Paper

Problems of Broadband in Rural Areas in Light of the BReATH Project Experiences

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Abstract—Some lessons learned from the EU project "Broadband e-Services and Access to the Home" (2005–2007) are presented concerning the broadband development in rural areas. In particular, the paper discusses the common problems of broadband deployment in the rural environment, various aspects of stimulating demand for broadband, the limitations of public aid and, most importantly, the problems of techno-economic analysis.

Keywords— broadband initiatives, demand, rural area, techno-economic analysis, WiMAX.

1. Introduction

This paper presents selected results of the research done within the framework of the EU project BReATH (Broadband e-Services and Access to the Home), which has run from 2005 to 2007. The project involved partners from several EU countries, among others – the National Institute of Telecommunications (NIT) from Poland. The project aimed at transferring know-how and good practices in broadband (BB) deployment to EU new member states (NMSes).

The scope of the research was rather wide. The project did not surround itself to rural areas. The research activities varied from techno-economic analyses of broadband deployment in selected areas in Europe, done on the base of mathematical simulation models to sharing experience of various broadband market players (the incumbent operator, their competitors, the local authorities, the regulator, research institutions, etc.) during numerous workshops in the partners' countries and other discussion fora like special interest groups, meetings with local authorities. Thus the outcome of the project is rather rich and the purpose of this paper is to discuss the lessons learned with respect to a particular, narrow area. Namely, we shall concentrate on the Polish specificity. Also, we shall direct our considerations to rural areas. There, the problem of broadband development is most crucial due to natural technical and economic difficulties and, consequently, the threat of digital-divide is most real.

Due to the summary character of this paper the author will often refer to more exhaustive papers and documents in order to give a more precise discussion or substantiation of the claims. It must be also stressed that some of the claims do not come from the author's own work or experience, they might be, for example, opinions expressed repeatedly by broadband professionalists during workshops and, as such, seemed valuable to the author of this paper.

The BReATH project will be shortly summarized in Section 2. Section 3 reports selected findings from the project, grouped in subtopics (like demand stimulation) techno-economic analysis made by the National Institute of Telecommunication during the project and lessons learned from it are described in Section 4. The whole paper is summarized in Section 5.

2. The Outline of the BReATH Project

The BReATH project [1] was constituted by the following 7 partners: Eindhoven University of Technology (the Netherlands), Research and Education Society in Information Technology (Greece), Gtel Consultancy Limited (UK), National Institute of Telecommunications (Poland), Institut Jozef Stefan, University of Ljubljana (Slovenia), Institute of Photonics and Electronics (Czech Republic), European Institute for Research and Strategic Studies in Telecommunications GmbH (Germany), accompanied by about 20 affiliated partners – companies, institutions, government bodies, supporting the research.

The project's goal, to transfer know-how and good practices in broadband deployment to NMSes, was realized by various research activities:

1. Benchmarking the current status of broadband development in the 7 partners' countries, including the broadband infrastructure, the internet services using broadband, the legal circumstances [2], [3]. Also, the survey of Internet access technologies was made.

2. The analysis of best practice case studies, i.e., the outstanding successful broadband initiatives; with the emphasis on the business models which had been taken [4]. The broadband development, either in Europe or outside it, seems not to have a form of a monolithic process, conforming to a single theoretical model or some regulation act. Rather, it is formed by individual initiatives of communities, cities, regions, programs of various spread, etc. Thus analyzing case studies is of utmost importance to our understanding of broadband development.

3. For some of the case studies also illustrative *techno-economic analyses* was performed, that assess their financial viability and approximate the amount of the necessary network equipment [5]. Such analyses use precise mathematical models, usually simulation

models. One of the analyses, performed by the National Institute of Telecommunications for the city of Łódź (Poland) and its surroundings, will be further reported, not only to show the results regarding the particular area but also to describe the process of performing techno-economic analysis, the problems which are then met, and the profits from having done such analysis.

4. Exchange of experiences of various actors of the broadband market. Having stated that the broadband development hardly conforms to a single theoretical model, we appreciated such experience. Workshops have been organized in the project partners' countries. They gathered scientists, representatives of the incumbent operators, other telecommunication companies, authorities (both the regulator and local authorities), non-governmental organizations (NGOs). Two of the workshops were organized in Poland [6], [7] and we shall mainly refer to the findings gathered from them. One of the workshops was much appreciated by the project partners for having revealed the important difficulties in broadband development. The interaction between various broadband players also took other forms: specially created Internet groups, cooperation with particular local authorities (e.g., Łódź, Podlasie).

