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OPTIMAL RISK ALLOCATION IN RURAL NEXT GENERATION INFRASTRUCTURE PROJECTS AND THE ROLE OF ADEQUATE NETWORK MODELING

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Abstract

Throughout the last decade, the telecommunications sector has been subject to substantial changes in most countries of the world. Increased computational power, higher transmission capacities in combination with an openly and independently designed transport layer for packet switched data (IP) allow for a vast degree of freedom regarding the architecture and independence of services. Especially the transition towards All-IP networks in both, the mobile and the fixed sector, is expected to further extend the scope for end user applications.

The usability of the IP-protocol for multiple types of services enables their provision via the

same network, and thus services become more independent from physical network infrastructure. Networks with these features are commonly referred to as “Next Generation Networks” (NGN) or “Next Generation Access” networks (NGA), respectively. In consequence, operators are confronted with the challenge to fulfill a large number of technological requirements that emerge from the huge variety of distinct service characteristics.

In the light of the previously mentioned conditions, reasonable infrastructure investment, especially by small and medium-sized firms which act on a local scale, strongly depends on a critical assessment of the economic, financial, legal and technological risks and options. Such analysis requires on the one hand a qualitative examination which points out the strategic options of the investing firm and its partners (e.g. SWOT analysis) and on the other hand, a quantitative part (business case) which delivers figures that provide reliable information on key project features, such as financial requirements, return on investment, etc.

This paper addresses the quantitative aspects of small infrastructure deployment projects. It focuses on methods how to achieve a precise estimate of project relevant parameters by means of an adequate business case model. In that context a framework is developed, which considers the special features of small network deployment projects and the way they have to be integrated into a consistent model structure. The assessment refers to fiber networks, as these are, in the long run, most suitable to provide sufficient performance for upcoming applications and includes an evaluation of potential risks that are related to investment projects and how business case models may contribute to their minimization.

1. INTRODUCTION AND BACKGROUND

Modern communication networks are required to support a multitude of new and traffic-intensive applications such as IPTV or several cloud services as well as traditional applications like telephony, fax and other data services – which are all subject to individual requirements with respect to the provided service quality and security issues (1), (2). By using the IP-protocol for multiple types of services, their provision via the same network is enabled, which implies that a connection with sufficient transmission capacity must be available.

The independent design of networks and services also creates considerable effects on the value chain, as it eases the separation of traditional vertically integrated telecommunication enterprises. This leads, especially in countries with a widely liberalized regulatory framework, to a situation in which a large number of small or medium-sized enterprises that focus on different levels of the value chain have access to the market (1). In that context, a multitude of business models has emerged, which provide numerous constellations for enterprises to cooperate or to compete. Within this by far more complex and competitive environment as compared to the times of the traditional telco-monopolies, the new NGN/NGA paradigm with the related requirement of substantial infrastructure investment, imposes severe obstacles on small and medium-sized infrastructure providers and network operators, due to high investment and demand (i.e. revenue-) risks (3). Additionally, in most countries these providers have to compete with an incumbent operator that already possesses a fully equipped and amortized copper network, which has been inherited from its prior state monopoly. Although these networks may not be technologically competitive in the long run, e.g. with new fiber networks, they constitute as of today the most economical solution to provide a sufficient degree of service to a great part of a country's population (4),(1).

Thus, neither the technological, nor the economic conditions under which new networks are to be built are as favorable as they were in the days of the initial, state-driven and nationwide deployment of copper-based ICT-infrastructure, due to the following reasons: First, private investors have limited access to public funds and hence full amortization after a certain period of time is required and causes them to act more carefully, as they are left with the entire risk of investment failure (5). Second, the separation of network and services, especially if an "open access" approach is pursued, bears the risk of lower revenues for pure network operators, as the major part of the potential revenue volumes may be skimmed by the service provider (6). This situation is even aggravated by the fact that timing of investment plays a crucial role: A sudden shift in the demand for services may also cause an immediate need for new infrastructure (which might increase within few months), whereas planning and the construction of networks is a process of several years. Hence, if investment is not triggered before the actual demand rises, this will cause immense delays of the network availability, which could pave the way for competitors who have started deployment at an earlier stage or even bring subscribers to rely on upgraded legacy networks (3). As a result, another important component of investment planning consists in an anticipation of market developments which includes a reliable demand forecast in order to determine the optimal timing of investment.

The remainder of this paper focuses on the emerging consequences for the design of analytical tools to calculate investment profitability, which arise in the context of the previously described environment. It is organized as follows: In chapter 2, a definition of the considered networks is given and typical elements of the network lifecycle are outlined, including involved partners as well as their functions within the deployment process or during the operational stage, respectively. In the last subsection, a more detailed view on investment profitability is outlined. The subsequent chapter provides an overview on different types of investment risk that have to be considered in the course of viability assessment. Special focus is given to the influence of biased risk perception and a method is presented that allows mitigating forecast errors due to intended or unintended misinterpretation of the respective indicators. Chapter 4 presents an example how business case models could be structured in order to minimize the inherent investment risks and provides guidelines on how to integrate data from prior projects into a consistent framework. Chapter 5 contains a brief summary and conclusions are drawn.

2. NGA INVESTMENT PROJECTS

The expected increase in demand for high speed connections has also been addressed on a political level, as specified by the European Union in its "Digital Agenda 2020", which sets out the target of 100% of the Europeans to have a broadband connection of at least 30 Mbit/s and 50% or more to be connected at speeds above 100 Mbit/s by 2020" (4). Although the political targets do not stipulate the provision of a certain technology or business model, fixed networks, in particular fiber networks, are seen to meet the rising at best (5). Hence, they are focused on in the following and central technological properties are outlined as well as the special characteristics of fiber deployment projects.

