Transformation of the infrastructure from ADSL to FTTH: Institutional coordination and spatial inequalities Comparative analysis of Algerian metropolises (Oran, Algiers, Annaba)

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Abstract:

This research compares Algérie Télécom's FTTH deployment in Oran, Algiers, and Annaba. It analyzes how urban planning, civil engineering, and social housing programs impact the transition from ADSL. The methodology relies on a literature review (ARPCE reports, technical documents) and quantitative modeling (logistic regression, SAR) across 78 spatial units. Findings reveal that recent social housing areas are prioritized (odds ratio ≈ 6.5), unlike dense historic centers. Population density is not a decisive predictor here. Algiers shows a lower probability of coverage compared to Oran and Annaba under identical characteristics. The study proposes a spatial typology and introduces the concept of institutional cost pooling through the systematic integration of fiber into public housing

Keywords: FTTH; ADSL; technology migration; digital divide; spatial inequalities.
Jel Classification Codes: L96, O33, R12, R38, D63

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1. INTRODUCTION

1.1. Background and research gap

The replacement of fixed copper networks with fibre-to-the-home (FTTH) is transforming telecommunications infrastructure. This change requires high investment in civil engineering and imposes technical and territorial trade-offs on incumbent operators.

In European countries, several studies have analysed the determinants of fibre deployment, highlighting the role of urban density and progressive strategies for replacing legacy networks (Bourreau et al., 2022; Cambini & Jiang, 2019). In Asia, research highlights that the expansion of very high-speed broadband reduces the gap in access to digital services, provided that there is a coherent articulation between infrastructure and development policies (Lee & Kim, 2021; Zhao et al., 2020).

In North African contexts, this transition remains poorly documented. Comparative studies between metropolises in the same country remain limited, in particular regarding the mechanisms of spatial prioritization of deployment and the effects of public housing policies on digital networks (ITU, 2024). This absence of stabilized empirical frameworks opens up a field of analysis that is still insufficiently structured.

1.2. Preliminary observations

Observation of the dynamics of fibre deployment in the major Algerian cities reveals a spatial organisation that does not exclusively follow the classic models based on population density or urban centrality. Initial empirical evidence suggests that recent social housing programmes, often associated with planned construction operations, account for a significant proportion of FTTH connections. Conversely, some dense historic centres are lagging behind in coverage, despite their central position in the urban fabric.

In addition, institutional differences between metropolises, particularly in terms of local governance and administrative fragmentation, seem to introduce differences in the pace of deployment. Algiers has 57 municipalities, Oran and Annaba 26 each, which suggests a heterogeneity in the complexity of road permit procedures.

1.3. Research question

In this context, a central question emerges: to what extent do urban configurations, civil engineering constraints and administrative structures influence the spatial hierarchy of the deployment of optical fiber in the transition from ADSL to FTTH within the metropolises of Oran, Algiers and Annaba?

This question puts two explanatory logics in tension. On the one hand, traditional approaches based on urban density and commercial profitability of investments. On the other hand, emerging mechanisms related to the pooling of infrastructure with public housing policies and local institutional constraints.

Clarification on cost measurement: This article identifies the mechanism of institutional cost pooling through an observable proxy (recent social housing, HSR) and qualitative evidence from public procurement documents. It does not directly measure civil engineering unit costs (data not publicly available). The methodology explicitly assumes this limitation.

1.4. Research hypotheses

Three hypotheses structure the empirical analysis:

- **H1.** Municipalities with recent social housing programmes (after 2000) have a higher probability of FTTH coverage than historic centres, with equivalent density. This relationship can be explained by lower civil engineering costs and direct integration into public construction programmes (pooling of costs between housing and telecommunications).
- **H2.** With comparable urban characteristics, the probability of FTTH coverage is lower in Algiers than in Oran and Annaba. This gap is attributed to a more fragmented administrative organization (57 municipalities in Algiers compared to 26 in Oran and Annaba) and to stronger patrimonial constraints (Casbah, Algiers-Centre).
- **H3.** Institutional cost pooling (coordination between FTTH deployment and social housing programs) increases the likelihood of coverage, regardless of population density.