5. Preparation of instructive materials for authorities willing to undertake a broadband deployment initiative, together with the *road maps* for particular partners' countries that suggests that some levels of several broadband development indicators (penetration, and others) should be attained at the specified points in the future [5], [8].

3. Problems and Solutions for Rural Areas

3.1. General Problems

Specialists name the common problems of broadband rollout in rural areas [6]. The low population density often prevents the operators from making investments there, since no viable business case is possible. Local authorities may have limited technical background, as well as too limited financial and organizational possibilities to conduct broadband initiatives.

Low density is not only a business obstacle but also a technical obstacle. Let us take an example of one the most natural technologies for rural areas, i.e., the digital subscriber line (DSL) technology, that may require only moderate changes to the existing copper telephone infrastructure in order to make it also possible to transmit digital data. Due to low population density, subscribers must be fairly distant from the exchanges. However, the more is the distance, the less band can be offered – see Table 1 (repeated after [3]). With the radio WiMAX (worldwide interoperability for microwave access) technology [9], similarly, the more distant from the base station the subscriber is, the less band the subscriber can use. In both the cases the reason is that with the growth of the distance, the signal attenuation grows and we must switch to more and more robust modulation types.

Table 1
Asynchronous DSL (ADSL) transmission reach versus bandwidth for 0.5 mm copper cable

Band (up/down) [kbit/s]		Reach [km]	
ADSL	ADSL G.Lite	ADSL	ADSL G.Lite
2048/16	64–1563/ 32–512	4.8	5–6
4096/160	–	4.0	–
6144/384	–	3.7	–
8129/640	–	2.7	–

In Poland, the relatively big land masses, together with the heritage of the monopolist position of the incumbent operator cause an observable neglect of the telecommunication access infrastructure, expressing in low broadband penetration in villages (Table 2), and even some neglect in voice services.

Table 2
Presence of Internet access in households in July 2004 [3], [10]

Space	Broadband (over 128 kbit/s)	Analog modem
Total	32%	36%
Cities	37%	35%
Villages	9%	44%

In turn, Poland has a quite well developed skeleton optical network [3]. Moreover, we should not overlook the cost barriers to broadband on the customer side. Beside the service monthly Internet access fee, we should take care about the costs of a computer set itself which, being similar to the average salary, might be a barrier to some households. Local authorities, which often have also a neglected road or water supply infrastructure, prefer improving it instead of rolling out broadband.

On the technology side, we must point at an interesting variant of DSL, used by Polish incumbent. Its reach is up to 8 km from a switchboard. However, it has a band up to 115 kbit/s, so it is disputable whether it can be called broadband (today's broadband definitions require at least 128, 256, or even 512 kbit/s). Thus, WiMAX solutions seem more prospective.

The Cornwall case – an interesting example of broadband initiative for rural areas was presented during a BReATH workshop [7, presentation by J. Cowans]. This example will

be present throughout the rest of this section. Now we call this example in order to show that the neglect of some rural areas by Internet providers is neither the specificity of Poland, nor of NMSes.
Cornwall is a peripheral, rural county in UK, geographically isolated. It has half a million inhabitants.
It used to be a mining area, producing china clay, tin and copper. Through the 20th century mining has declined.

In 1999 its market position was limited, the gross domestic product (GDP) was below 60% UK average and below 70% of EU average; the emigration became a problem. Cornwall was then not only poorly interconnected but also had no prospect of being on any broadband operator's map. Moreover, the computer skills of the inhabitants were poor.

3.2. Problems with EU and Other Public Aid

Public aid, including EU structutral funds, seems a natural remedy for areas where private investments in broadband seem not profitable. However, several drawbacks of such aid in its current state have been pointed during the workshops [6], [7]:

- Mr Sadowicz stated that the structural funds in Poland, which were intended to lower the digital divide, may in practice increase it, since they prefer large projects [6]. Mr Sadowicz with his organization Cities on Internet investigated the use of funds from *Integrated Regional Development Operational Programme, Measure 1.5* (directed to building the information society). In the period of 2004–2006 over 202 broadband projects were granted funds by the programme. In general, poorer regions got less or smaller grants (with the difference approaching PLN 42 million = EUR 10.5 million, which already exceed the total budgets of some regions). Moreover, only 12 of the projects could be considered "authentic" in that they do not limit themselves to particular beneficiaries, like public administration, schools, etc. These "authentic" projects were run only in half of the regions.