2.1 Next generation fiber access networks

For the purpose of this article, the deployment of small-scaled, rural fixed line NGA-networks is considered, which range down to a number of a few thousand or even several hundred subscribers and which are intended to serve a contiguous area. According to the ITU definition of next generation networks, a NGN has the following properties (7):

- The network is packet-based (IP-connectivity is assumed)
- Provision of various different telecommunication services
- Use of multiple broadband, QoS-enabled transport technologies
- Service-related functions are independent from underlying transport-related technologies.
- Unfettered access for users to networks and to competing service providers and/or services of their choice is enabled.
- Supports generalized mobility which will allow consistent and ubiquitous provision of services to users.

Due to the assumption of IP-connectivity, services are largely independent from the available network equipment. Furthermore, the evaluation comprises the entire value chain up to the provision of telecommunication services including basic applications that are commonly offered in combination with a broadband connection, such as telephony or television. Although the scope is limited to fiber networks, methodical results may be extended to other access technologies, as the presented framework focuses on the establishment of calculation tools that are capable to capture the general nature of risks in NGA infrastructure investment and that most of the different network types are subject to.

As regards the access technology, FTTB (Fiber to the building) and FTTC (Fiber to the curb/street cabinet) are addressed exclusively, as the treatment of in-house cabling – which would be the case for FTTH (Fiber to the home) – and the related costs and risks would be beyond the focus of this article. For FTTB, only costs up to the connection points of the building are considered. Regarding the implemented network technologies, P2P solutions are considered as well as PON/GPON. As only the establishment and operation of access networks is examined, the backbone is not included here and all considerations start from a central point of presence (PoP) which is assumed to provide sufficient of transmission capacity between access and core network.

2.2 Network lifecycle and cooperative deployment

In order to assess the economic viability of fiber investment, the entire lifecycle of such networks has to be taken into account, which requires considering the relevant project phases and the respective tasks that have to be fulfilled as well as the involved actors. For that purpose, several studies on fiber investment profitability rely on a total cost of ownership (TCO) approach, which considers both, deployment and operation of the network (8).

However, with respect to the entire lifecycle, network planning costs, as being notable transaction costs, would also need to be incorporated, but due to their minor overall impact they are not subject to extensive assessment in many cases (5), (6), (9). Figure 1 depicts the entire lifecycle of a network that is relevant for the calculation of TCO. It is based on a modified version of the definition of Verbrugge et al. (8) and consists of a realization stage, in which the network is deployed, and an operational stage. The realization stage is further subdivided into two phases: A rollout phase, which contains all deployment activities and a transition phase where the network is configured and tested, but not yet available to customers. From a project management point of view, a development stage must be included, which consists of three additional planning phases that differ in the degree of precision (10), but are not treated in detail here. Viability assessment is considered to be the first step of the conceptual phase.

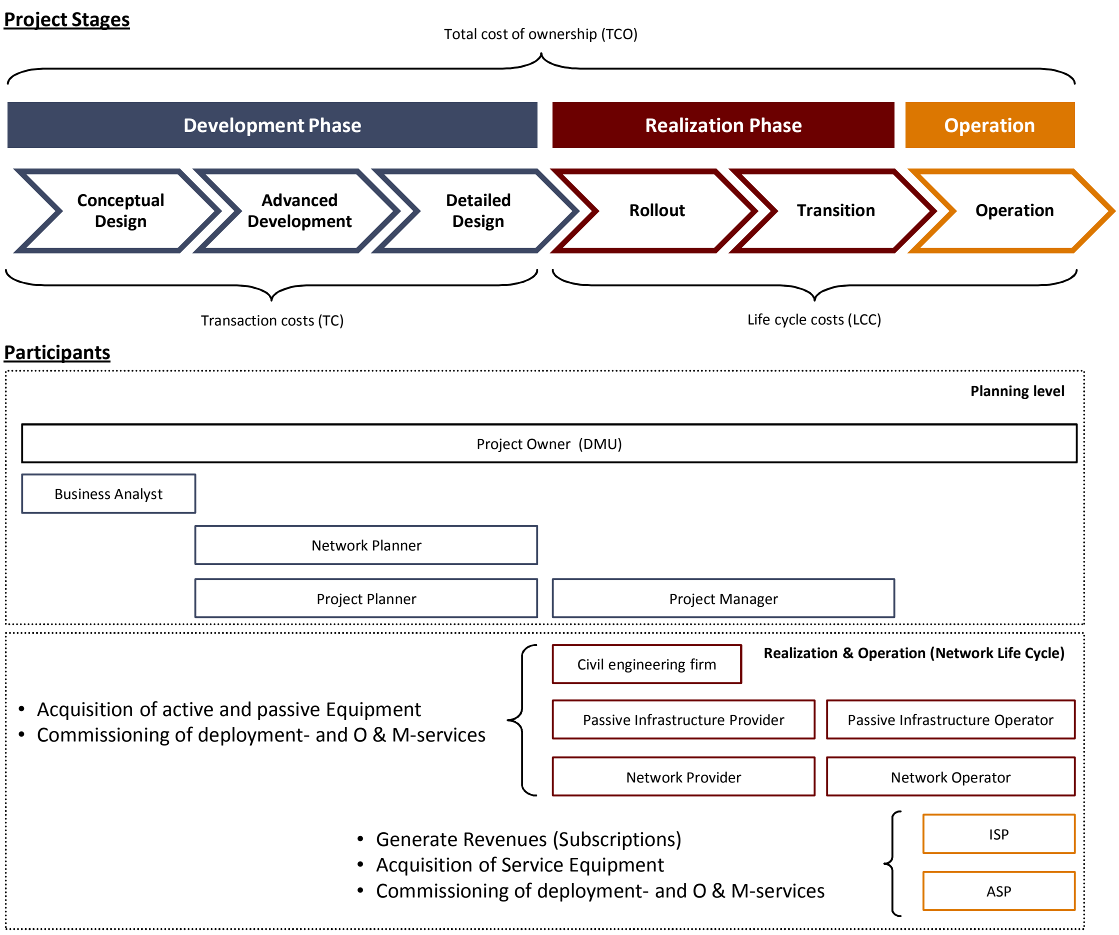

Figure 1: Project stages and activity of participants

According to (8), who analyzed the FTTH-rollout[1] process in context of the OASE (Optical

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[1] The quoted study focuses on FTTH deployment projects, which are not considered here. However, most of the properties apply to FTTB and FTTC as well.

