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ANALYSIS OF THE PUBLIC TRANSPORT EFFICIENCY, PRODUCTIVITY AND ECONOMIES OF SCALE: THE CASE OF SFAX – TUNISIA

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ABSTRACT

This study aimed to determine the efficiency and productivity of the production factors in the case of public transport in Sfax – the second most important agglomeration in Tunisia–. The analysis of factor productivity enabled identifying the shortcomings in the supply of this service and advocating certain strategies to boost supply. We use an estimation of the trans-logarithmic costs function with different restrictions while relying on the foundations of the microeconomic theory. We relied on annual statistical data from the Regional Transport Company in Sfax over the period preceding the COVID 19 crisis spanning from 1985 to 2018. The estimation results showed the presence of scale diseconomies, the gain in productivity over the years is too slow. The technical progress of public transport in Sfax is very low and the technical efficiency is also very limited. The results revealed that there is a decline in productivity growth due to a growing inefficiency throughout the study period.

The underutilization of production capacities in the transport sector was judged as a consequence of excess of capacity and lack of efficiency attributed mainly to the lack of competition. The study identified some external factors that have an impact on the measured efficiency but are outside the company control. Public authorities should act on these factors to help companies improve their performance. A deregulation of the public transport sector by redefining the most important objectives has become urgent.

Keywords: *Public transport, Efficiency, Productivity, Economies of Scale, Translog Cost Function*

1. INTRODUCTION

The relationship between transport and urban development is determined through two factors: (i) the demand effect: "an increase in economic activity requires more transport", this is the most prevalent and most cited effect; and (ii) competitiveness effect or feedback effect: "a better transport leads to more economic activities". The productivity of urban transport contributes to the overall productivity of the economy. The demand for transport is generated by the demand for other goods and services, and the resulting need for mobility. An efficient transport sector improves the standard of living of individuals and households by participating in the reduction of costs and prices of other goods and services. However, urban transport is often as accused

of being responsible for several problems faced by cities. Some economic and ecological problems, such as global warming, air pollution noise and the rising fuel prices are said to be direct consequences of urban transport.

Owing to its high capacity, low CO_2 emissions, and alleviation of traffic congestion, public transport has become an important alternative in ensuring citizens' mobility. Policies giving priority to public transport are generally widely appreciated. The answer to the question "To what extent such policies can impact travelers' attitudes in a complex traffic environment" remains unclear. In order to encourage citizens to rely more on public transportation, reduce private car travel, and reduce congestion, the policy has made some efforts that are clearly noticeable in two aspects. On the one hand, it encourages the use of public transport by improving service quality and reducing travel costs, public transport subsidies, and bus lane and signal priority. On the other hand, the use of private cars is reduced by imposing higher parking fees, restricting the purchase of cars, limiting access to city center alternatively to odd and even number plates, and collecting road tolls (Zhu, Chen, Wang, & Ma, 2018).

Public transportation is one of the most important alternatives to reduce reliance on private cars. Compared to the private cars, public transport (public buses) is more environmentally friendly, efficient and sustainable (Moraliyska, 2023). Its use can be encouraged by improving service quality, reducing commuter fares, providing government subsidies, adjusting bus fares, and providing "park and ride" facilities, all of which have attracted considerable attention of the public transport systems, to relieve congestion. Traffic jams - especially in the city centre. However, in many cases, public transport operators/companies have traditionally balanced their income and expenses. They try to maximize their revenue through higher fares, which ultimately reduces the quality of service, which causes people to turn to personalized transportation for commuting (Ali, Nakayama & Yamaguchi 2022).

The frequently forwarded solution was to promote public transport over the long run. Managers of such companies often sought to improve the vehicles schedule, their spatial coverage, the quality of their service and the comfort of their passengers (renovation of the vehicle fleet, tramway construction, expansion of networks).

In Tunisia, the public authorities are currently adjudicated in favor of a more efficient and effective public transport system. Nevertheless, the public transport has always been on the decline compared to the other particular modes. Numerous factors may explain the abusive recourse of the use of private cars in urban areas. The door-to-door service, the choice of journey and departure time, comfort and flexibility of use are the major factors which advocate the use of the automobile (Makhlouf, 2013). The problems plaguing public transport supply in Sfax explain the users fleeing to private modes. In fact, they run away from the permanent imbalance between supply and demand, the irregularities of the frequencies, and the very uncomfortable travel conditions. These problems originate in the market structure of this service. The Regional Transport Company of Sfax, SORETRAS (Société Regionale des Transports à Sfax), is the monopoly that offers public transport services. Like most of public companies, it suffers difficulties related to the management and productivity of its factors of production, bureaucratic problems, centralization of decision making and financing by the appropriate ministry (Martin, 2023). For this public transport company, not only are fares and their variations set by the supervisory ministry, but it also depends on this ministry for staff recruitment, bus purchases and subsidies.

Taking into account these conditions, the purpose of this research was to examine the efficiency and productivity of the production factors in the case of public transport in Sfax. In this context, we sought to reveal whether the public transport company in Sfax enjoys a natural monopoly

position and whether the sector should be completely deregulated by opening it up to competition. Similarly, calculating the factor efficiencies and productivity enabled us to explain the sources of these inefficiencies. The research study also investigated if the public monopoly and protectionism enjoyed by SORETRAS are at the root of these inefficiencies; and the possible innovations and management and organization methods that are likely to improve the conditions provided to the company of Sfax.

Most of the recent studies that have looked at the efficiency of public transport systems have taken a non-parametric approach relying the DEA (Data Envelopment Analysis), SFA (Stochastic Frontier Analysis) or other methods (Bugheanu, 2018; Vigren, 2016; Carvalho, Syguiy, & Silva, 2015; Karim & Fouad, 2019). These methods, however, are often used in the case of panel data and allow the classification of all the companies operating in this sector and the comparison of their efficiencies. In our case, since we dealt with only one firm, we have chosen to use a parametric approach to analyze its productive and allocative efficiency. We used an estimation of the translogarithmic costs function with equations that were added to the different restrictions while relying on the foundations of the microeconomic theory of the costs. Although this is a traditional approach, it is still valid for analyzing and explaining the problems of allocative and productive inefficiency of the firm in question, especially when using time series data. The calculation of the economies of scale would allow us to decide whether to be a in favor of the monopoly status enjoyed by the SORETRAS. The determination of the productivity of the factors and the calculation of the allocative and productive efficiency helped us to suggest the effective measures to possibly improve the performance of the public transport sector in Sfax. This study would enable us to provide some answers to the issues raised above, and suggest some measures susceptible to improve the performance of this sector (Alimi & Lassad, 2023).