- The usual complains about procedures complexity and inability of some local governments to apply for structural funds were rosen.

- Using the existing regions in allocating funds may be irrelevant. One from the audience, prof. T. Grzeszczyk, gave an example of the Mazovia region. As containing the capital of Poland, it has a relatively big GDP, on average, thus its position while applying for public aid is weak. But it is enough to go a few tens kilometers away from Warsaw to observe one of the deepest poverty levels in Poland.

- Some hope for rural regions may be attributed to the European Commission's concept of universal service [7, presentation by P. Kenney]. With this concept, where the market fails to assure broadband connections, an intervention could take place (whose framework cost would amount to 50 euro cents per EU citizen). However, at least until 2009, this concept is not in power and countries are not very enthusiastic about introducing it.

The remedies must be found to all the above problems; some hope is connected NGOs supporting the local authorities in acquiring public funds (like Cities in Internet and Information Society Building in Rural Areas – e-Vita, mentioned later).

3.3. Stimulating Demand as a Key to Success

One of the most important findings of the BReATH project was the importance of the economic demand stimulation. Instead of funding building the network infrastructure by local authorities (or consortia including them) we can have it done by the network operators/providers present on the market. However, to make their business case viable, we could increase the demand by donating the broadband subscribers with the use of public funds. Directing public funds to the subscribers instead of the operators seems to less disrupt the market mechanisms. More importantly, such a concept is firmly supported with practical cases.

The Cornwall case success lies – according to their authors – in a suitable demand stimulation. The ACTNOW project, that brought broadband to Cornwall, was started in 1999 and was a sort of public-private partnership, using EU funds (the main stakeholders were, except of the authorities, the incumbent, British Telecom (BT), the Regional Development Agency, the Business Link company). ADSL was chosen as the most viable technology at that time.
The main idea of the project was to stimulate broadband demand by subsidizing small and medium enterprise (SME) connections. The SMEs that subscribed to broadband were for two years donated 50% of their subscription costs. Extensive campaigns were conducted to convince the SMEs that broadband is what can leverage their businesses. A part of these campaigns was monitoring local GDP and some other business activity merits (also, there were voices for directing public funds to other goals: building roads, perhaps an airport or a university and the local community was persuaded that broadband would give better economic effects). The businesses were given also an extensive support in using services.
The project amounted to £12.5 million has been run in several stages. The targets of covering 50% of businesses and modernizing exchanging offices have been exceeded with a business coverage of 99%. Above 5000 jobs have been created and safeguarded and the overall take up in Cornwall has reached 30%, which exceeds the national average of 25%. The 80% of the surveyed businesses now consider broadband critical for their activities. Most Cornwall

business employ 2–5 people. There is higher employment, inward investment, and even some immigration.

Some similar case is the case of Polish community of Stoszowice [6, presentation by Patryk Wild]. Stoszowice is located in the Lower Silesia region. With 5700 inhabitants and 28% unemployment in 2004 it has one of the lowest tax incomes in the area. Sewage and water supply systems were lacking but the mountainous and rural landscapes, and unpolluted environment have potential of attract tourists. The TP SA ignored Stoszowice in their broadband development strategy, Stoszowice did not possess any Internet connection.

The initiative of Stoszowice was co-funded by the Ministry of Science and Information and by the partners of the e-Vita programme, Cisco Systems, the Rural Development Foundation and the Polish-American Freedom Foundation. The e-Vita and Cisco brought also a considerable technological and organizational know-how inside to the initiative.

The demand was stimulated by making the Internet access free of charge for 2 years. Patryk Wild, the president of Stoszowice, who is a young and vivid person, was able to convince the citizens the profits from broadband to the extent that they preferred investing broadband over investing in roads. The network has been promoted via community newspaper and community meetings. A communal educational portal has been built and is still being developed. It is directed to parents of kids from communal schools and kindergartens as well as to teachers and pupils.

The access infrastructure was built by various subjects, including the incumbent, using various technologies (WiFi IEEE 802.11b, ADSL). In 2006, more than 75% of the communal households were within the range of the WiFi (wireless fidelity) network. Over 110 families (out of the community total of about 1600) used the Internet. There were then about 100 new orders for connections to the network. An extension of the network was planned so that it would reach about 95% of all households in the community.

Both local and national press gave very positive comments about the initiative.