Access Seamless Evolution) project and identified the roles of different project members, similar functional categories of participants shall be considered here as well, including some modifications though, which comprise additional actors and a slightly different scope of individual charges. The following listing gives an overview on the different types of participants. It is assumed, that several types of actors may be represented by a single company and vice versa.

- **Project Owner:** A single firm or consortium that seeks to engage in fiber network deployment and therefore initiates the entire process of feasibility assessment, project development and realization. It is the main decision making unit (DMU) that assigns the different tasks to the involved parties, which are considered as subcontractors and it is responsible for the entire project. Hence, the project owner formally bears the entire investment risk,[2] even if he does not become active in any project phase.
- **Business analysts:** These are in charge with prior analysis of the economic viability of an investment project. There is no constraint whether analysts are part of the project owning firm or a separate entity. Based on the result of the economic assessment, a decision is made, whether the project will be realized or not. Their point of view is the basis for the considerations regarding investment profitability within this article.
- **Technical network planning firms:** Enterprises which elaborate a detailed and final deployment plan of the network that is to be built, including a specification of the required active and passive network equipment, locations, excavations and other civil works. Such plan can be developed in close cooperation with a future project management firm or civil engineering company.
- **Project Planning Firms** elaborate a plan which includes a detailed schedule of all deployment activities, as well as the necessary resources (staff, funds, etc.).
- **A Project Managing Firm** is responsible for the execution and supervision of the deployment process, as well as the related administrative tasks. It might act as general contractor on behalf of the project owner and mandate other subcontractors.

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[2] Although multiple firms may participate in a project and thus would be financially affected by potential investment failure, it is assumed that prices which are based on negotiations with subcontractors, as well as financing conditions already include a risk-component and hence all financial risks can be considered as shifted towards the project owner.

- **Civil Engineering Company:** Each firm which is contracted to execute any kind of construction work, such as excavation, site construction, power installation, air conditioning (collocation), etc.
- **Passive Infrastructure Providers:** A passive infrastructure provider constructs cable ducts (or exploits already existing conduits), lays optical fibers within cities and intends to provide every dwelling with a connection. Once deployment is completed, passive infrastructure providers might remain in charge with the operation and maintenance of passive infrastructure (i.e. they become passive infrastructure operators).
- **Passive Infrastructure Operators** operate and maintain the passive network within the phase of operation.
- **Telecommunications (or Network-) Providers** deploy communications equipment, such as routers, switches, splitters, modems, etc. which is necessary for IP-based transportation of data. After deployment, they may also act as network operators.
- **Network Operators** are in charge with the operation and maintenance of the active network equipment and provide IP-connectivity towards Internet service providers.
- **Internet Service Provider (ISP):** An Internet Service Provider offers his customers access to the Internet, keeps the customer data and provides AAA[3] functionality; however, these companies do not necessarily operate their own network.
- **Application Service Provider (ASP):** An ASP develops and offers internet and communication services to the end-customers. Depending on the business model, some services might already be offered by the ISP, especially "traditional" services like telephony, television (IP).

The network is assumed to be planned and constructed either by a single firm or a group of cooperating firms at the respective stage i.e., given the former, one enterprise would possess the functionalities of *all* types of actors. For simplification it is assumed that only one network of the above specification is planned at a time and hence there exists no competition between infrastructures of the same type.

Among the different stages, partners may change, indicating that some firms only engage temporarily, whereas others remain part of the consortium throughout the entire lifecycle.

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[3] AAA stands for authentication, authorization and accounting. It refers to a standard of security architecture for systems that enable to control the users' access to services, and resources utilization.

Indeed, the form of cooperation between different partners is subject to intensive discussions and there exists a multitude of approaches with different degrees of integration, ranging from open access to full vertical integration (3). Although, the adoption of a certain cooperative model has considerable strategic implications they will not be discussed in detail here, as the latter would be hard to quantify and thus integration into a standardized business case model would not be suitable. The following section therefore outlines the concept of a “hypothetical operator” who would fulfill all tasks by himself and who constitutes the basis for the subsequent chapter that addresses to implications on the modeling framework.

2.3 Profitability of fiber networks

The profitability of any network depends to a large extent on infrastructure costs, which can be split into costs for active and passive *equipment* that has to be acquired (fiber-optical cables, conduits, switching elements, etc.) and costs for *services* that are necessary for deployment, installation, operation and maintenance (O & M) of equipment (e.g. excavation works, installation of equipment, but also electricity and network surveillance) incurred by all of the project partners.[4] These costs have to be recovered by the revenues that are generated by subscribers who have contracts with ISPs and ASPs (5).

Following the TCO-approach, all costs and revenues that emerge in the panning, realization and operational stage have to be taken into account. Fundamental cost parameters that are characteristic for fiber networks have been identified by (11):

- Excavation, (S)
- Installation of fiber-optical cables, (S)
- Costs for Technical Planning, official permits, etc., (S)

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[4] Even though infrastructure costs in most cases account for 60 to 80 per cent of the overall costs, it has to be mentioned that the provision of internet and application services is subject to additional equipment and service costs. In the following, they will be considered as included into infrastructure costs (15).

- Active Network Equipment, (I)
- Passive Network Equipment, (I),
- Collocation, (S)
- Building Connection, (S)
- Operational Costs (OPEX), (S)

The declaration in brackets indicates whether the respective parameter is a service that has to be commissioned (S) or an item that has to be acquired (I) – which is relevant for the way data is processed (see chapter 4).