The rest of this study is structured as follows: Section 2introduced the new challenges for the public transport and the renaissance of this sector in developed countries. Section 3 analyzed the supply and the demand of public transport in Sfax region during the period 1985 – 2018. Section 4 detailed the empirical approach and the obtained results. Finally, Section 5 concluded the study and provided some policy implications.

2. THE NEW CHALLENGES OF PUBLIC TRANSPORT

The past decades have witnessed a huge popularity of private cars use not only in Western countries but also in developing ones. The use of cars has increased considerably. Due to various mobility needs governed by physiological, psychological and economic reasons, new travel alternatives are emerging. To satisfy this growing travel demand, citizens tend to use private modes rather than public ones. These modal changes have been observed in developing countries, which ultimately led to major urban transport problems (Gajera, Dawda, Dave, Joshi, & Arkatkar, 2019).

Public transport has experienced a spiraling downward trend in terms of attendance, investment and service quality. In addition, territorial development and land use plans often focused on the use of the automobile (Candea et al., 2023). Moreover, some studies have argued that apart from a few large cities, there are few reasons to extend the public transport service or to encourage the use of this mode (Orski, 2000; Balaker, 2004). However, recent trends have increasingly favored the use of public transport. Recent studies highlight the advantages of this collective mode (Litman, 2006; Puentes, 2008). Many reasons have accelerated the shift of transport demand from private to alternative modes. Among these we can state the rising of fuel prices, increasing urbanization, traffic congestion, increased expansion and maintenance costs of the road network, and the evolution of consumer preferences.

The recent decades have revealed new demographic, urban and economic trends providing more support for an increased urbanization. Agglomerations have experienced a rapid shift towards becoming urbanized centers. Many areas, that were previously classified as suburbs, are gradually urbanizing. Their sizes and the resulting travel demand justify the authorities' resort to public transport. The increase of congestion, business clustering and parking problems make the investment in public transport more profitable and efficient. Traditionally, transport policies have always aimed at balancing supply and demand (Puška, Kozarević, Stević & Stovrag, 2018). However, for sustainability reasons, transport policies have undergone paradigm shifts, emphasizing the movement of passengers rather than vehicles. It is evident that public transport systems can mitigate the drawbacks associated with private vehicles and, therefore, contribute to sustainability goals (Dawda, Gajera, Joshi, Arkatkar, & Dave, 2020).

There is a rising awareness among transport professionals and general public that it is more beneficial to have a more diverse transport system (Pusher, 2002). Since the mid-1990s, public means of transport have grown in popularity at the expense of private ones. According to BTS[1] 2003, public transport trips in the USA increased by 24%, while the private automobile mileage increased by only 10%. This trend is predicted to continue in the future years. A renaissance of public transport is about to take place in major US and European cities. Increasing congestion in most of the cities and rising warnings to environmental issues make public transport the ideal alternative in cities (Fitzová, Matulová & Tomeš, 2018).

In small towns, the public means of transport mainly provide trips for the most disadvantaged. They are an adequate alternative for those who cannot afford a private car. It also supports development and equity goals. However, when these cities increase in size and density, this type of transport serves several discretionary categories (people who can use their cars). It offers significant benefits to city dwellers reducing traffic problems and supporting development and land use plans. Given the traffic conditions in these large agglomerations, some drivers prefer to drive less and to use more comfortable and more accessible alternatives. Satisfying this rising demand for alternative modes can provide a variety of benefits. Improving public transport is profitable measure of the whole urban transport system. Litman, 2010 enumerates several measures that allow to improve the public transport service and encourage its users. Among these we can cite:

- Increasing the supply of the service, through the extension of the network and the operation hours, and the increase in the number bus trips.
- Improving the coordination among and with the other modes; giving passage and parking priorities to public transport vehicles in order to reduce delays and increase the commercial speed; besides specific routes can be preserved for buses and non-motorized modes as a measure to improve their commercial speed.
- Making buses appealing to users through improving the comfort inside vehicles by limiting the number of passengers and taking care of cleanliness and comfort.
- Modernizing the bus stations and stops network, providing waiting seats, useful user information, and signaling the vehicle direction and itinerary.
- Adopting lower fares and providing special discounts for some customer categories, installing more convenient payment methods, and conducting marketing and information campaigns on the benefits and advantages of public transport, real-time information about the vehicle's arrivals and departures.

Other strategic and long run measures have to be taken like promoting development focused on public transport ; getting better access to stops and stations for the pedestrians and cyclists;

[1] BTS : "the Bureau of Transportation Statistics"

ensuring an easier and more appropriate combination of the public transport with the other modes (walking, bicycle, private car and carpooling); conceiving adequate vehicles, stations and pedestrian crossings that can accommodate people with special needs, increasing safety for public transport users and pedestrians; issuing "Access Guides", including all necessary information about travel and pointing such specific needs as express suburban bus services during special events. As it was cited by Sénquiz-Díaz for the relation between transport infrastructure and economic performance, (Sénquiz-Díaz, 2021). The government should prioritize the integration of other logistics and urban transport players into the public sector to maximize the benefits of the networks (Al-Ansari & Al-Khafaji, 2023). Thus, the importance of transport infrastructure and logistics should not be overlooked, as logistics providers play an important and relevant role in practice (Aytekin, Korucuk, & Karamaşa, 2023).

The improvements and incentives for the collective mode tend to offer significant advantage. These may even be more significant when the public transport substitutes automotive travels (Liu & Wang, 2023). It is notably an economical advantage through achieving several savings on vehicles costs, the renunciation of driving, reducing congestion, parking cost savings, increasing road safety and security, economizing of energy and the cutting down polluants emissions. Shifting from a reliance on private cars to public transport allows not only lower variable or operating costs, but also fixed costs which are independent of the traveled mileage (Kuncoro & Fafurida, 2023). Indeed, this substitution can result in a renunciation of some consumers of using their cars or even buying one (Litman, 2016). McCann established that the US households, in collectivities enjoying good public transport conditions, can economize on average about $ 3,000 per year on travel costs (McCann, 2000). Litman found that annual savings of transport cost of about $ 1,300 per household in cities having rail transport systems, compared to other cities. A better public transport system can result in remarkable effects on the economic and social development of a region or a country (Litman, 2004). The table below summarizes the different economic impacts and how they can be measured.