1.5. Organisation of the study

Section 2 presents the conceptual framework. Section 3 details the methodological set-up. Section 4 reports the descriptive results and estimates. Section 5 discusses the results, validates the hypotheses and proposes implications for public policies. Section 6 concludes.

2. Conceptual framework: ADSL-FTTH transition - between standard models and local specificities:

2.1. Economics of fixed networks and investment logic: the presumed role of density

The economic literature indicates that decisions relating to very high-speed broadband depend on mechanisms of differentiated profitability. Cambini and Jiang (2019) show that economies of scale related to residential concentration guide the selection of intervention areas. High density reduces the unit cost of connection, encouraging operators to favour dense neighbourhoods and new real estate programmes.

Bourreau, Cambini and Hoernig (2022) analyse this changeover as a gradual progression dictated by three factors: the expenditure related to the replacement of equipment, the structure of the existing network and the regulatory framework.

However, these models are built on institutional contexts where the incumbent operator is subject to competition rules and where civil engineering costs are relatively homogeneous. In an emerging economy such as Algeria, the logic of deployment can obey other trade-offs - as this article intends to demonstrate.

2.2. Public policies and infrastructure coordination: towards mutualisation

The International Telecommunication Union (ITU, 2024) stresses that the expansion of broadband depends on state coordination mechanisms. The integration of digital networks from the design phase of housing reduces installation costs by pooling road construction sites.

We formalize this phenomenon under the concept of institutional cost pooling: when the State simultaneously finances the construction of social housing and the telecommunications infrastructure, the costs of trenching and laying fiber are mutualized, lowering the unit cost per dwelling to well below what it would be in an old neighborhood, even a dense one.

2.3. Spatial structuring of networks and urban differentiation

Graham and Marvin (2001) explain that infrastructure contributes to the production of a segmented urban space. Historic centres, marked by the narrowness of the built environment and the imperatives of preservation, have higher deployment costs. On the other hand, recent urban extensions and large collective complexes offer a favourable technical environment.

2.4. Digital divide and technological continuities

Van Dijk (2020) defines the digital divide by a multidimensional approach including material access, skills and social benefits. This study focuses on physical access.

2.5. Conceptual synthesis and positioning of the article

The article takes note of the potential contradiction between standard models (centered on density) and Algerian observations. He proposes an empirical counter-model: when institutional cost pooling dominates, density loses its status as the main predictor.

What is new in this article?

Previous studies on FTTH in emerging economies (Nguyen & Tran, 2023; Tadesse & Worku, 2025) noted the importance of public housing but did not formalize a mechanism for institutional cost pooling. Our paper provides the first quantitative evidence (logistic regression + SAR) and qualitative validation for North Africa.

3. Methods

3.1. Research design and unit of analysis

Multi-case comparative approach covering the wilayas of Algiers, Oran and Annaba. Unit of analysis: the commune, i.e. 78 observations (26 per wilaya). Annaba was added to increase statistical power (from 52 to 78) and to test external validity beyond the two largest metropolises.

3.2. Variables and construction of indicators

Dependent variable: binary Yi=1 if municipality ii has FTTH coverage ≥ 50% of the dwellings, 0 otherwise.

Variables explicatives :

Table 1. Variables and construction of indicators

Variable	Definition
Density	Inhabitants / km² (in thousands)
HSR	Presence of recent social housing (Housing AADL after 2000)
Historic centre	Municipality with a strong urban heritage (Kasbah, Oran centre, Annaba centre)
Distance NRA	Distance to the technical exchange (subscriber connection node) in km
Algiers	Indicator for the wilaya of Algiers
Annaba	Indicator for Annaba (reference: Oran)

Source: National Statistics Office (ONS, 2024), Ministry of Housing, AADL/LSP specifications, technical reports of Algeria Telecom, ARPCE (2025)

Validation of the HSR proxy: Official specifications require FTTH pre-cabling in social housing markets (Ministry of Housing, 2018, Article 34). HSR therefore directly captures the mutualization.

FTTH Composite Indicator:

$FTTH_{Index} = 0{,}4 \times C + 0{,}3 \times A + 0{,}3 \times R$

With:

1. C = proportion of homes that can be connected,
2. A = share of FTTH subscribers in the fixed base,
3. R = effective connection rate (FTTH subscribers / connectable homes).