2.3.1 Subject of assessment

In order to assess the profitability of fiber projects, analysts are faced with the challenge to estimate the required equipment and services as well as timing and amount of costs and revenues and hence they need detailed *knowledge* of the deployment and operational processes, but also reliable *methods* to identify and to capture special characteristics of individual projects. This situation is further aggravated, if the business model, i.e. the form of cooperation among the involved firms, is not defined by the project owner from the beginning. As mentioned before, the choice of an adequate cooperative model in fact has a considerable impact on economic viability (1).

Cooperation between different firms has to be specified on a contractual basis and comprises, amongst others, the assignment of responsibilities to the involved partners, including the organization and execution of individual project tasks. A decision on the applied business model then has to be taken with respect to the constellation that promises to provide the best economical outcome. Thus, feasibility assessment would be required to consider multiple options for the assignment of different tasks, which would considerably complicate the analysis and be in most cases beyond reasonable effort.

2.3.2 Hypothetical operator approach

In order to avoid such extensive analysis, an intermediate approach is suggested that relies on the quantitative result of a “hypothetical first best” and then evaluates the business model which enables a solution that is *closest* to the obtained optimum in a qualitative manner.

For that purpose, a “hypothetical operator” is considered, that is able to coordinate all relevant tasks by himself and who remains exclusively responsible throughout the entire stages of planning, realization and operation. Furthermore, no inefficiencies as they might arise within a project consortium are assumed, and hence investment profitability would depend only on the relevant cost parameters and revenues but not be influenced by the coordination of different partners. In the course of the assessment, such hypothetical operator has to be modeled, which requires a detailed analysis of the deployment process and the operation of networks and services, including a decomposition of the project tasks into single items and additional research on relevant parameters. Input information regarding the costs for equipment and services can be gathered either by individual research, i.e. products, services and prices from local firms, or by referring to reference data, which may consist of data from other projects or official statistics.

The use of such hypothetical operator does not only ease the calculation of profitability indicators, but allows for the application of standardized business models and therefore the inclusion of data from reference projects. In the subsequent section, the latter will be shown to contribute substantially to the minimization of forecast errors. A drawback of this concept is a loss of accuracy that has to be accepted, as business models are not subject to the quantitative analysis. However, on the basis of the hypothetical first best solution, different cooperative approaches can be discussed regarding their influence on the model outcome and thus on investment viability.

3. UNCERTAINTIES AND INVESTMENT RISK

As already mentioned fiber infrastructure investment is subject to strong financial engagement on one hand, accompanied by numerous uncertainties on the other hand, indicating substantial risks for the involved project partners. In this section, potential risks are identified and classified. This analysis constitutes the basis for further assessment regarding the design of qualified and robust business case models. Three risk categories are introduced, according to which project risks are classified into *business risks*, *financing risks* and *operational risks*, following (12).[5] In order to capture the entire lifecycle of fiber networks, additional risks have to be taken into account, which arise in the operational phase, but have substantial impact on the economic viability. Thus, the classification refers to both deployment and operation of the network. With regard to the special features of fiber deployment, those factors who contribute most to the overall project risk are identified and examined in more detail. Based on these findings, recommendations are derived, which address the establishment of *unbiased* forecasting methods.

3.1 Business risks

Business Risks are related to the achievement of the overall and intermediate objectives (milestones) within a certain period of time. With respect to fiber networks, such intermediate steps might consist in the completion of all excavation works within a certain area up to fixed date or in the achievement of a certain number of subscribers within the first year of operation. It has to be noted though, that business risks focus on the *assumptions* that are made for the establishment of an adequate and realistic project schedule (business plan), whereas – provided such realistic schedule – further risks of failure concerning the execution of individual tasks would rather be considered as operational risks. Furthermore, this category applies to general internal and external *conditions* and thus also includes different types of legal risks such as regulatory uncertainties, official permits (e.g. construction permits) as well as dependencies on external partners (which are not part of the project consortium) (12). A common feature of business risks is that once deployment has started, there is only little

[5] According to (12), there exist additional risks, which include rather political or strategic dimensions (e.g. strategic positioning) than the realization process and hence are related to the internal project support by the project owning company, which shall not be covered by this article.

influence on these factors, which emphasizes their relevance for a proper assessment prior to the project kickoff.

3.1.1 Demand-related risks

Amongst the named uncertainties, demand-related risk plays a crucial role, as after completion of the network considerable investment repayment is to be achieved by the revenues, which are to be generated by the total number of subscribers. The achievement of a sufficient quantity of subscriptions in turn requires that the perceived benefit of additional bandwidth among customers is enough in order to induce their willingness to sign new contracts (3). Inauspiciously, the valuation of fast broadband connections, especially by residential customers, is hard to predict and mainly driven by the additional value that is created by new services rather than by a pure increase in up- or download speeds (2). As mentioned, it is expected that demand for such services will rise in the long run, but an anticipation of the timing seems to be difficult. Moreover, such increase is likely to come about in a sharp rise i.e. within a few weeks or months (13) – and thus too fast for operators in order to meet the additional demand by a reactive enhancement of network capacity, as network deployment is usually a process in the range of years. Throughout 2011, for instance, the volume of IP-traffic grew 44% in Western Europe and is expected to grow 3-fold from 2011 to 2016 (14). In addition to that, demand for broadband services is responsive to fluctuations in prices as well as in individual incomes, and thus customers might tend to rely on cheaper traditional technologies instead of signing new contracts (3).

3.1.2 Competition and market risks

Beyond the previously described individual demand risk, there may exist additional market risks, even if a sufficient number of customers is willing to subscribe to new broadband contracts. This might be the case when further operators enter the local (fiber) broadband market or when already existing legacy networks are (or become) able to offer the same performance, such as upgraded copper, cable or even mobile networks, and thus several operators compete for the customer base (3). Figure 2 illustrates this situation and gives an implication on the parameters that have to be estimated in terms of percentage shares that reduce the new networks' customer base with regard to the maximum of connectable premises.