Table 1. Impact of public transport improvements on economic developmen

Category	Description
Employment and activity level	Increasing the volume of transactions, economic activity and employment opportunities.
Consumer expenditure	Some expenditures will be transferred to other consumptions.
Effectiveness of facilities	Increase of accessibility providing better efficiency of agglomerations
Productivity profits	Improvement of the access to education and jobs, and reduction of costs for companies by reducing travel time and costs for employees and students and reducing goods delivery costs and energy consumption for companies.
Economic development strategies	Supporting development strategies and increasing the opportunities of achieving the objectives
Effectiveness of the transport system	Reducing unit costs and improving the performance of the sector.

Source : Litman (2015)

Given all these advantages, the organization of urban spaces and the management of mobility in large agglomerations inevitably require the rehabilitation and reorganization of public trans-

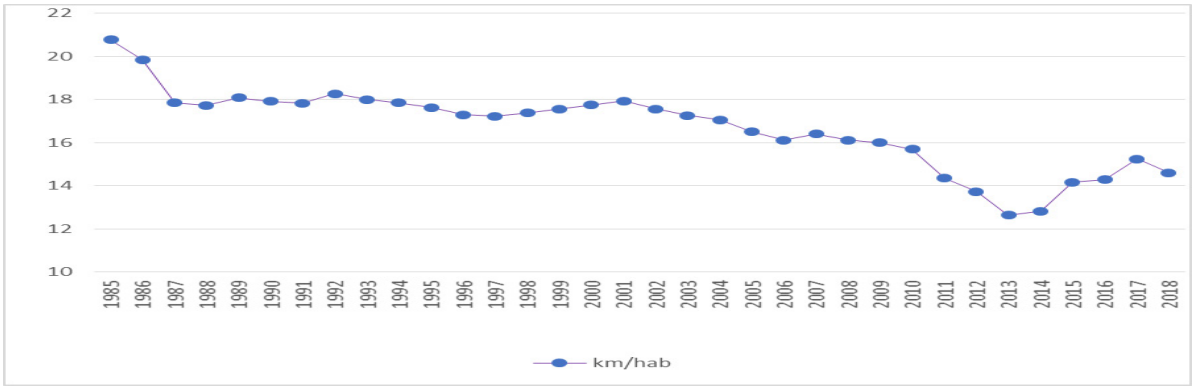
port. Its capacity to ensure the displacements of a large number of users enables this sector to rank first while examining the transport policies that can be adopted. The specificities of each region and city make it almost impossible to suggest universal measures that would suit them all. The scope and effectiveness of policies largely depend on the diagnosis of the current status of an urban transport system. Thus, in the following section, we proceeded with a descriptive analysis of the public transport system in the region of Sfax, Tunisia.

3. PUBLIC TRANSPORTATION IN SFAX REGION

Sfax city is the second pole of Tunisia. It hosts a population of one million inhabitants in 2017, among which 65% live in the urban area of "Grand Sfax". This agglomeration is characterized by a strong urban sprawl, and a low density of urbanization (30 inhabitants / Ha). The spatial organization is radio-concentric. The infrastructure of land transport consists principally of 14 radials and four radial roads. The traffic on the various radials is too dense to reach the center easily. 40,000 vehicles per day are recorded on some sections. Traffic conditions, especially during rush hours, are difficult due to the intersections saturation and anarchic parking. On the institutional level, the Ministry of Transport remains the major authority organizing the urban transport in the city with an extremely limited role of local collectivities. Their involvement is weak especially in the planning and programming phases. This is not specific to the region of Sfax but characteristic of all the governorates of the country. The SORETRAS- local transport company- is a public monopoly of urban and regional transport. The urban public transport network involves about 30 regular lines with an average length of 20 km (round-trip). Substantially, all of these lines converge towards the city center, which causes overloaded journeys in some cases and empty returns in others.

The public transportation supply is measured by "Vehicle kilometers per inhabitant" statistics. Initially, there has been a relative stability in the service supply during the Tunisian pre-revolution period in 2011. This is explained by the fact that the public transport supply is not correlated with the demand. Most of the diverse company vehicles trips were set for equity and social stability reasons. The huge number of lines and journeys exclusively devoted to students constitutes one of the major reasons for this stability of the public transport supply in the region of Sfax. Several trips were achieved with a limited number of users.

Figure 1. Evolution of mileage per inhabitant



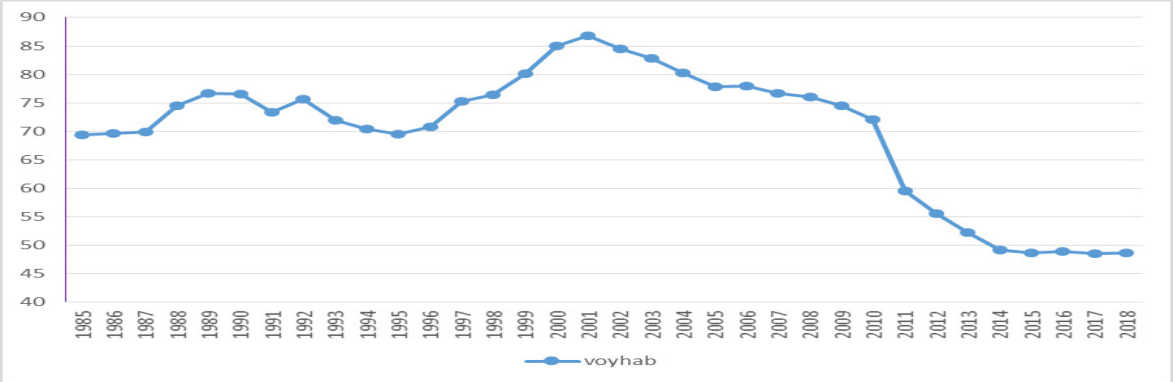
Source : processed by authors

Buses often ensure either driveways or almost empty returns. The existence of unexploited capacity is also due to the use of articulated buses, which are sometimes inadequate with the nature and schedule of some trips. The fall in supply observed in the period 2012-2014, is due to strikes and social movements. Thus, numerous trips are canceled, which reduces the number

of kilometers traveled by the vehicles of the company.