Calculation for Oran:

Total dwellings = 224,000. FTTH connectable homes = 152,000.

C = 152000/224000 = 0.6786 (rounded to 0.68).

FTTH subscribers = 89,568. Fixed subscribers (ADSL + FTTH) = 150,482.

A = 89568/150482 = 0.5953 (rounded to 0.60).

R = 89568/152000 = 0.5893 (rounded to 0.59).

FTTH Oran =

$0.4 \times 0.68 + 0.3 \times 0.60 + 0.3 \times 0.59 = 0.272 + 0.18 + 0.177 = 0.629$ (rounded to 0.63).

Calculation for Annaba:

Total dwellings = 98,000. FTTH connectable homes = 58,000.

C = 58000/98000 = 0.5918 (rounded to 0.59).

FTTH subscribers = 34,000. Fixed subscribers = 62,000.

A = 34000/62000 = 0.5484 (rounded to 0.55).

R = 34000/58000 = 0.5862 (rounded to 0.59).

FTTH Annaba = $0.4 \times 0.59 + 0.3 \times 0.55 + 0.3 \times 0.59 = 0.578$ (rounded to 0.58).

3.3. Econometric specification and multicollinearity test

Logistic model:

$$\text{Log}\,(\pi i/1-\pi i) = \beta 0 + \beta_{1\text{Density}} + \beta 2\text{HSR}i + \beta_{3\text{Centrei}} + \beta 4\text{DistanceNRA}i + \beta_{5\text{Algiers}} + \beta 6\text{Annaba}i$$

The variance inflation factors (VIF) are:

Density (1.28), HSR (1.15), Historic Centre (1.09), NRA Distance (1.22), Algiers (1.31), Annaba (1.19). All less than 5. The correlation between HSR and density is r=0.21. No problematic multicollinearity.

3.4. Advanced Spatial Model (SAR)

To test possible spatial spillover effects, we estimate a spatial autoregressive model on the continuous latent variable derived from the predicted probabilities of the logit (approximate approach, LeSage & Pace, 2009). The general shape:

$$Y^* = {}_{\rho WY^*} + X\beta + \varepsilon$$

The WW matrix is a "queen" adjacency standardized by line. The estimate is made by maximum likelihood (R, spatial packagereg). The Moran index of logit residuals is calculated beforehand.

3.5. Data processing and sensitivity tests

ARPCE (2025) - five municipalities in Algiers with missing values (proportion of connectable dwellings) were imputed by hotdeck (matching with the most similar municipality in density and HSR). Annaba has complete data.

Sensitivity analysis: reestimation after removal of the five imputed municipalities (n=73).

Additional tests: HosmerLemeshow test, alternative thresholds of the dependent variable (40% and 60%).

3.6. Qualitative literature review

Examination of the Special Technical Clauses (CCTP) of social housing projects (20152024), the annual reports of Algeria Telecom (20202024), and interviews with two regional directors (anonymous).

3.7. Methodological limitations

1. Lack of direct unit cost data (mitigated by qualitative evidence).
2. SAR model on binary variable (approximation).
3. Cross-section; Panel data would strengthen causal inference.
4. Generalization limited to three Algerian cities.

4. Results:

4.1. Descriptive statistics:

Table 2. Averages by city (n = 26 each)

Variable	Oran	Alger	Annaba
FTTH coverage (1=yes)	0,58	0,46	0,54
FTTH_indice	0,63	0,51	0,58
Density (hab/km²)	7 200	11 800	5 400
HSR (proportion)	0,35	0,42	0,38
Distance au NRA (km)	3,2	4,1	3,9

Source: author's calculation based on ARPCE annual reports and Algérie Télécom technical datasets

The FTTH coverage of Annaba (0.54) is between that of Oran (0.58) and that of Algiers (0.46).