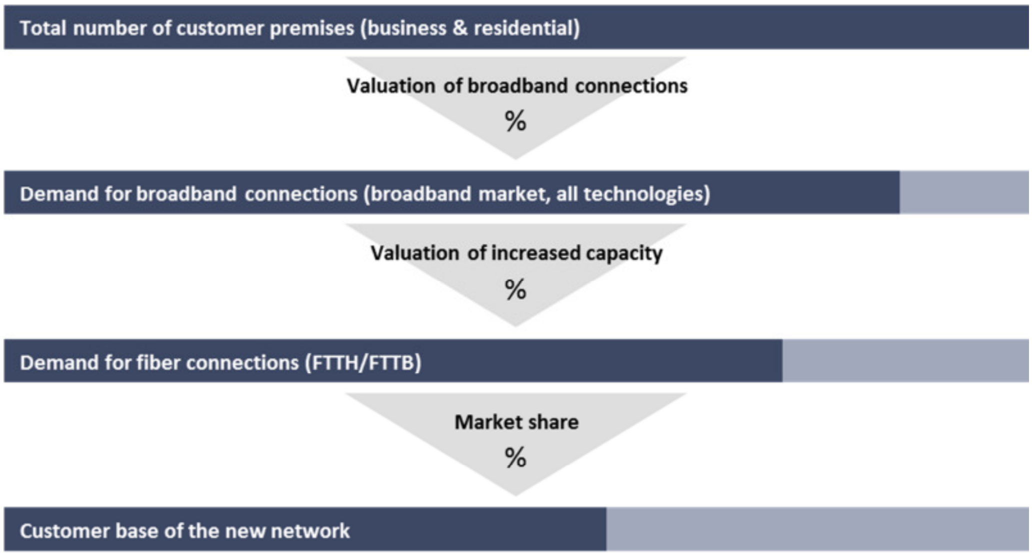

Figure 2: Derivation of the customer base (Source: SBR)

Facing the hardly predictable nature of local market developments and customer behavior, their evaluation in the course of an ex ante feasibility assessment becomes crucial, as they are – more than other business or operational risk factors – affected by local conditions and the related risk cannot be shifted alike (see 3.3). Due to that reason, the presented framework in chapter 4 concentrates on demand forecasts, whereas other business risks are left aside – as they might be treated without special reference to the examined type of projects as well and thus are beyond the direct scope of this article.

3.2 Financing risks

Financing risks include internal sources such as budget overruns as well as external risks which are related to project financing conditions. The latter comprises the possibility of changes in interest and currency exchange rates over time, the availability and condition of loans and grants as well as the financial support by public and private investors or sponsors

(12). Financing conditions depend to a large extent on the financier's appraisal of the presented profitability forecasts and hence reliable revenue and cost estimates are capable to considerably reduce the risk of unfavorable financing conditions (e.g. increasing risk premium) or even a withdrawal of investors within the deployment phase. The budget risks, however, constitute a central element that can be directly influenced by the consortium itself and thus it is more than others, subject to the special characteristics of fiber investment. For that reason, the following evaluation focuses on budget risks, whereas other financing risks are left aside.[6]

3.2.1 Budget risk and cost forecasts

The control of budget risks strongly depends on a precise cost forecast and therefore detailed assessment of the cost structure as well as payment-timing and hence it is crucial in order to assure liquidity and to avoid budget overruns throughout the project and during operation. As a consequence, a precise cost model, which is capable to account for the different regional facets, is mandatory for prior viability assessment.

The cost risk of NGA projects depends to a large extent on the network cost characteristics. Once undertaken, a significant part of investment cannot be recovered which applies especially for civil engineering costs which account for 60-80% of the deployment costs (sunk costs). Uncertainties thus may arise in combination with market risks, as the network is built before a sufficient degree of demand has been reached and hence investors might be faced with substantial risk of asset stranding (3), (15).

Another source of cost-risk is the individual character of such projects, which implies that there is limited data on similar projects that could be used as a reference (3). Especially in small towns or rural areas, cost conditions may differ considerably among projects (e.g. due to

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[6] In contrast to external financial risks, an improper evaluation of costs is much more likely to compromise the overall project success, as unanticipated costs may lead to a termination of the entire project, whereas financing conditions can be previously set by contracts with the involved financiers and thus would also base on the result of prior cost and demand assessment. Further external financial risks, such as variations in exchange rates or price stability are not considered here.

deviating ground conditions, leading to higher or lower excavation costs) and thus could lead to erroneous cost-forecasts. Furthermore, there may be different technological approaches to be followed that become optimal in different regions (6). Their evaluation is also subject to prior cost assessment, which requires cost models to be flexible with regard to local conditions as well as towards the choice of technology.

3.3 Operational risks

Operational risks are related to uncertainties which arise in context with the execution of single tasks and thus in the course of the deployment process and throughout the entire operational phase of the network. Given that the network has been properly planned and the different tasks and processes have been designed adequately, operational risks cover the prevailing risk due to their realization by the involved project members or sub-contractors who are responsible for a proper execution of all assigned operational issues like project controlling, communication, methods, structural aspects (leadership, coordination and responsibilities), on-time delivery, quality etc. As operational skills of the individual project partners or sub-contractors are hard to assess in advance, operational risks can only be addressed in the course of prior evaluation of feasibility through the establishment of a realistic schedule and by designing contracts with sub-contractors which include rules (e.g. penalties) in case of non-compliance with defined objectives. The latter implies a shift of risks towards the executive members or sub-contractors of the consortium which usually comes along with a markup that is included in the price of the delivery that has to be considered in the evaluation (12). Beyond their impact on delivery-pricing, operational aspects will not be treated in further detail within this paper.