To assess the demand for public transport by bus in this context, various studies opted for an aggregate which is the number of passengers transported per inhabitant. We can easily observe the considerable variation in demand during the period 1985-2018. The annual average of people transported per capita is 70. This is particularly explained by the quality of the network of public transport and the urban nature of the region. In Sfax, the SORETRAS essentially serves the urban areas, where demand is quite important. Together with the important number of the Sfax city inhabitants, the large number of students in this agglomeration could account for the increased resort to a collective mode for daily commuting. This category of users actually represents more than 80% of all the company customers.

Figure 2. Evolution of the number of travelers per inhabitants



Source : processed by authors

The urban spread, on the one hand, and the inability of the public transport system to meet the needs of commuting between the center and the periphery on the other hand, have led citizens to shift to private means of transport (taxis, motorcycles and passenger cars). This resulted in a considerable drop of public transport use in the motorized trips, from 30% in the early 1990s to nearly 20% today. The sharp rise of individual transport has aggravated the problems of congestion and pollution in the city of Sfax. The SORETRAS low service quality is also a fundamental factor explaining the users evasion phenomenon. Although the fleet in operation included more than 350 vehicles in 2005, the availability rate has declined steadily from 85% in 2000 to 54% in 2013, with a steadily aging fleet. In 2013, the average age of vehicles reached 7 years and 4 months for urban bus network and 10 years and 7 months for the inter urban one. This caused very uncomfortable travel conditions and continuous nuisance for the users. In addition, frequencies rose up to 60 minutes and the commercial speed continued to drop, especially when moving close to the city center.

In order to analyze the reasons underlying the disequilibrium between supply and demand of the public transport in Sfax, it is necessary to analyze the company's cost structure. This allows us to determine the productivity of the factors of production, identify the extent to which they are used efficiently and see whether the current organization of the market for urban public transport in Sfax is optimal or not.

4. EMPIRICAL ANALYSIS

4. 1. SAMPLE AND DATA

The data used in this study cover the operation of SORETRAS for the period 1985-2018. The choice of this period was dictated by the consequences of the covid-19 pandemic on economic activity and public transport in particular. Indeed, the containment, established in Tunisia for relatively long periods in the years 2020 and 2021, had a direct impact on urban mobility in the city of Sfax. Taking into account the statistics on public transport and the operation of the SORETRAS for these two years could affect the overall results of the estimated econometric model.

These data include production output (Y) expressed as the number of passengers per capita, labor force (L), capital stock at the beginning of each period (K) expressed by the number of available seats, energy cost value (VE), average annual salary (p_L), payroll (MS), energy price (p_E) and total cost (TC) which represents the sum of the variable cost (VC) and the fixed cost (FC). Table 2, presents the main descriptive results of the used variables.

Table 2 . Descriptive Analysis of variables

Variables	Y	K	L	VE	p_L	p_E	TC
Mean	70.18	31618.38	1379.529	3754949	13209.31	0.517	3.29 e+7
std dev	11.39	6140.04	65.86	2405366	9122.57	0.318	2.04 e+7
Minimum	48.58	23762	1284	1334526	3259.26	0.230	1.03 e+7
Maximum	86.73	43397	1518	8733108	36952.53	1.14	8.29 e+7

Source: Authors' calculation

We can note the small fluctuations in the value of output Y. As noted above, the evolution of the number of travelers is due mainly to the dramatic increase in the number of students at the end of the years 1990. This same production knew from the years 2004 onwards a continuous decrease explained by the competition by the collective taxis. The factors prices, P_L and P_E, are measured by the ratio of expenditures devoted to each of these factors to the number of workers and the quantities of fuel consumed. The increase in prices for these two factors is explained by the increase in wages and other advantages to the company's personnel, as well as by the surge in oil prices and their consequences during the last decade. Although the number of workers underwent small changes during the study period, staff spending rose steadily at incredible rates, especially during the years that followed the Tunisian revolution. Concerning the price of energy, the increase in world oil prices and changes in the price of gas oil in the domestic market explain the fluctuations of this aggregate. For the capital factor, we have chosen to consider it as a quasi-fixed factor. It is measured by the number of seats in all the vehicles of the company. It is the theoretical capacity of the vehicles noted K. The variations in this variable can therefore be explained by the changes in the SORETRAS fleet, following the acquisition of new buses or, the abandonment of other buses.

4. 2. TRANSLOG COST FUNCTION, TOTAL FACTOR PRODUCTIVITY AND TECHNICAL EFFICIENCY

To analyze total factor productivity and technical efficiency, most of the models used assume the full factor utilization and a long-run equilibrium state. They are generally based on the assumption that companies use efficient technological and economic combinations. Thus, productivity growth can be denoted by $\varepsilon_{ft} = \partial LnY/\partial t$, where Y is the output, and t represents the

technological state, or $\varepsilon_{Ct} = -\partial LnC/\partial t$ where C is the total cost (Baldwin, Gu,& Beiling, 2013; Gu & Wang, 2013). The evolution of the total cost, based on technical progress, is represented by *dLnC/dt*. It describes the total response of inputs (variable and fixed) to long-run equilibrium levels.

$$\frac{\dot{C}}{C} = \frac{dLnC}{dt} = \frac{1}{C}\left[\frac{dC}{dt|_{Xm=\overline{Xm}}} + \sum \frac{\partial C}{\partial X_m}\frac{dX_m}{dt}\right] \quad (1)$$

This measure represents an estimate of long-run cost elasticity in the same way as long-run price and production elasticities. Indeed, the short-run Translog variable cost function with variable returns to scale (VRS) can be written as:

$$LnVC = \alpha_0 + \alpha_t t + \frac{1}{2}\gamma_{tt}t^2 + \sum_{i=L,E}\alpha_i Lnp_i + \beta_Y LnY + \beta_K LnK + \frac{1}{2}\sum_{i=L,E}\sum_{j=L,E}\delta_{ij}Lnp_i Lnp_j + \frac{1}{2}\gamma_{YY}(LnY)^2 + \frac{1}{2}\gamma_{KK}(LnK)^2 + \sum_{i=L,E}\rho_{Yi}LnYLnp_i + \sum_{i=L,E}\rho_{Ki}LnKLnp_i + \rho_{YK}LnYLnK + \rho_{tY}tLnY + \rho_{tK}tLnK + \sum_{i=L,E}\rho_{ti}t\,Lnp_i \quad (2)$$