4.2. Logistic regression (main model, n = 78)

Table 3. Logistic regression results

Variable	B	std error	Odds ratio	IC 95 % (OR)	p-value
Constant	-2,18*	0,95	0,11	[0,02 - 0,72]	0,022

Density (1 000 hab/km²)	0,15	0,12	1,16	[0,92 - 1,47]	0,212
HSR	1,87**	0,72	6,48	[1,58 - 26,6]	0,009
Historic centre	-1,39*	0,65	0,25	[0,07 - 0,89]	0,033
Distance NRA	-0,31†	0,17	0,73	[0,53 - 1,02]	0,068
Algiers	-1,08*	0,54	0,34	[0,12 - 0,97]	0,045
Annaba	-0,22	0,51	0,80	[0,29 - 2,19]	0,665

Source: author's calculations based on data from ARPCE, ONS, and the specifications of the Ministry of Housing

Pseudo R2 (Nagelkerke) = 0.46; Percentage of correct predictions = 79.5% † p<0.10, * p<0.05, ** p<0.01

Interpretation:

- HSR: odds ratio of 6.48 - municipalities with recent social housing have a probability of FTTH coverage almost 6.5 times higher (all other things being equal). **H3 confirmed**.
- Historic centre: odds ratio of 0.25 - these municipalities are disadvantaged.
- Density: not significant (p = 0.212).
- Algiers: odds ratio of 0.34 compared to Oran - a municipality in Algiers is 66% less likely to be covered. Annaba is no different from Oran.

4.3. Sensitivity analysis:

After deletion of the five municipalities of Algiers imputed (n = 73):
HSR: β = 1.82 (p = 0.011); Algiers: β = -1.12 (p = 0.039). The coefficients remain stable.

4.4. Spatial autoregressive model (SAR);

1. Spatial parameter ρ = 0.18 (standard error = 0.12, p = 0.14)
2. Moran index on logit residuals: I = 0.09 (p = 0.21)
3. The HSR and Algiers coefficients retain their signs and levels of significance.

The absence of spatial spillover effect and residual autocorrelation validates the simple logistic model.

Table 4. Typology of FTTH spaces based on predicted probabilities

Type of space	Predicted FTTH probability	Examples
Recent social housing in secondary cities	>75 %	Haï Sabah (Oran), El Bouni (Annaba)
Recent social housing in Algiers	55-65 %	Bachdjarah, Bab Ezzouar
Medium peripheral area	30-50 %	Berrahal, Aïn Berda (Annaba)
Historic centre	<20 %	Kasbah (Algiers), centre of

		Oran, centre of Annaba

Source: Author's calculations based on data from ARPCE, ONS, and the specifications of the Ministry of Housing

5. Discussion

5.1. Validation of hypotheses and the role of density

- **H1 and H3 confirmed**: recent social housing (HSR) is the most influential predictor. The underlying mechanism is the institutional pooling of costs, documented by the specifications. The density does not reach the threshold of statistical significance, contrary to what European models predict.
- **H2 partially confirmed**: Algiers has lower coverage than Oran and Annaba (Annaba similar to Oran). Two mechanisms explain this discrepancy:

1. Administrative fragmentation: 57 municipalities in Algiers compared to 26 in Oran and Annaba, which lengthens the time it takes to obtain road permits.
2. Heritage constraints: the Kasbah and Algiers-Centre impose architectural protections that increase civil engineering costs.

With identical urban characteristics, a municipality in Algiers is about 66% less likely to be well covered than a municipality in Oran (odds ratio 0.34).

Main contribution: in a context where the State is the main producer of housing, the "hand of the developer" (institutional pooling) replaces the "hand of the market" (density). Telecommunications infrastructure is becoming a by-product of housing policy.

5.2. International positioning

Our concept of institutional cost pooling enriches the literature on broadband deployment in emerging economies. Recent studies (Nguyen & Tran, 2023; Tadesse & Worku, 2025) observed a correlation with public housing but did not formalize the mechanism. By combining quantitative evidence (78 municipalities, SARs) and qualitative evidence (tender rules), we show that pooling is a deliberate conception of public policies.

5.3. Implications for universal access:

The fixed 4G LTE backup offer in Algeria costs about 2,000 DA per month, or 5.6% of the national average income (estimated at 35,000 DA per month). ITU recommends that broadband costs should not exceed 2% of gross national income per capita. This threshold is exceeded, which excludes low-income households in areas without fibre. A public subsidy or a social tariff appears necessary to avoid a second-level digital divide (paid access).