3.4 Risk perception and reference classes

As regards the process of decision-making whether infrastructure projects are realized or not, it has to be noted that there exists substantial risk of inaccurate predictions that is due to a biased perception of cost and demand indicators in the course of the evaluation process. Such bias does not necessarily emerge unintentionally but can also be due to strategic behavior, as (16) suggest:

> *"Psychological and political explanations better account for inaccurate forecasts. Psychological explanations account for inaccuracy in terms of optimism bias; that is, a cognitive predisposition found with most people to judge future events in a more positive light than is warranted by actual experience. Political explanations, on the other hand, explain inaccuracy in terms of strategic misrepresentation. Here, when forecasting the outcomes of projects, forecasters and managers deliberately and strategically overestimate benefits and underestimate costs in order to increase the likelihood that it is their projects, and not the competition's, that gain approval and funding. Strategic misrepresentation can be traced to political and organizational pressures; for instance, competition for scarce funds or jockeying for position. Optimism bias and strategic misrepresentation both involve deception, but where the latter is intentional – i.e., lying – the first is not. Optimism bias is self-deception. Although the two types of explanation are different, the result is the same: inaccurate forecasts and inflated benefit-cost ratios."*

The authors show that both optimism bias and strategic misinterpretation have led to substantial forecasting errors in most of the infrastructure projects that have been examined by them. As a consequence, they suggest making use of reference class forecasting, a method which has been described first by Kahneman and Tversky (17), (18) and which considers statistical information from reference projects in order to crosscheck evaluation results. It bases on the following three steps (16):

1. Identification of a relevant reference class of past, similar projects. The class must be broad enough to be statistically meaningful, but narrow enough to be truly comparable with the specific project.
2. Establishing a probability distribution for the selected reference class. This requires access to credible, empirical data for a sufficient number of projects within the reference class to make statistically meaningful conclusions.
3. Comparing the specific project with the reference class distribution, in order to establish the most likely outcome for the specific project.

According to the first point, a necessary condition is given with the examination of a sufficient number of projects that serves as a basis for an analysis of actual projects. For fiber projects this indicates that figures from former projects could serve as a reference for future ones, only if differences with respect to local conditions can be captured by the establishment of reference classes. As (11) show, projects can indeed be classified according to certain key indicators that had been derived by performing a cluster analysis on a given sample of projects. Such analysis might mark a first step for the establishment of reference class based forecasting.

4. IMPLICATIONS ON BUSINES CASE MODELS

Early techno-economic assessment often relies on approximation methods, which consider a detailed network model that is used only within a first step, that is, only for the analysis of a few reference areas (19). Then, results are extrapolated in order to obtain estimates for the entire region in a top-down manner. Of course, such approach minimizes the effort that has to be made in order to bring about an investment decision at the cost of forecast precision. In many cases, however, this can be justified if the results suggest that there is sufficient tolerance for input variables to take on rather pessimistic values, and the ensuing detailed network planning can be expected to outweigh the imprecision of the initial calculation.

In this regard, population density is widely considered to be a significant indicator of regional fiber investment viability (5). Beyond that, indicator-based forecasting may comprise additional variables that have proven relevant for profitability assessment, as (11) suggest. According to their analysis of several FTTB/H deployment projects, key-indicators have been derived that refer to the following features:

- Population and settlement (Number of inhabitants, population density, etc.)
- Geography and topology (Type of laying, ground characteristics)
- Network architecture (PON, PTP)

Given the values of the different parameters, it can be determined, whether infrastructure investment is promising or not. The advantage of this methodology is that the required socio-geographic input data is widely available or can be gathered from local authorities and hence feasibility assessment can also be performed within a short period of time.

However, relying on such approach will always bear the risk of a misjudgment of specific local conditions, which might not be captured by the model specification. This is especially the case when project conditions deviate from a well-suited project context, which might be given for very small towns or villages, strongly scattered distribution of buildings, or when existing infrastructure can be reused. Facing this situation, a top-down approach would not lead to a sufficiently precise forecast, whereas relying on a pure bottom-up approach instead, would be a promising but rather complex and expensive option, which should be left to detailed network planning.

In order to overcome the tradeoff between a fully specified but imprecise top-down model and an exact but complex bottom-up model, an intermediate approach has to be found, which integrates a maximum of the available information into a model which allows for a flexible adaptation to a variety of possible local contexts.

For that purpose, a modular approach is presented in the following section, which bases on separate and exactly specified modules. In this way, several alternative methods may be provided to for the same evaluation step (e.g. different methods of demand forecasting) and hence the one which suits best with respect to the local conditions would be selected. The possibility to select and combine of subsequent modules grants a large degree of both flexibility and precision and allows for the reduction of perception bias as it enables reference class forecasting.

4.1 The reference class approach for fiber networks

In order to use reference classes as a part of viability assessment, relevant data from prior projects has to be consulted and used for parameter estimation within the current project. In that context, it is not only crucial to choose the most suitable class of reference projects, but also that reference data from different projects has been collected and figures have been processed according to coinciding methods. If, for example, the total length of the network is compared with that of a reference class, it has to be assured that for all projects the same definition of “total length” is used. The establishment of reference classes thus requires a standardization of parameters and methods which grants comparability. However, the introduction of such standards that relate to reference projects “as a whole” is possibly one step too far, as local conditions may differ or combine in such a way that no reference can be found that matches the actual situation.

This motivates the introduction of a modular standard which allows for the comparison of single "reference modules" (building blocks) rather than entire projects. By that means, modules may be fed module-wise with input data that has been obtained by observations of former projects. Once actual outcomes – such as e.g. the evolution of subscriptions within the first year – of a sufficient number of projects are available, robust estimates for future projects can be derived on the basis of detailed stochastic analysis (see Figure 3).