In Poland, the *law on development of information technologies for subjects realizing public tasks* from 17 February 2005, had an extreme potential of stimulating demand on broadband throughout the whole country. It had a revolutionary character in enforcing introducing e-government services to numerous government institutions. The law was also to impose the creation of necessary, uniform data formats for such services. Unfortunately, before the law came into force, it became clear that its broad plans would remain only "on paper", since the government was not able to fulfill the law and concrete actions were not taken.

3.4. The Role of Social Leaders

In demand growth it is important that some future broadband consumers learn to use it from the current users (the later are called social leaders). In many cases we can observe the activity of social leaders:

- The conductors of the Cornwall initiative claim to have observed an increased broadband take-up in households after the businesses had signed for broadband.

- In one of the biggest projects in Poland, Broadband Communication Network of Kuyavia and Pomerania Region [11], the role of social leaders is attributed to universities, libraries, hospitals, etc., who were the first customers of the network being built.

- The e-Vita treat their successful initiatives as social leaders for future initiatives, that's why they describe/disseminate their successful cases.

4. Techno-Economic Analysis

We shall describe the techno-economic model and analysis performed for the city Łódź and its rural surrounding. However, even more important than particular results for Łódź will be the general remarks regarding problems of performing techno-economic analysis and the potential role of research institutions.

4.1. The Importance of Techno-Economic Analysis

A techno-economic analysis (TEA) aims at dimensioning the network, meaning assessing the necessary number of particular equipment items and at assessing the profitability of the undertaking under various economic and market assumptions. The profitability assessment uses various financial indicators like internal rate of return, net present value, cash balance, payback period. Thus TEA seems a natural component of any broadband initiative undertaken by local leaders. Then, however, a problem arises to whom to entrust the TEA.

The City Hall of Łódź observed that it was difficult to find a company willing to perform a TEA that would be really independent on any operator – a potential contractor of their initiative. In general, not many can perform a TEA. The necessary TEA know-how is a pretty well protected knowledge. Publications, like [12]– [14] or [15] are rare and many solutions are based on particular subjects' knowledge. An example is the Titan tool used in the analysis of the broadband development in Rome [14], or the STEM series of tools. The team of NIT agreed to build a techno-economic model for Łódź and to perform an independent TEA, based on the broad expertise of the institute in telecommunication networks gained during the several decades of the research. The TEA was done within the framework of BReATH project.

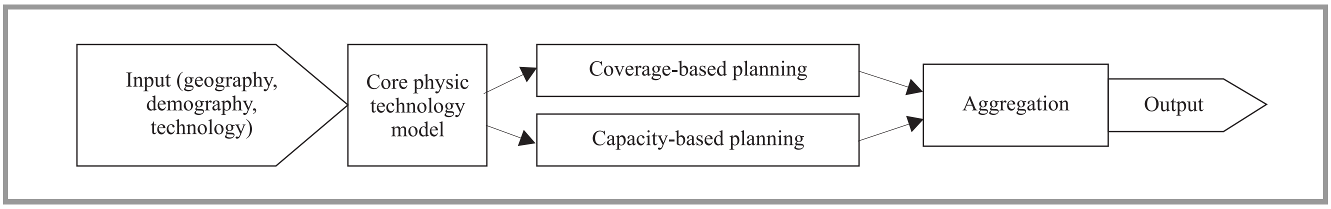

Fig. 1. Technological model.

4.2. The Techno-Economic Analysis for the City of Łódź and Surroundings

Our TEA and the model are described thoroughly in [5], [16] and [17].

Łódź is the second largest city in Poland. It has well distinguished urban, suburban and – recently incorporated – rural regions. The main network infrastructure was to remain the property of the town. It can be thus the subject of our analysis. However, serving customers was to be done by private companies. These companies should be responsible for added-value, such as security and the software side of the Internet services. Thus, there arose one more question: how the revenue should be divided between the infrastructure owner and the service providers.

The city has been split into 3 areas urban (a), suburban (b) and rural (c), an further – into 20 smaller ones, for which we obtained data about the number of inhabitants and several types of businesses/institutions from the Statistical Office.

The WiMAX technology was chosen for areas a, b and c in our analysis, due to its simplicity in terms of the civil work needed and the need to gain independence of the incumbent operator.

Our TEA was based on the simulation model we build (with elements of inverse simulation, i.e., solving equations and elements of the constrained analysis). The model parts (demand model, technological model, economic model) will be now described.

The **demand model** calculates the demand, i.e., the expected number of users categorized by:

- user types (individual, companies, schools, municipality offices),
- bandwidths,
- areas.