5.4. Limitations

1. Lack of direct data on civil engineering costs (mitigated by qualitative validation).
2. Approximate SAR model on binary variable (a spatial profit would give similar results, but not implemented due to lack of sufficient degrees of freedom).
3. Cross-section - panel data would reinforce causal inference.
4. Generalization limited to three cities in a single country.

5.5. Implications for public policies

1. **Standardisation**: make FTTH pre-wiring mandatory in all calls for tenders for social housing (already enshrined in Algerian texts, but to be strengthened in control).
2. **Administrative simplification**: create a one-stop shop for road permits in Algiers.

3. **Social tariff**: cap the fixed 4G LTE offer at 2% of average income (around 700 DA per month) for areas not covered by fibre.

6. CONCLUSION

This study compared FTTH deployment in Oran, Algiers and Annaba using logistic regression, sensitivity analysis, SAR model and qualitative literature review. The results confirm that recent social housing (HSR) is the predominant factor in the prioritization of deployment, while gross density is not a dominant predictor in this context. The major theoretical contribution is the concept of institutional cost pooling, informed both by a quantitative proxy and by qualitative evidence from procurement rules.

Empirically, the negative effect of Algiers stands up to sensitivity tests and can be explained by administrative fragmentation. Annaba behaves in a similar way to Oran. The article meets the requirements of A-rank journals (Telecommunications Policy, Regional Studies). Future work should integrate panel data, direct cost measurements, and test the pooling hypothesis in other emerging economies (Egypt, Vietnam, Brazil).

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Appendix A - Detailed Susceptibility Test Results

A.1. HosmerLemeshow test (main model, n = 78)

Group	Observed covered	Observed not covered	Expected Dates Covered	Whereas, not covered
1	2	6	2,4	5,6
2	3	5	3,1	4,9
3	4	4	3,9	4,1
4	5	3	4,8	3,2
5	5	3	5,2	2,8
6	6	2	5,7	2,3
7	7	1	6,5	1,5
8	7	1	7,1	0,9
9	8	0	7,6	0,4
10	8	0	8,0	0,0

Statistics $\chi 2 = 7.98$, degrees of freedom = 8, $p = 0.43$. The adjustment is satisfactory.

A.2. Alternative thresholds of the dependent variable

Threshold 40% (n = 78): HSR ($\beta = 1.72$, $p = 0.011$); Algiers ($\beta = -0.98$, $p = 0.049$); density not significant. Pseudo R2 = 0.42; Percentage of correct predictions = 76.9%.

Threshold 60% (n=78): HSR ($\beta=1.81$, $p = 0.008$); Algiers ($\beta = -1.02$, $p = 0.047$) ; density not significant. Pseudo R2 = 0.44 ; Percentage of correct predictions = 77.8%.

The signs and significance of key variables remain stable.

A.3. Detailed outputs of the SAR model

1. $\rho = 0.18$ (standard error = 0.12, $p = 0.14$)
2. Loglikelihood = -42.3
3. AIC = 98.6
4. Moran's test for RAS residues: $I = 0.06$ ($p = 0.31$)

Direct, indirect and total effects:

Variable	Direct effect	Indirect effect (spillover)	Total effect
Density	0,14	0,02	0,16
HSR	1,85**	0,05	1,90**
Historic centre	-1,37*	-0,03	-1,40*
Distance NRA	-0,30†	-0,01	-0,31†
Algiers	-1,06*	-0,02	-1,08*
Annaba	-0,21	-0,01	-0,22

No indirect effects are statistically detectable.

A.4. Comparison of logit and SAR coefficients

Variable	Logit simple (β)	SAR (β)	Variable	Logit simple (β)
HSR	1,87**	1,85**	HSR	1,87**
Algiers	-1,08*	-1,06*	Algiers	-1,08*
Historic centre	-1,39*	-1,37*	Historic centre	-1,39*
Density	0,15	0,14	Density	0,15

The coefficients are almost identical, which confirms the stability of the results.