Within a modular framework, not only input data from prior projects can be reused, but also the provision and case-by-case selection of alternative *calculation methods* is possible. Especially for the establishment of a network module, different optimization algorithms should be available that capture the nature of the considered technological approaches (here PON/GPON or P2T).

4.2 Selection of input data and methods

Under certain conditions, different reference projects that are included into the individual samples can be selected module-wise and hence independently from each other, as shown by Figure 3, where input data comprises data from various combinations of reference projects. This suggests that classification of data is to be made with regard to single modules rather than to entire projects, which permits the establishment of reference modules, even with a comparatively small number of observed projects. Such approach, however, requires parameters of the different modules to be uncorrelated (i.e. stochastically independent) in order to obtain a consistent estimate.

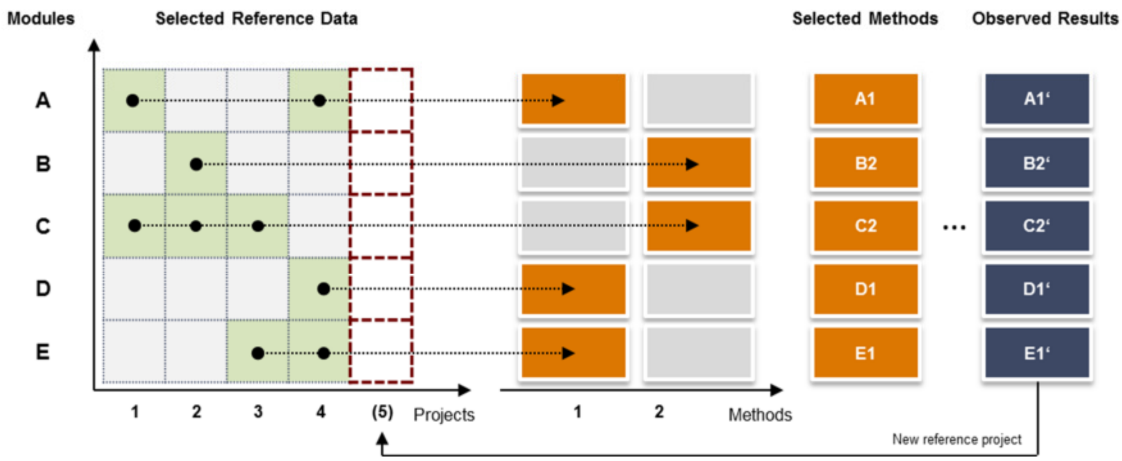

Figure 3: Utilization of reference classes

For the separate consideration of demand and cost modules, for example, this condition is probably fulfilled at first sight, as the consumers' willingness to pay does not seem to be *directly* correlated with network costs, and reference projects would be selected separately according to criteria which are considered appropriate to either module. However, there may indeed be a common influence on both, costs and willingness to pay, as *both* may depend on the deployed technology which has itself an effect on the connection capacities and thus on the perceived benefit, as illustrated by the following figure.

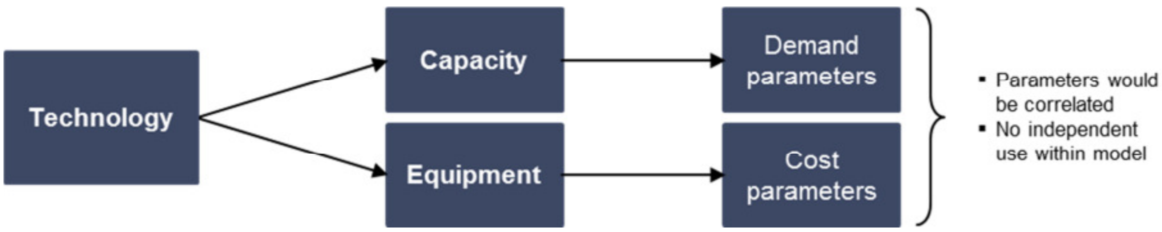

Figure 4: Dependencies of cost and demand parameters

Consequently, the use of several modules which are fed with data from different projects has to be carried out carefully, including a case-by-case analysis whether the respective data sets can be jointly and independently used or whether only a certain combination of multiple modules should be considered instead. With regard to the given example, the common influence of technology could be eliminated when only projects that rely on the same technology are considered – then cost and demand parameters could be treated as stochastically independent.

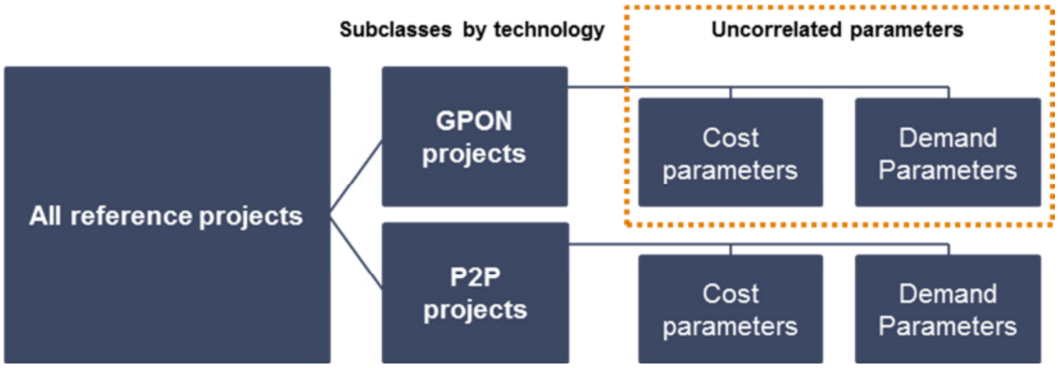

Figure 5: Decomposition of reference data

Provided the applicability of such modular approach, the business case model will be both, flexible towards the adaptation of project specific conditions and robust in terms of statistically backed input data. If new technologies or methods of calculation are introduced, only single modules need to be replaced, instead of the entire model. Even if no reference information is available for the new components, the joint use with other, already approved, modules is capable to considerably reduce uncertainty.