The verification of the homogeneity with respect to the prices of degree 1 requires the imposition of the following constraints:

$$\alpha_L + \alpha_E = 1;\ \delta_L + \delta_E = 0;\ \delta_E + \delta_E = 0;\ \rho_Y + \rho_E = 0;\ \rho_K + \rho_K = 0;\ \rho_L + \rho_E = 0 \quad (3)$$

In order to reflect the optimization behavior and based on Shephard's lemma, it is useful to resort to other additional equations. These optimal demand or cost minimization equations (variable cost shares, Si) results from the logarithmic differentiation of the variable cost function with respect to variable input prices logarithms Lnp_L and Lnp_E knowing K, Y and T. Indeed,

$$S_i = \frac{\partial LnVC}{\partial Lnp_i} = \frac{p_i X_i}{VC} = \alpha_i + \delta_{ii}Lnp_i + \delta_{ij}Lnp_j + \rho_{Yi}LnY + \rho_{Ki}LnK + \rho_{ti}t \quad (4)$$
$$\forall\, i \neq j = L, E$$

By imposing the different restrictions on the cost function as well as the parts share equations, we will have the system of equations (5). To solve the singularity problem, it is necessary to eliminate the equation S_E from the fact that $S_L + S_E$. The system is estimated by the iterative SURE method under constraints of Zellner (Zellner, 1962).

$$\begin{cases} Ln\left(\frac{VC}{p_L}\right) = \alpha_0 + \alpha_t t + \frac{1}{2}\gamma_{tt}t^2 + \alpha_E Ln\left(\frac{p_E}{p_L}\right) + \beta_Y LnY + \beta_K LnK + \frac{1}{2}\delta_{EE}Ln\left(\frac{p_E}{p_L}\right)^2 + \frac{1}{2}\gamma_{YY}(LnY)^2 + \frac{1}{2}\gamma_{KK}(LnK)^2 \\ \qquad + \rho_{YE}LnYLn\left(\frac{p_E}{p_L}\right) + \rho_{KE}LnYLn\left(\frac{p_E}{p_L}\right) + \rho_{YK}LnYLnK + \rho_{tY}tLnY + \rho_{tK}tLnK + \rho_{tE}tLn\left(\frac{p_E}{p_L}\right) \\ S_L = \alpha_L + \delta_{LE}Ln\left(\frac{p_E}{p_L}\right) + \rho_{YL}LnY + \rho_{KL}LnK + \rho_{tL}t \\ S_E = \alpha_E + \delta_{EE}Ln\left(\frac{p_E}{p_L}\right) + \rho_{YE}LnY + \rho_{KE}LnK + \rho_{tE}t \end{cases} \quad (5)$$

After applying the homogeneity and concavity restrictions, the average variable cost (CV) equation and the demand equations are the equations to be estimated in the short run. If we assume that the cost function is $y_{it} = \alpha_i + \beta' X_i + \varepsilon_i$, then, the error term can be identified as $\varepsilon_{it} = v_i + u_t$. The Panel's error can be defined as the sum of the behavioral errors u_{it} and an individual specific effect v_i. This individual effect can be estimated by using fixed or random effects models. To improve the efficiency of the estimation of the cost function parameters and the corresponding demand equations, a seemingly unrelated iterative constraint regression of Zellner (1962) is often used.

The concept of elasticity plays a central role in econometric models because of its synthesizing property. From a methodological point of view, elasticity might appear, only with the estimated coefficients of the equations. The logarithmic form of the Translog cost function facilitates the imposition of constraints and the calculation of elasticities in order to explain the impact of input prices on the costs and the quantity of output and capital.

For the ASE (Allen Substitution Elasticities), elasticities of substitution between inputs, we note σ_{ii} the direct price elasticity of factor i, and σ_{ij} the price elasticity for factor i following the change in the price of factor j. Indeed,

$$\sigma_{ij} = \frac{\partial LnX_i}{\partial Lnp_j} = \frac{\partial X_i}{\partial p_j}\frac{p_j}{X_i} \text{ and } \sigma_{ii} = \frac{\partial LnX_i}{\partial Lnp_i} = \frac{\partial X_i}{\partial p_i}\frac{p_i}{X_i} \text{ so that}$$

$$\sigma_{ij}^{CT'} = \frac{\delta_{ij} + S_i S_j}{S_i} \text{ and } \sigma_{ii}^{CT'} = \frac{\delta_{ii} + S_i^2 - S_i}{S_i} \quad (6)$$

Farrell was the first to conceive of a firm's efficiency as being the product of two components (Farrell, 1957) : technical efficiency defined as the ability of the firm to produce as much as possible of outputs from fixed quantities of inputs, and the allocative efficiency which reflects the firm's ability to use its inputs in optimal proportions with regard to their respective prices. A random error term v is added in relation (2). We thus obtain a composite error model:

$$y = f(x,\beta) + (v - u) \quad (7)$$

$u \geq 0$ and $-\infty \leq v \leq +\infty$ v represents the variance due to the contingencies which influence production and which are not directly under the control of the manager. Moreover, v and u are independent of each other as well as of x. The relationship (7) can be re-parameterized as follows:

$$y_i = \beta_0' + \sum \beta_j x_j + \varepsilon_i' \quad (8)$$

With $\beta_0' = (\beta_0 - \mu)$ and $\varepsilon_i' = v_i - (u_i - E(u_i)) = v_i - (u_i - \mu) = \varepsilon_i + \mu$

To estimate the technical efficiencies from (8), a particular distribution must be specified for each of the error terms. We can first estimate μ by the method of moments and then β_0 (Aigner, Lovell, & Schmidt, 1977). Indeed, from the residual vector $\hat{\varepsilon}'$ of (8), one can obtain an estimate of the moments of order two ($\hat{\mu}^2$) and three ($\hat{\mu}^3$) and therefore of $\hat{\sigma}_u^2$ and $\hat{\sigma}_v^2$. The variances $\hat{\sigma}_u^2$ and $\hat{\sigma}_v^2$ are convergently estimated by:

$$\hat{\sigma}_u^2 = \left[\hat{\mu}_3 \sqrt{\frac{2}{\pi}}\left(\frac{\pi}{\pi - 4}\right)\right]^{2/3} \text{ and } \hat{\sigma}_v^2 = \hat{\mu}_2 - \left(\frac{\pi - 2}{\pi}\right)\hat{\sigma}_u^2 \quad (9)$$