The demand model can be decomposed into 5 main processes and uses input data coming from diverse sources, varying from the Statistical Office to heuristic observations, own expertise of the NIT and results of other researches, often collected through the Internet.

The **technological model** (Fig. 1) calculates the necessary amount of equipment (mainly base stations and their sectors, consumer premise equipment – CPE). It follows the work [15] and adopts the path loss model from [13].

The part depicted as "core physics and technology model" describes the physical phenomena taking place in the network. The licenced frequency of 3.5 GHz was chosen, with the bandwidth of 56 MHz, which be divided into channels of either 3.5 or 7 MHz. The model takes account of number of sectors, radiation angles, transmission powers and gains, the sensitivities of CPE. *Link budgeting* is used in the model, i.e., the loss of a logarithm of signal power is calculated. This loss is a sum of several components connected with the distance from the base station, terrain attenuation, gain from emitter angle, etc. For example, the terrain attenuation is defined as

$$A - B \cdot h_b + C/h_b ,$$

where h_b is the height of base station installation and A, B, C – the terrain coefficients, each of them defined differently for three different terrains: a, b, c. Signal losses connected moving people, tree leaves, cars passing are computed from a probabilistic model using lognormal distributions.

The most important decision made during the calculation is the choice of modulation type, since it changes the trade-off between the necessary sensitivity of the receiver and a channel width (Table 3) and – in consequence – influences the trade-of between the coverage and capacity of our network. We compute the minimal possible number of base stations (together with the modulation type) such that both the constraints on coverage and on capacity are satisfied.

Table 3
Sensitivities of the receivers [dBm]

Channel width [MHz]	Modulation type					
	QPSK 1/2	QPSK 3/4	16-QAM 1/2	16-QAM 3/4	64-QAM 2/3	64-QAM 3/4
1.75	–90	–87	–83	–81	–77	–75
3.5	–87	–85	–80	–78	–74	–72
7	–84	–82	–77	–75	–71	–69
14	–81	–79	–74	–72	–68	–66

QPSK – quadrature phase shift keying,
QAM – quadrature amplitude modulation.

The **economic model** simulates the cash flows during the project duration. It is a dynamic model. The time horizon has been set to 7 years, as this seems the longest time the telecommunication companies want to wait for investment payback; otherwise they do not make the investment. Also, economic, market and demographic prognoses exceeding a 7 year horizon are certainly not much reliable.

There are 4 outputs of the model: cash balance and net present value – NPV (both scalar functions of time) and the payback period and internal rate of return – IRR (both scalars). We assume that the project starts at time $t = 0$ and that time is measured in months (i.e., $t = 1$ means the time 1 month after the start of the project).

The definitions of economic quantities taken in this model are the following:

- Capital expenditure (CapEx): the sum of money spent on investments (assumed to be made once, at the beginning).
- Operational expenditure (OpEx(t)): the sum of money spent in the time interval $(t, t+1]$. It includes only money that is paid periodically to enable running a project (e.g., maintenance costs).
- Cash balance (t): the sum of revenues from the period $(0, t+1]$ minus sum of expenditures from period $(0, t+1]$. All the flows are taken in their nominal values, in which they are booked.
- Net present value, NPV(t): a measure similar to cash balance (t), taking into account, however, that money depreciates in time: equal nominal values correspond to different real (discounted) values. More precisely, with a monthly money depreciation rate r, NPV is defined as follows:

$$\mathrm{NPV}_r(t) = \sum_{u=1}^{t} \left(\frac{\text{cash balance}(u) - \text{cash balance}(u-1)}{(1+r)^{u-1}} \right).$$

- Payback period: the minimal time t such that $\mathrm{NPV}(t) = 0$. Usually, due to capital investments made, NPV is initially below zero and it grows during the project run:

$$\text{payback period} = \min(t | \mathrm{NPV}(t) \geq 0).$$

- Internal rate of return: r for which $\mathrm{NPV}_r(t) = 0$. Comment: we treat our business as investing money in a bank and getting them back. The "surrogate bank rate" is our IRR.

The economic model takes into account customers' fees, subsidies, the cost of installing and maintenance of equipment, taxes, depreciation of the equipment. The customers are assumed to pay a monthly fee and no initial (installation) fee. A constant part of revenues goes to the service operators (this part is a model parameter, called end operators' profit margin) and the rest goes to the city.

