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Research article

Digital infrastructure strategies: the case of the province of Caserta

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Abstract: The digital economy and the associated productivity gains generated by the diffusion of the Internet are considered fundamental components of growth models. Scientific reflection converges in considering balanced access to digital services as a diriment factor for the promotion of competitiveness, equity, economic development and social and environmental sustainability. Although the availability of infrastructure is not sufficient to achieve the full development of the territory and the community, it is nevertheless an unavoidable prerequisite for today's and future technological and digital applications and, therefore, investigating the type of association between the presence of communication networks and the socio-economic structure of the territories is essential to understanding the very nature of multidimensional inequalities and their spatial and geographical distribution, within a framework that sees infrastructure as a conversion factor and means of development for capabilities. Based on the theories of social exclusion, the capability approach and critical theory, the research presented aims to investigate, through the analysis of a case study, the possible association between the state of progress of broadband implementation and specific territorial configurations, considering also different variables of a geographical nature.

Keywords: digital infrastructure; ultra-wideband; socio-economic dynamics; digital divide; Regione Campania; Italy

1. Introduction

The scientific debate, albeit with a diversity of approaches, converges in considering balanced access to digital services as a decisive factor in promoting competitiveness, equity, economic

development and social and environmental sustainability [1–3]. This is also the direction taken by the European Commission, which, highlighting the persistence of significant territorial disparities that characterise above all the peripheral regions of the Union and the correlated risk for social cohesion, emphasises the potential of the digital transition as an important growth engine [4].

The deployment on the territories of the positive effects referred to in the literature, however, is directly related to the widespread presence of physical infrastructure, "the foundation—the backbone and circulatory system—for the functioning of the digital world" [5].

Network-driven spatial development is a theme whose genesis can be traced back to the widespread acceptance of regional planning in the post-World War II era, when a distributed economy was considered a factor in the structural transformation and modernization of newly independent countries. It is only recently, after the economic crisis of 2008, that *Keynesian* spatial approaches have regained their traditional valence, replacing the neoliberalism based on the free-market principle that had established itself around the 1980s.

The interdisciplinary scientific debate on the role of infrastructure services and their impact on territories and communities does not always converge on the importance of their contribution to development. While some consider them an invariant [6–12] others, conversely, consider them functional to growth, regional competitiveness, private investment and employment, especially where the territorial concentration of digital infrastructures is high [13–19]. The prevalence of this current of thought is reflected in the large-scale increase in connective infrastructure spending and the involvement of government institutions, multinational corporations, development banks and consulting firms attracted by the cheap capital and low interest rates associated with such investments [20]. However, the direction of causality, more specifically between the Internet infrastructure and regional economic development, is an open question in the relevant literature at least for the past two decades [21,22].

A study conducted by Lorenzetti and Matteucci [23] highlighted, through the use of socio-economic indicators, the positive correlation between the Internet infrastructure and regional economic development. In fact, if the network can be decisive both in attracting investment from outside and in increasing the productivity of existing economic realities, the role played by pre-existing socio-economic development in the locational choice of digital infrastructure cannot be denied. Analysing the direction of this relationship can provide, therefore, valuable information for the policy agenda: a causal relationship oriented by infrastructure to local economic development, could justify the inclusion of significant investments in the policy forecast; an inverse relationship, on the contrary, would see pre-existing territorial development as an important driver in location choices with the consequent risk of making infrastructure investments that are not homogeneous and respond to market logic rather than territorial cohesion models [24–26]. The policies of liberalisation, deregulation and introduction of competition introduced since the 1980s, mentioned above, fuelled concerns that territories that were unprofitable for service operators could be excluded from service provision [27,28].

The Commission, therefore, in the context of digital policies, in order to reduce possible market distortions and manage the risk of social exclusion, has expressed the need for interventions that, according to the principle of subsidiarity and taking into account national differences, can provide a social safety net where the market alone is unable to guarantee democratic access to services, especially for citizens residing in marginal areas, with low incomes or with disabilities. This approach is an expression of the widespread belief that the mitigation of infrastructural disparities represents an opportunity to develop the externalities essential to processes of innovation and economic development and to compensate for the locational disadvantages of the most remote and marginalised areas [29].

