the effectiveness of the PLS regression since the predicted and observed values are very close (Table 13). Indeed, the R2 is equal to almost 95% with 4 PLS components. The prediction results confirm this efficiency since the predicted and observed values are very close and the MSE is low.(figure 17 and figure 18).

Following the insufficient quality of port infrastructure, the European Bank for Reconstruction and Development estimated in its report on the transition (2017-2018) that Tunisia should devote 23.8% of its GDP to modernizing and developing its infrastructure in 2022. As a conclusion, the forecast results confirm this efficiency since the predicted and observed values are very close.
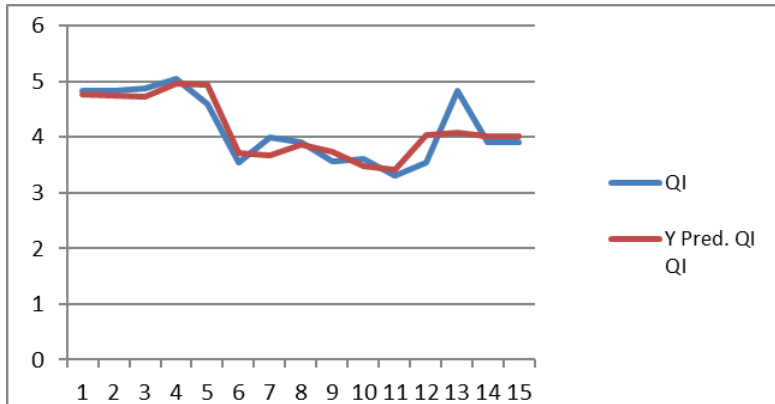
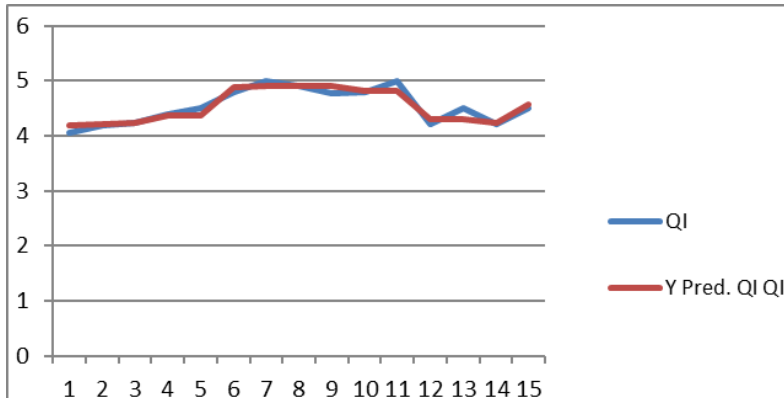Fig. 17. Comparison between Y observed and Y predicted (Second case) : Tunisia

Fig. 18. Comparison between Y observed and Y predicted (Second case) : Morocco

6. Conclusions

The objective of this paper is to evaluate the development of port infrastructure to improve the competitiveness of port systems in Tunisia and Morocco according to 9 competitiveness criteria. This work was carried out using the PLS method from 2007 to 2021.

The results indicate that the key factors for the development of the Tunisian port infrastructure are import delays and ease. For Moroccan port infrastructures, it is frequency and ease. For Morocco, another less important factor; but determining the quality of port infrastructure, is connectivity. In addition, this country has experienced a very important evolution compared to Tunisia following its political stability and its strategy used during the crises.

Overall logistics performance in Tunisia lags behind most countries in the Mediterranean basin. Tunisia outclassed the southern Mediterranean countries until 2012. After this date, its position decreased leading to a drop in the logistics performance index from 3.17 in 2012 to 2.54 in 2018. This may be because the quality of transport-related infrastructure has continued to deteriorate since 2012. During this period, Tunisia's competitor countries, on both sides of the Mediterranean that are active in the cargo transport and logistics sectors, improved their logistics performance index. The Moroccan economy has experienced a significant decline in several economic variables. On the other hand, Moroccan port activity could indicate resilience, showing an up-

ward trend. This evolution comes following the initiatives of elaboration and implementation of the "Strategy of the Moroccan Maritime Transport Sector and the development of the National Flag in Morocco" (METL, 2013-2016) and the adoption of new legal documents for the delimitation of maritime borders. In addition, Morocco aims to build a solid platform and reduce dependence on foreign fleets. In the same vein, its objective is to have a maritime transport system capable of recovering and supporting the national economy in the face of all threats and crises.

Improving port infrastructure quality will contribute to the competitiveness and economic growth of both countries, fostering trade facilitation and attracting foreign direct investment.

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