The estimation of the center moments is given by the following formulas:

$$\mu_2 = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}(\varepsilon_{it} - \bar{\varepsilon})^2 \text{ and } \mu_3 = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}(\varepsilon_{it} - \bar{\varepsilon})^3 \quad (10)$$

Which correspond to the moment equation of Schmidt and Lovell (1979):

$$\mu_2 = \frac{\pi - 2}{\pi}\sigma_u^2 + \sigma_v^2 \text{ and } \mu_3 = \sqrt{\frac{2}{\pi}}\left(\frac{4}{\pi} - 1\right)\sigma_u^3 \quad (11)$$

Cost inefficiencies are estimated by the mean of the conditional distribution of u_{it} knowing ε_{it}, (Jondrow, Lovell, Materov & Schmidt, 1982) using the following expression:

$$E(u_{it}|\varepsilon_{it}) = \left(\frac{\sigma_u \sigma_v}{\sigma}\right)\left[\left(\phi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right) \Big/ \Phi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)\right) + \frac{\varepsilon_{it}\lambda}{\sigma}\right] \quad (12)$$

$\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\lambda = \sigma_u / \sigma_v$ and $\phi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)$ and $\Phi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)$ are the density functions of the standard normal probability and of the respective distribution.

4. 3. ESTIMATIONS AND DISCUSSIONS

Following the correction of the serial correlation and the heteroscedasticity adjustment, the estimation of the final iterative SURE model is summarized in Table 3. From this Table, we can conclude that the translog variable cost function at VRS shows the economic evidence concerning the signs of the production factors and especially those of the quasi-fixed capital. In fact, the convexity with respect to *K* and concavity relative to the prices of variable inputs are verified.

Table 3 . Estimation results

Variables	Value	Std Deviation	t-statistic	p-value
Constant	10.84	10.18	1.06	0.287
β_K	1.81	1.65	1.1	0.272
β_Y	3.47	3.85	0.9	0.367
α_E	-0.52	0.25	-2.06	0.039
α_L	-0.99	0.19	-5.35	0.000
δ_{EE}	0.12	0.005	21.7	0.000
δ_{LL}	0.12	0.005	21.7	0.000
δ_{LE}	-0.14	0.004	-33.14	0.000
γ_{KK}	-0.13	0.27	-0.48	0.633
γ_{YY}	-0.19	0.43	-0.44	0.663
ρ_{YK}	-0.22	0.27	-0.82	0.410
ρ_{YL}	-0.043	0.009	-4.40	0.000
ρ_{YE}	0.043	0.009	-4.40	0.000
ρ_{KL}	0.033	0.02	1.62	0.106
ρ_{KE}	-0.033	0.02	1.62	0.106
α_t	-0.19	0.05	-3.89	0.000
γ_{tt}	-0.5 e-3	0.2 e-3	2.35	0.019
ρ_{tY}	0.015	0.6 e-2	2.25	0.024
ρ_{tK}	0.013	0.8 e-2	1.67	0.096
ρ_{tL}	-0.15 e-2	0.4 e-3	-3.24	0.000
ρ_{tE}	0.15 e-2	0.4 e-3	-3.24	0.000
R^2_Cost	0.98			
R^2_S_L	0.90			

Source : authors' calculation

The estimated coefficients have conforming signs to those recommended by the economic literature and mentioned previously, in particular that of $\gamma_{KK} > 0$. The energy factor is negatively correlated with the capital, which justifies the effect of substitutability between these two factors and especially because of the increase in oil prices over the past few years. The majority of

trend effects are significant in at least 5%, but with different amplitudes except for that of the production which will influence the level of technical progress.

Starting from the findings of the cost Translog at RENC, we evaluated all the technical efficiency estimations, of the elasticities, of the economies of scale and of the technical progress in terms of parameters estimated based on the theoretical developments of the second section. Table 4 summarizes the major results found for some years and for the entire research period in which we specified the overall growth rate (R) and the average annual growth rate (r).

Table 4. Descriptive Analysis of the estimated scores

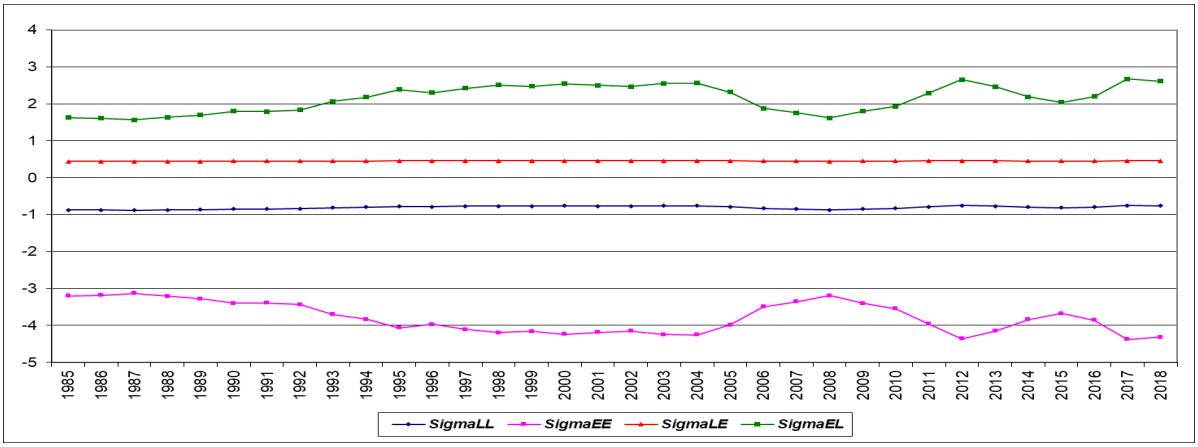
Year	Economies of scale	Technical Progress	ε_{LL}	ε_{EE}	ε_{LE}	ε_{EL}	Technical Efficiency
1985	0.270	-0.078	-0.874	-3.197	0.444	1.626	0.821
2000	0.090	0.028	-0.764	-4.238	0.458	2.543	0.958
2018	0.025	0.096	-0.758	-4.316	0.459	2.615	0.518
Average	0.170	0.019	-0.807	-3.790	0.452	2.145	0.751
Std dvt	0.246	0.063	0.043	0.414	0.005	0.0.366	0.129
R	-90.6%	-222.6%	-13.3%	35.0%	3.3%	60.8%	36.9%
r	6.9%	-200.6%	-0.4%	0.9%	0.1%	1.5%	-1.4%

Note : R : Overall growth rate; r : Average annual growth rate.