The risk of the theoretical framework outlined, however, is that of considering the digital infrastructure as an automatic generator of development: many have argued that the modernisation of certain areas would automatically lead to a "transfer" of competitive advantages to more disadvantaged territories [30]. Other studies, on the other hand, have pointed out that poor infrastructure and digital governance can lead to a strengthening of agglomeration advantages and the consequent creation of new territorial gaps [31]. Therefore, it can be argued that, as with any infrastructure [32,33], digital infrastructure is a necessary, but not sufficient, condition for growth [34–37].

The digital infrastructure, in fact, appears to generate important positive economic spillovers where precise contextual factors integrated with global production and trade networks exist, where a skilled labour force that is not excessively expensive is available, where a regional innovative environment is present (e.g. presence of service industries, presence of university students number of high-tech patents) [38]. In the case of territories characterised by greater socio-economic deprivation, development is primarily related to investments in social infrastructure that, integrated with actions of an economic nature, can reverberate on an increase in regional income [18]. The availability of infrastructure, while not sufficient to achieve the full development of the territory and the community, is nevertheless an unavoidable prerequisite to fully realise the opportunities offered by the knowledge society. In this context, therefore, the criteria and motivations underlying the allocation choices of digital infrastructures assume great importance.

In addition, reasoning on the topic, in order to better understand how the design of technologies, as well as policies and actions aimed at their diffusion, depend primarily on political strategies and ideologies rather than on social or economic factors, an analysis of critical theory is introduced that has its roots in the Frankfurt School and in particular in the studies of Marcuse, Adorno, Habermar Horkheimer. This theory through a philosophical-scientific approach, aims at the critical analysis of society as a whole, its structures and functions, thus focusing on its components. A further goal is the pursuit, through a careful critique that unveils the mechanisms of power and oppression, of the emancipation of the human being. [39]. Critical theorists emphasize the practical nature of scientific research, which is therefore based on praxis.

From this perspective, the emancipation of the person is realized concretely in circumstances of oppression or marginalization. [40]. Following the acceleration of the technological-digital revolution, many critical theorists have sought to analyze its impact on society and human beings. In particular, critical theory has been concerned with investigating the possible threats posed by the technocratic digital system to people's agency, revealing how it conceals superstructures of power and proposing more participatory and democratic approaches to technologies, their design and dissemination. [41].

The paper is thus also structured around critical theory, highlighting how with the development of new technologies, the threats posed by digital technocracy to the harmonious development of communities require new forms of awareness and participation in infrastructural democratization interventions in territories, to avoid new forms of exclusion and marginalization.

The aim of the presented research was to investigate the relationship between the implementation of digital infrastructure and the and socio-economic structure of territories, also considering central variables of a geographical nature. The work is divided into two macro-sections. The first briefly describes the institutional framework within which digital policies are deployed, with a focus on actions related to the implementation of ultra-wideband infrastructure. In the second section and through a case study that takes as its statistical unit the so-called white areas in which the municipalities of the Province of Caserta fall, aims to investigate the relationship existing between

certain socio-economic variables and the political-administrative decision-making processes in digital infrastructure actions.

2. National digital strategy

The DESI report of 2020 mercilessly depicts Italian inefficiencies, delays and shortcomings in relation to the implementation of digital infrastructure. The delays, which are primarily attributable to the difficulties in accessing existing networks and obtaining the necessary authorisations to carry out the work [4], can however also find a more ancient motivation in the Italian telecommunications regulation which, over the years, has imposed a long series of limitations that have prevented the effective deployment of strategies [42,43].

The monopolistic condition that persisted at least until 2013, and which strongly contributed to an uneven infrastructural situation, manifested itself in all its drama during the pandemic: with the introduction of the mobility-restrictive measures and the radical digital rethinking of everyday activities, many households suffered from increased marginalisation especially where the digital divide was combined with socioeconomic inequalities, confirming the link between digitalisation and human rights [43–45].