Analysis – many runs of the model has been done [5], [17], for various terrains (a, b, c) and various assumptions regarding the values of market share by our network, amount of subsidy, end-operators' margin profit and others. Here we shall only call the results for the experiment most relevant to our subject. This experiment conceived the rural (c) part of Łódź and showed the influences of the subsidy to the economic indicators. The results are given in Table 4 and Fig. 2. In the rural area of Łódź there are about 10,000 households, 4600 businesses (most of them being small businesses), 1000 offices, schools and other public institutions. The rural area of Łódź is 151 km^2.

Table 4
Influence of the subsidies to IRR and payback period

Subsidy [million PLN]	0	7	15	30
Payback period [month]	46	39	31	20
IRR (monthly) [%]	2.25	2.76	3.50	5.92

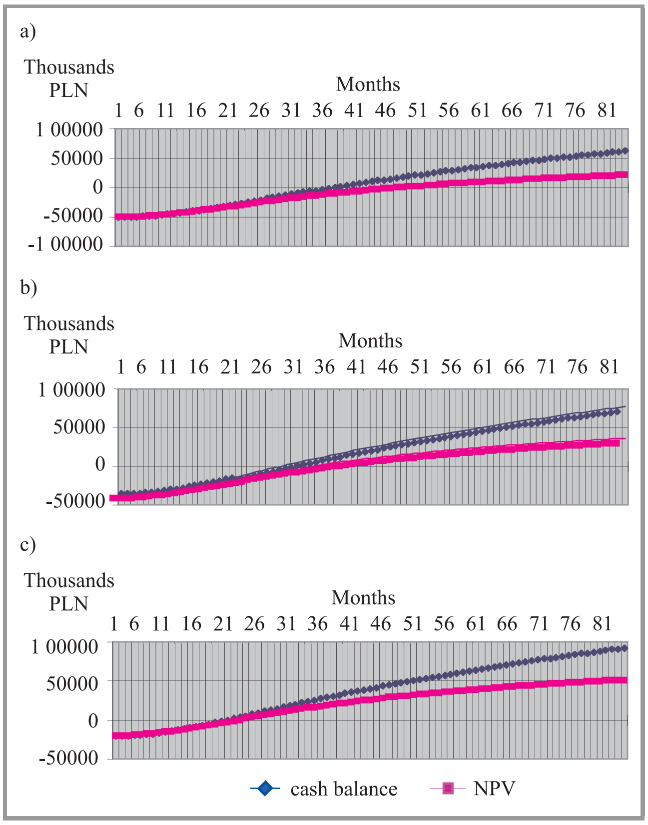

Fig. 2. Influence of the subsidies to cash balance and NPV. Subsidy: (a) 0 PLN; (b) 15 million PLN; (c) 30 million PLN.

The results seem somewhat astonishing, since even under the absence of subsidies the investment pays back after 3 years. The common experience says for rural areas the investments do not pay back. This was explained with the fact that the rural surroundings of Łódź, not typically, have a high ratio of institutional subscribers among all the subscribers (and institutions are known good clients due to high prices for their high bandwidth and high quality Internet connections). Subsidies, however, have a potential of essentially shortening the payback period (increase the IRR).

4.3. Problems of Techno-Economic Analysis

Our experience with TEA for broadband initiatives showed a need of undertaking systematic research in this area by research institutions of various specialties (telecommunication, economy, demography, etc.). The know-how in TEA is not public knowledge, and as broadband initiatives need independent techno-economic analysis, they could refer to research institutions. They, however, require a great amount of detailed information and firm experience that could only be gained in systematic research, perhaps in cooperation.

Let us name the problems we met during our analysis to see how specialized knowledge is necessary. Collecting necessary data was extremely difficult. Some coefficients (A, B, C) expressing the terrain attenuation (by plants, cars, people) are obviously very hard to obtain. Foreseeing a demand generated by particular was often more art than knowledge. It turned out that the Polish Statistical Office does not make statistics with granularity less than a single town: obtaining data for our 20 pieces of Łódź required a dedicated research by them. The lack of the supporting literature has already been mentioned.

5. Conclusions

The BReATH project brought many interesting findings about developing broadband in communities; the reach material from this project can be further referred. The advantages of the technique of stimulating demand market demand for broadband connections were stressed. The role of social leaders is essential. The main domain for the activity of research institutions seem to be techno-economic analysis, which, however, requires a period of creating the necessary knowledge, in a cooperative research.

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Paweł Białoń – for biography, see this issue, p. 39.