Source : authors calculations

In addition, to better explain the economic situation of the SORETRAS company, we resorted to a number of figures showing the evolutions of the major estimated aggregates. We calculated the price elasticities of production factors demand (own price elasticity for each factor and cross price elasticity between factors). The net price-elasticities show how the production factor i demand evolves when its price increases or decreases. For cross prices elasticities, it indicates how the production factor i demand evolves when the price of another factor increases or decreases. Table 4 shows these elasticities. Cross prices elasticities are positive. The production factors taken into consideration in our formalization of the variable costs function are then a priori substitutable. This may seem absurd at first. A substitution between work and energy (and more precisely fuel) is hardly conceivable.

Figure 3. Evolution of short-term prices elasticities

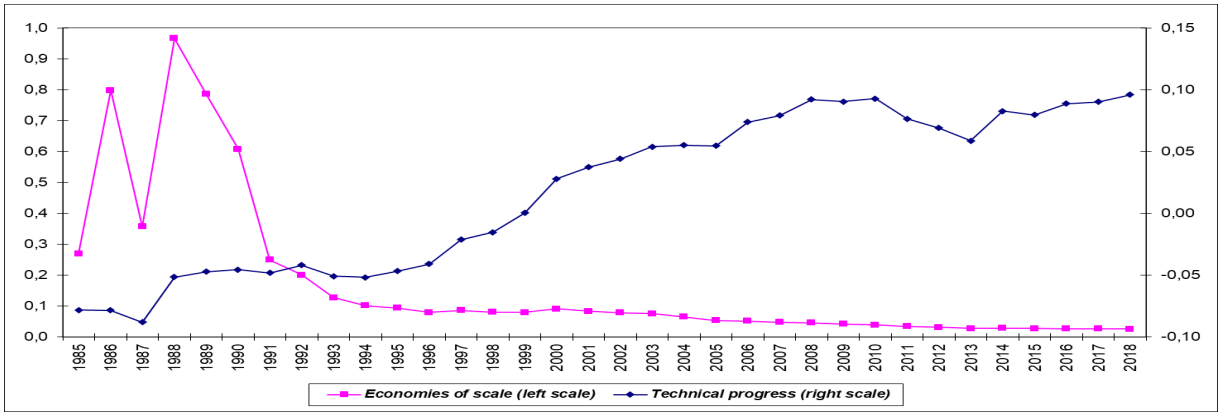


Source : processed by authors

The additional demand of factors, and essentially that of labor, results in a cost increase, often,

at a faster pace. Indeed, this increase in demand is reflected in a rise in overtime hours, but not in an increase in the number of workers. The labor cost as above defined increases considerably. The amount of fuel increases and its price is almost the same. This can therefore be considered as a substitution between the two factors.

Figure 4. Evolution of the technical progress and the economies of scale



Source : processed by authors

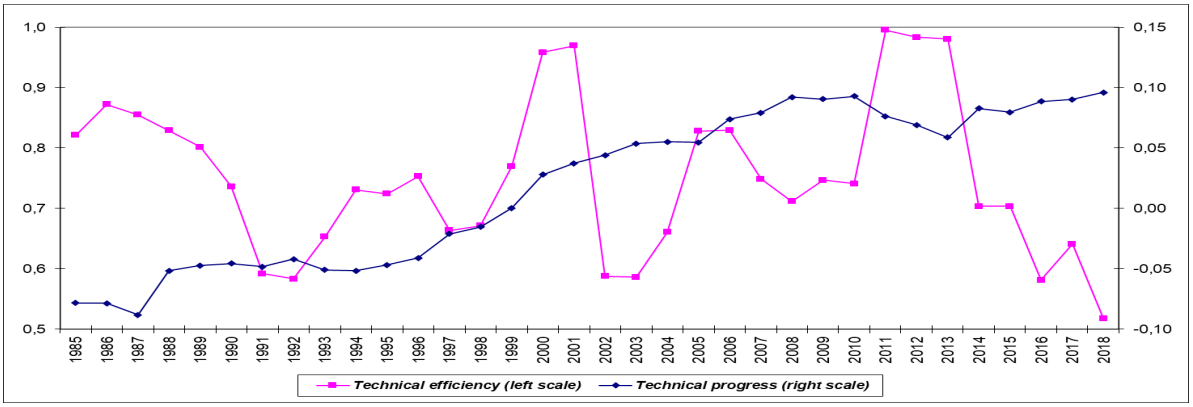
The price elasticities values indicate a negative sensitivity of the cost compared to the price of these inputs. This is in total agreement with the teachings of microeconomic theory. These elasticities are relatively high. The expenditures of the company are then more sensitive to factor price increases than to the production variation. The increase of costs is generally caused by increases in staff and energy expenditures rather than the increase of demand. The decline even in production, during the past decade, has been accompanied by a significant increase of the costs. The syndical pressures and the social movements suffered by the company are in fact at the origin of this paradoxical relationship between costs and output level. This results in the degradation of labor productivity. On the other hand, the rise in oil prices on the world market and relative stability of the traveled distances are at the origin this high sensitivity of the costs relative to the price of the energy P_E.