Mitigating or, where possible, eliminating the "infrastructural barriers" that have fuelled the digital divide in many areas of the country was the main objective of the Ministry of Economic Development's "National Broadband Plan" (Art. 1, Law No. 69 of 2009). The interventions defined by the Plan within the framework of the EU guidelines translated, as a priority, into the construction of infrastructures (cable ducts and optical carriers) necessary for the development of broadband in the marginal areas of the country and into the possibility of incentivising the development of access networks, where these did not allow the use of basic broadband service. The next step was taken in 2015 when, following the launch of the European Digital Agenda, the Council of Ministers approved the "National Strategy for Ultra Broadband", taking into account what had been specified in the previous plan and integrating the key objectives contained in the European policy documents, i.e. 100Mbps connection for 85% of the population (especially in areas of public interest), universal coverage of 30Mbps connection and fast fibre in industrial areas.

With the National BUL Strategy (2015) and the resulting "National Ultra Broadband Plan", a state aid scheme was adopted, approved by the European Commission in June 2016 (Phase I) and April 2019 (Phase II), aimed at supporting the implementation of ultra-wideband for the realisation of an inclusive digital society. To facilitate the allocation of resources and the monitoring of implementation, the Plan envisaged the subdivision of the Italian territory into four clusters, defined according to macroeconomic and infrastructure planning indicators. On the basis of this subdivision, in a first phase, interventions are envisaged to be implemented where private operators do not consider the investment sufficiently profitable, the so-called white or market failure areas ("White Areas Plan"). Only later will ultra-fast networks be deployed in those territories where one or more ultra-wideband networks are already present, the so-called black or grey areas. The objective of digitisation is also a priority in the National Recovery and Resilience Plan (NRP), which, under Mission 1, defines the methods, investments and target sectors for technological and digital modernisation processes.

Table 1. Number of FTTH municipalities of the "White Areas" Plan by Italian regions (2021). Sources: elaboration by the authors [47].

Region	Number of FTTH municipalities	FTTH Commons/Total Region Commons ratio
Abruzzo	174	57%
Basilicata	103	78,6%
Calabria	238	58,9%
Campania	449	81,6%
Emilia-Romagna	242	73,3%
Friuli-Venezia Giulia	182	84,6%
Lazio	329	87%
Liguria	201	85,8%
Lombardia	1.147	76,1%
Marche	221	98,2%
Molise	132	97%
Piemonte	1.115	94,4%
Puglia	223	86,7%
Sardegna	135	35,8%
Sicilia	318	81,3%
Toscana	210	76,9%
Trentino-Alto Adige	214	75,8%
Umbria	78	84,7%
Valle d'Aosta	68	91,8%
Veneto	453	80,4%

With reference to infrastructure, the NRP, in full continuity with the planning of the "National Ultra Broadband Strategy" and with European objectives, identifies the resources needed to achieve 1 Gbps connectivity throughout the country by 2026. With this in mind, a total of €40.32 billion has been earmarked for the implementation of Mission 1 on the digitisation of the country, to be divided into three priority components: C1. Digitisation, innovation, and security in PA (€9.75 billion); C2. Digitalisation, innovation and competitiveness in the production system (€23.89 bn); C3. Tourism and Culture 4.0 (€6.68 bn). Component 2, whose general objectives include the realisation of strategic investments for fibre connections and 5G, is divided into further actions. The realisation of the ultra-fast network is defined in Investment 3, which, ascribable to the Italian Strategy for ultra-wideband "Towards the Gigabit Society" and articulated in 6 further operational plans, provides for an allocation of €6.71, about 28% of the entire funding allocated to Component 2 (Figure 1).

For the purposes of this research, of particular interest is the "1-Giga Italy Plan" which, with a forecast expenditure of about 3.8 billion euros, aims to provide connectivity to about 450,000 real estate units falling in areas of market failure, which, as recalled by the previous "White Areas" Plan, are those territories in which there are no infrastructural coverings such as to guarantee a stable connection, equal to or greater than 300 Mbit/s in download, nor are such coverings expected (for the next 5 years). The intervention model envisaged is gap funding, or "incentive funding", which envisages additional funding for operators already present in the areas of interest of the Plan.

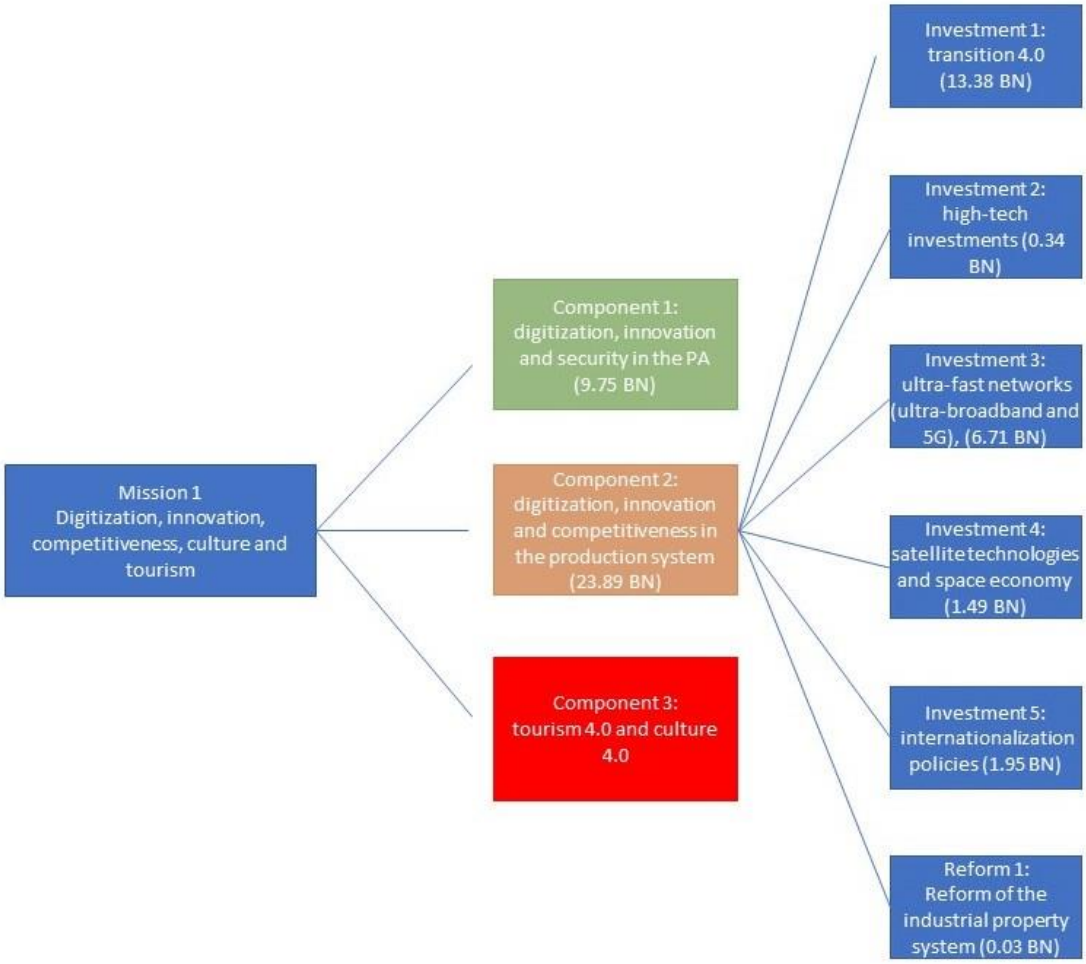

Figure 1. Articulation of Mission 1 and Component 2 of the NRP. Source: elaboration by the authors [46].

The municipalities already served by BUL are mainly concentrated in the North-West and North-East regions of the country (87.03% and 78.53% respectively). Counting the two northern divisions together, the average reaches 83%, compared to values for the South and the Islands of 76% and 58.55% respectively (calculated together, 72.11%). This situation indicates a clear national gap that can only be explained by the economic and political cruciality and strategic nature of the Northern regions compared to the South where digital marginality persists, albeit mitigated (Table 1).