As far as the economies of scale are concerned, and as shown in Figure 4, all the estimated values are low. Therefore, it is all about insensitivity of costs compared to the production volume. The decline in the number of the transported passengers, the rigidity of the demand of factors and the increase in their prices are the main reasons behind this weakness of scale returns. The traditional developments of the industrial economy result in resorting to the concept of economies of scale to determine the efficient market structure. They consider that the less than "1" values of the scale elasticities justify the competitive structure of the market. Such is the case in our study. However, the recent developments prove that this is still insufficient, especially when it is about a multi-product industry. In the case of the public transport market in the region of Sfax, we can already say that the SORETRAS company undergoes a very tough competition on this market. On the urban segment, the collective taxis are in fact just providers of a highly substitutable service to that offered by the SORETRAS. These taxis are micro-enterprises that are direct competitors of the public company. Their structures, sizes, ways (illegal) with which they operate, are all factors in favor of these mode. Sfax transport company is facing an unfair competition with these taxis, which led to the fall of its share on the market. Similarly, on the interurban segment, besides the competition faced from the other public transport companies, hired cars are other rivals of the SORETRAS.

The negative effect of time on the production costs can be interpreted as a technical progress

within the company over the years. The estimated technical progress for the period of study presents quite low values (Figure 5). The average is 1.9%. Indeed, the use of such production factors remained relatively the same over the study period. The innovations at the level of the means or methods of work are too limited. The technical progress can be clearly noticeable at the level of the administrative work and of the workshops of maintenance. The use of new technologies and processes has reduced costs by limiting the workload. Since 2000, it can be observed that the elasticity of cost across time has become positive. This results from the costs increases of other variables that affect the company's operations.

Figure 5. Evolution of technical progress and technical efficiency



Source : processed by authors

The technical efficiency indicates the utilization rate of factors in the company. This rate increases on average at 75%. In other words, 25% of the factors available to the company are under-exploited or even unexploited. The SORETRAS relies on aging vehicles, the unavailability of an important part of the fleet and the obligation to satisfy the demand even when it is low, are elements which, to a great extent, explain this inefficiency of the company activities. Furthermore, it can be admitted that the SORETRAS inefficiently assigns the tasks to its personnel. A large number of the trips are aimed for schools where the use of two agents is almost useless since almost all the users have their prepaid subscriptions. It is therefore more judicious to call for a driver only.

Figure 5 shows the instability of the technical efficiency. However, this efficiency can be observed to have been on a steady decrease since 2013. The increase in the workers' salaries was related neither to the volume of their achieved work nor their productivity, which explains the drop in the efficiency score for this period. Moreover, the low efficiency value is due to an underutilization of the capital as a fixed factor; in fact, the decline in the number of seats offered during those years has had no effect on the number of transported people (Y) and on costs. The acquisition of new vehicles has not even helped in reducing fuel consumption.

Finally, all of our results highlight the several problems public transport suffers from in Sfax, such as diseconomies of scale, low factor productivity and technical progress, and loss of efficiency. This can be explained by several factors, some of which are exogenous and others are internal to the company. The exogenous factors are linked to the general macroeconomic situation, the political and social situation of the country, and the institutional and legal framework mainly in the recent past years. As for internal factors, the most important is the weak corporate governance regime.

The monopoly position of the public transport market in Sfax enjoyed by SORETRAS company is no longer economically justified. Market restructuring should be considered as soon as

possible. A better allocation of resources and better governance have to be introduced and reinforced. In this context, even partial privatization can be a solution. However, the social, political and economic framework in Tunisia seems to be unfavorable to such measures. Moreover, these problems of efficiency and poor governance characterize the functioning of all public enterprises in Tunisia while economic reforms are installed at a very slow pace.

5. CONCLUSION AND IMPLICATIONS

In the current research, we first highlighted the importance of public transport for the community. The analysis of the characteristics of the public transports' market in the region of Sfax has allowed us to extricate an increasingly significant disequilibrium between supply and demand. To explain this market dysfunction, we resorted to analyze the SORETRAS costs and efficiency. We also used the Translog variables costs function estimation for the period 1985-2018 as the means to analyze the productivity and the technical efficiency within the company. The major contribution of this research was to capture a preliminary image of the efficiency of public bus transport in Sfax - Tunisia using limited available data. This might also be one of the main shortcomings of the study. Indeed, the availability of other socio-economic data for the Sfax region could have enabled us to identify the external factors influencing the performance and efficiency of the urban transport system in Sfax.

The estimation results showed the presence of scale diseconomies. This result suggests that the company does not enjoy a natural monopolistic position. The need to open the public transport market in Sfax to competition is obvious since the SORETRAS public monopolistic position has no economic foundation. Moreover, the decline in the modal share of public transport in Sfax compared to other modes, mainly collective cabs, justifies the urgent need to open this market to competition. The relatively high sensitivity of costs to factor prices is, in fact, the result of increases in wages and fuel prices, which are not linked to changes in production. It is therefore necessary to adapt wages to workers' productivity and improve the correlation between wage increases and production growth. the reduction in energy consumption could be achieved by reducing the number of empty trips and improving vehicle maintenance. Similarly, the gain in productivity over the years is too slow. The technical progress of public transport in Sfax is actually very low. Innovation, in terms of methods and used means, is, indeed, too limited and involve only the administrative aspect and equipment maintenance. The technical efficiency is also very limited as huge production capacities are often unexploited. Numerous factors intervene to explain these results, among which we can enumerate the rigidity of demand of the factors and the increase in their prices; the syndical pressures; the aging vehicles of the SORETRAS; the unavailability of a significant number of vehicles of the fleet during the years of study; the absolute need to satisfy the required demand even when it is free or low and the unfair competition with taxis and hired cars.

A number of managerial and political implications could be drawn from this study. From a managerial viewpoint, the results inform the company management, regional and national authorities of the company's position in terms of efficiency and its scope for improving its performance (increasing production or reducing inputs to become efficient). From a political viewpoint, the study identified some external factors that have an impact on the measured efficiency but are outside the company control. Public authorities should act on these factors to help companies improve their performance. Thus, the deregulation of the public transport market in Sfax and in Tunisia in general, the structuring of bus networks and the creation of a public transport network are strongly recommended. Moreover, a deregulation of the public transport sector has become an urgent measure. However, this deregulation should by no means be seen

as privatization, given the social importance often associated with public transport. It seems, therefore, fundamental to redefine the most important objectives of the sector. This requires a capacity of a credible expertise, that is to say, a good knowledge of the technology in place and an improvement of the productive capacities and efficiency. Only when such objectives are achieved will the establishment of contractual structures prove perfectly relevant and effective. Finally, as a research perspective, we plan to collect data on the citizens' behavior in terms of demand for transport, in order to determine their needs and the improvements to be carried out to make this service more appealing.

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