3. The case study—digital infrastructure in white areas in the Province of Caserta

Having delimited the theoretical framework and the institutional references that direct infrastructural interventions, we proceeded to investigate the relationship between spatial planning and political—administrative decision-making factors in the digitisation processes of the territory. Verifying the possibility of an association between these dimensions can be considered a first step towards understanding the relationship between infrastructural processes and territorial realities. In particular, on the basis of previous research carried out in this direction, we set ourselves the objective of analysing the state of progress of ultra-wideband (FTTH) and some socio-economic and

geographical variables. While there are certainly those who would not consider advanced technologies, there are also those at any price who consider them crucial to achieving a better quality of life, also highlighting four factors, such as geographic disparities, profit discrimination, technology deployment costs, and socioeconomic factors, that play an important role in the digital divide [48–51].

3.1. Methodology

Given the qualitative and quantitative nature of the variables under study, and for greater completeness and accuracy in the interpretation of the data, the statistical association was assessed through the use of Pearson's Chi Square, together with other instruments such as Kramer's V index, p-value and Fisher's exact test. In statistical analyses, this test is used to verify the existence of an association between two quantitative and/or qualitative variables of interest X and Y by means of contingency tables. By comparing the observed frequencies with the expected frequencies in the case of independence, it is possible to derive a measure of the association between the variables: if they are very similar, the test will not detect any association; otherwise, it can be concluded that there is an association between the variables at the set level of significance. For the present research, the test was carried out for each pair of variables (X, Y), varying X between the variables listed above, in class-grouped ways, and considering Y = progress.

Once the value of the Chi-square test had been deduced, it became useful and necessary to calculate the pvalue and to proceed to Fisher's exact test, also in view of the low number of frequencies in certain cells of the contingency tables. Their degree of magnitude determines a higher or lower level of significance of the association. The smaller the p-value is compared to the set significance level, conventionally 0.05, the more statistically significant the association is. Therefore, where Fisher's p-value and p-value register very low levels, the hypothesis of independence between the variables can be rejected. For a more careful and accurate statistical analysis, also aimed at measuring the degree of association between the variables, the Cramer's V index was considered useful. Its result can range from 0 to 1, which makes the comparison between the different pairs of variables effective.

Furthermore, in the case of the present research, the index was useful for varying the number of classes into which the socio-economic variables were divided. Indeed, in order to understand which class division would have ensured greater interpretability and significance of the results, the observation had to take into account the variability of the available data in order to construct the frequency distributions appropriately. For each quantitative variable, it was necessary to apply a different logical criterion. An example of this is the altitude of the municipalities, which, in the case under consideration, does not record differentiated values: therefore, the classes were constructed based on the median (121.5 metres) and the ninth decile (423.9 metres). Likewise, the seventh decile was used for the variable of distance to the provincial capital, given the relative homogeneity of the spatial data. It should also be noted that the variable of industry turnover was manipulated more due to the absence of some data (10 values out of 80 municipalities), which were omitted from the calculations.

The area under analysis is represented by the 81 municipalities in the white areas of the province of Caserta, which account for 78% of the provincial municipalities and just over 18% of the 449 municipalities in areas of market failure throughout the entire region and mainly located in the inland areas (Figure 2). The study area is characterised by a low quality of life, a strong housing shortage and a demographic structure strongly skewed towards the younger classes. Nevertheless, or perhaps precisely because of these socio-economic conditions, the entrepreneurial vocation, with

approximately 6.5 enterprises per km^2 and 10 enterprises per 1000 inhabitants, is particularly pronounced. Businesses, mainly located in the industrial district close to the metropolitan city of Naples, show a fair degree of vitality: the differential between births and deaths, thanks to the first component, appears positive, settling at +1.47% for 2018 (i.e. 14.7 more businesses for every 1,000 registered at the beginning of 2018), a value that has ensured Caserta fourth place among Italian provinces with the highest growth in the number of businesses [52].

In spite of this good vocation for enterprise, entrepreneurial initiatives do not appear to enjoy adequate solidity: the percentage of new companies, born between 2016 and 2018, that closed in 2018 is 23% (with a peak in the tourism sector of 31%), against a national average of 19.3%. Similarly, critical is the mortality rate with 5.56 deceased businesses for every 100 existing at the beginning of the year: one of the worst levels in the country [52].

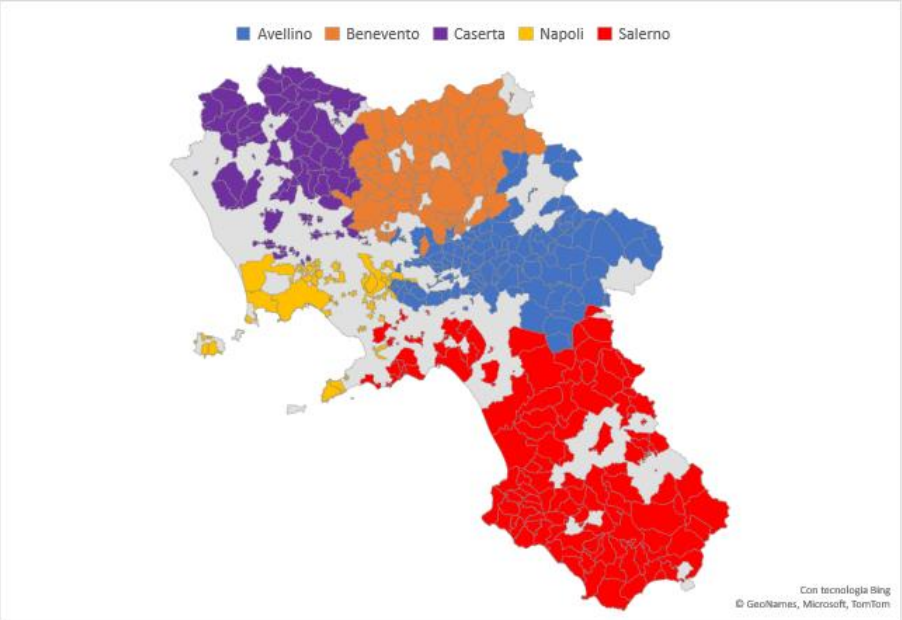

Figure 2. White areas of Campania (2022). Sources: elaboration by the authors [47].

In these territories, the state of implementation of ultra-broadband worksites, according to data made available by Infratel and constantly updated by Openfiber, is very articulated and can be schematically described with the following phases: Final Design, Executive Design, Execution, Completed Works, Testing and Finished (Figure 3).

Based on the analysed literature, it was chosen to identify the status of construction sites as the nominal variable [48–53]. The low number of observations and the need to make the results of the statistical analyses more interpretable, necessitated a grouping of this variable. The following structure was therefore used:

- Phase 1. Design: this refers to the Final and Executive Design phases.
- Phase 2. Execution: this refers to the Execution phase.
- Phase 3. Concluded: this refers to the states of Concluded, Accepted and Finished Works, which represent the very last phases of the life of the construction sites.

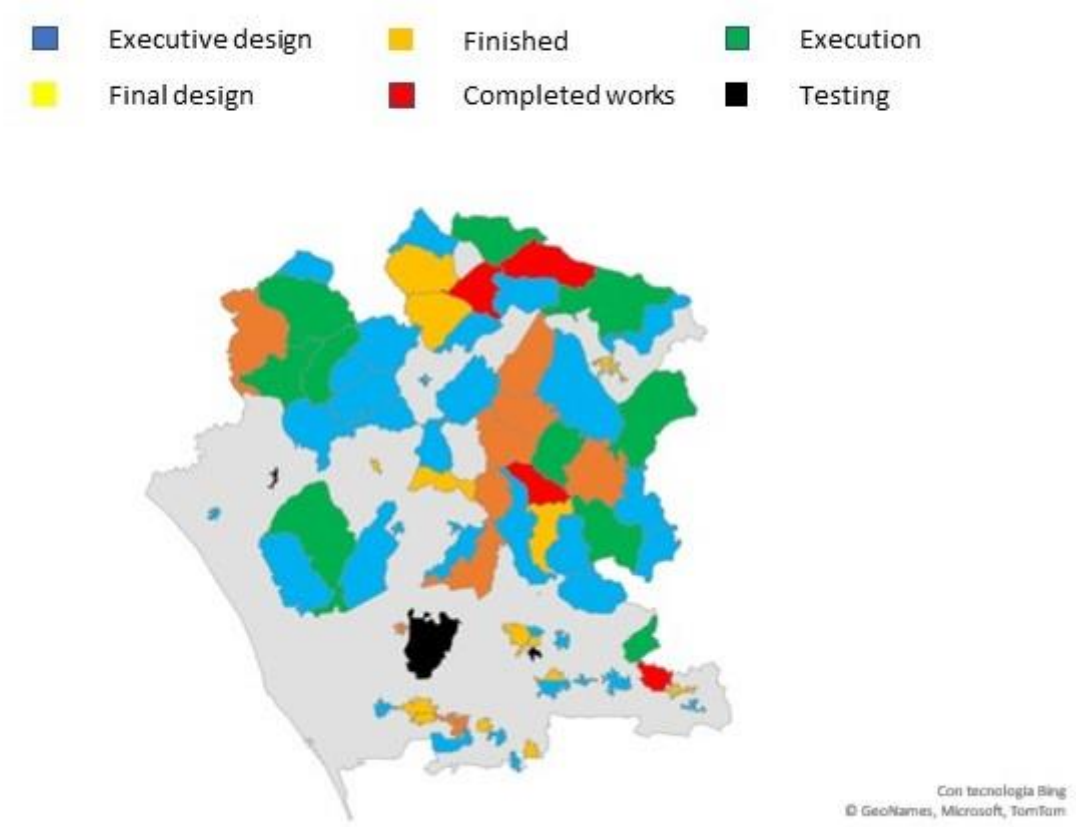

Figure 3. Status of works in the white areas of the Province of Caserta (2022). Sources: elaboration by the authors [54].

The socio-economic variables considered, which are in addition to spatial variables and which can be partially traced back to social exclusion theory and the insights of Reddick, Enriquez, Harris, and Sharma [51]; Whitacre and Gallardo [49], are as follows:

1. Spatial variable. Among the various territorial characteristics, the altitude level of the municipalities under examination and the distance from the provincial capital (CE) in km (as the crow flies) were taken as proxies. The conformation of the territory, in fact, and the distance from the centre, could lead to bureaucratic and executive delays in the implementation works.

2. Demographic variable. Data were collected on the working-age population of each municipality, divided into five-year classes (2020 data). In order to make the analysis more relevant and meaningful, given the low population size in some municipalities, the five-year distributions were grouped into three classes: youth age class, 15 to 34 years, adult age class, 35 to 54 years, and advanced age class, 55 to 64 years. Particular attention was paid to the youth age group: from some studies, in fact, the availability of the infrastructure and the consequent access to BUL also seems to depend on the age of the population [53] and, for the reverse reason, the older age groups that are less likely to adopt technological devices were excluded. Finally, gender-related variables were also taken into account, with the masculinity ratio being taken as a proxy.which summarises the relationship between the number of males and females in a given population [52].

3. Economic variable. Three sub-variables were used to calculate the association: the taxable income of individuals for each municipality (2019), as a proxy for the economic situation of the families in the area; the turnover of industry and that of services (2017), as a proxy for the level of wealth of the same territories [55,56].

4. Cultural variable. The literature shows that the level of education is also among the variables influencing access to digital infrastructures. Therefore, the aggregate number of residents, by municipality, who have obtained a secondary school degree, or a vocational qualification, or an ITS higher technical diploma, or a tertiary level tertiary degree, were taken as proxies.

3.2. Discussion

The Chi Square and Cramer's V statistical tests (Table 2) suggest there is a low relationship between the variables, with degrees of association too weak to assert a high connection between them. In other words, there is little relationship between the state of progress of BUL implementation, a proxy for digital infrastructure policies and specific socio-economic configurations of the territory. However, it is possible to indicate some substantial differences thanks to the results of the p-value and Fisher's exact test, which enriched the findings with additional facets. Table 2 shows the values of each statistical test for the various variables, to outline some considerations.

Table 2. Pearson Chi Square and p-value. Source: elaboration by the authors.

Quantitative variable	Chi Square	V of Cramer	p-value	Fisher's p-value
Class 15–34 years (2020)	7.78	0.22	0.1	0.1
Class 35–54 years (2020)	6.56	0.29	0.04	0.04
Class 55–64 years (2020)	6.56	0.29	0.04	0.04
Total resident population considered (2020)	7.78	0.22	0.1	0.1
Masculinity ratio (2020)	3.92	0.16	0.42	0.39
Personal taxable income (2019)	10.2	0.25	0.12	0.12
Altitude in metres	8.67	0.23	0.07	0.04
Distance to provincial capital (CE) in km	7.84	0.22	0.1	0.40
Industry turnover (expressed in thousands of €, 2017)	9.87	0.26	0.04	0.03
Services turnover (expressed in thousands of €, 2017)	10.54	0.26	0.03	0.03
Education (2019)	7.64	0.22	0.10	0.12

The demographic variables show some differences: in particular, the older age groups (35–54 and 58–64 years) show lower levels of significance of the association (p-value and Fisher's p-value) than the younger age group (15–34 years).

These results suggest that advancement status is weakly correlated with youth age, compared to a higher significance of the association for the adult classes, in contradiction to what the literature suggests. Similarly, the test did not reveal a consistent association for either the gender-related variable or the variable related to the level of education (again, the literature suggested a stronger connection between higher levels of education and greater Internet use). The data, on the other hand,

showed higher levels of education in municipalities in the design or execution phase (Phase 1), with the sole exception of the municipality of Alvignano.

In contrast, for the economic and geographical variables, the statistical analysis found a low association, but different levels of significance. Altitude has lower p-values, indicating that a connection between it and infrastructure levels cannot be excluded. Indeed, the data showed that the municipalities in the final stages of the work are concentrated on hilly and/or mountainous areas and are characterised by a low level of industrial turnover and individual income. Thus, the data confirm the hypothesis that the state of progress of works, an expression of administrative policies for digital infrastructure, does not follow logics dictated by the socioeconomic configuration of the territory, but rather different motivations, not paying attention to the needs and peculiarities of places.

The analysis of the case of Caserta, although obviously compressed by the smallness and particularity of the territory, confirms the hypothesis that the logic of territorial intervention may not respond to the priorities expressed by the territories.

4. Conclusions

According to Critical theory, as stated, the design of technologies, as well as the policies and actions aimed at their dissemination depends above all on political strategies and ideologies rather than on social or economic factors.

With the development of new technologies, the threats posed by digital technocracy to the harmonious development of communities require new forms of awareness and participation in infrastructural democratisation interventions in territories in order to avoid new forms of exclusion and marginalisation. Based on the theories of social exclusion, the capability approach and critical theory, the research aimed to investigate the relationship between socio-economic variables and administrative policy decision-making processes in the digital infrastructure processes of marginal and lagging territories and, at the same time, to develop a pilot analysis and methodology that could be replicated in other territorial contexts.

On the basis of the evidence of the research, focused on the municipalities falling within the white areas of the province of Caserta, it can be stated that, albeit with some distinctions concerning some variables, the actual specificities and needs of the places were not the main drivers of the BUL implementation actions. In fact, in the case under study, these digital infrastructural actions were based on a presumption of neutrality of geographical space. In this specific case, it seems necessary to refute the claimed neutrality and objectivity of the observation, since spatial dynamics should be considered as influencing factors for spatial development and policy orientation [57,58], especially where there is a past condition of backwardness and a consequent need for rebalancing, as in the case of market failure areas.

As is evident in the literature, bureaucratic and political motivations and processes, or even simply inability or indifference, have more weight, thus reinforcing the assumptions of critical theory that the design of technologies, as well as the policy and planning of their use, depend more on strategies and ideologies than on the concrete and composite reality of territories [59]. It follows that a more place-based approach must consider policies as steering tools in economic and social development processes, capable of catalyzing redistributive spillovers for greater territorial cohesion.

Attention, therefore, to the peculiar characteristics of territories is not marginal but central to the development of effective strategies and action plans, and it is to be hoped, therefore, that future policies and action plans will follow more participatory models, aimed at the transparency of processes and the uniform distribution of the opportunities deriving from them.

Conflict of interest

The authors declare no conflict of interest.

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