The following section outlines a modular framework for the establishment of business cases according to the previously mentioned conditions and refers to the characteristics of fiber deployment projects as presented in chapter 2.

4.3 Standardization

As stated before, the availability and the quality of input data is crucial for robust feasibility assessment of fiber rollout projects. Calculation modules for business cases must be able to adapt to situations with different degree of specific information and provide means that offer alternatives if datasets are poor. In such cases, modules should be designed in a way that they can switch to alternative methods. As a consequence, the model architecture has to offer defined interfaces between individual modules that provide relevant information independently of the method that has generated it, i.e. the ensuing step (module) of calculation is “blind” towards the internal calculation steps of prior modules. The use of specific interfaces assures that input and output data of the individual modules complies with a certain format and thus information can be accessed without exigency of additional adaptations. However, the definition of an appropriate format is challenging, as outputs shall be usable by a maximum number of modules, in order to reduce complexity. Especially if key performance indicators (KPI) are to be developed, information has to be handed over to other calculation modules, as well as to a project evaluation tool.

Due to the existence of standardized interfaces, alternative modules can be developed independently and the enhancement of the overall framework can be facilitated considerably. Multiple alternatively used network-modules allow for switching between different technologies “on a click” and thus different approaches (such as PON, Active Ethernet or PTP) can be analyzed and compared, enabling a more sophisticated evaluation of the overall project viability. Figure 1 provides an exemplary structure of a business case model.

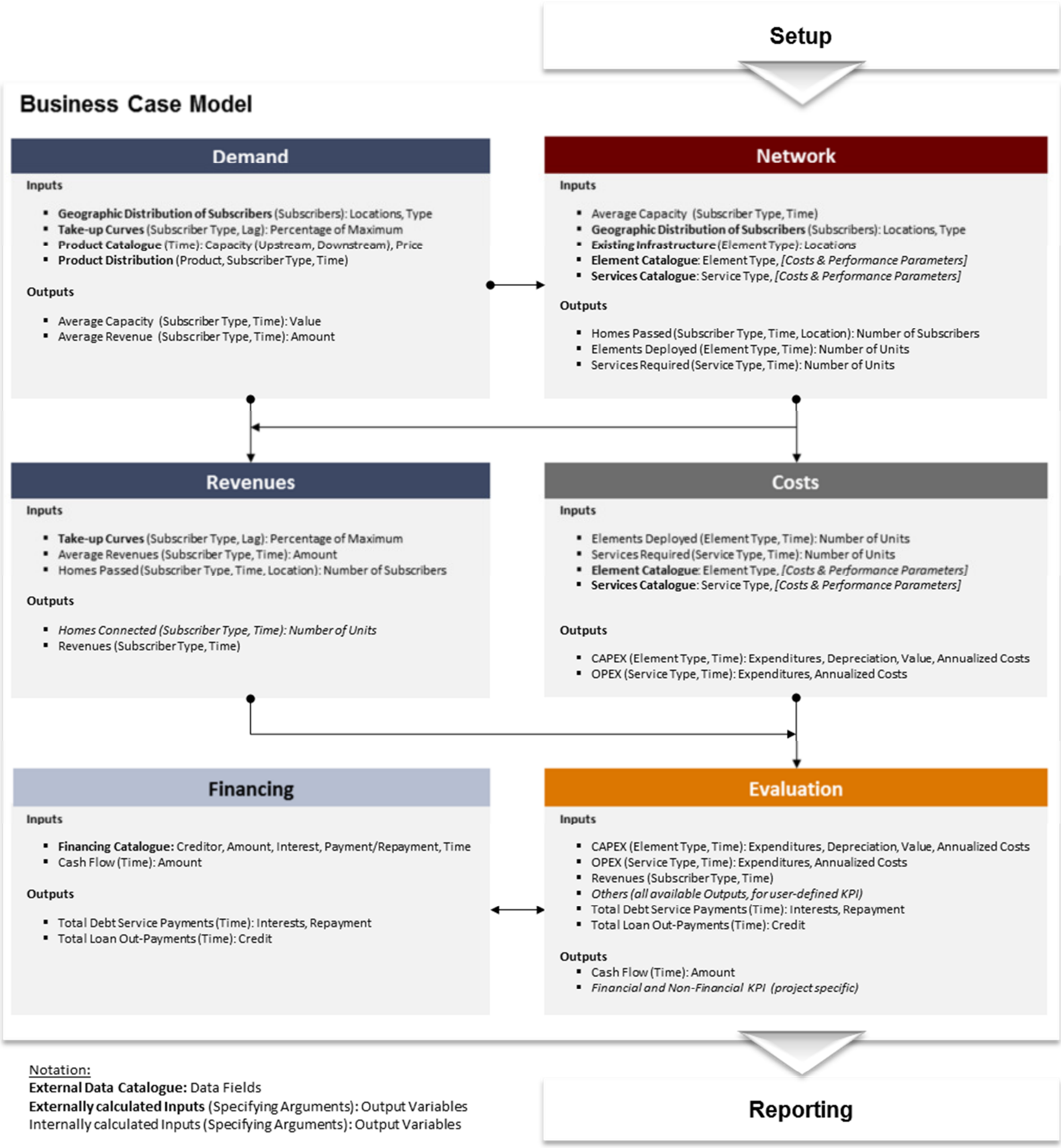

Figure 6: Modular framework for business cases

For each component, necessary inputs are given as well as the available outputs, including the dimensions (values in brackets) according to which the provided data is structured. Note that there exist three data types, which are explained below:

4.3.1 External data catalogues

Data, which is stored in databases, comprising a large number of elements and which needs no additional processing (except actualization) before it is used within the model. The presented approach makes use of four databases, which contain economically and technologically relevant information on active and passive **network equipment** (Network Equipment Catalogue), **services** that are required to build and to operate the network, including construction services as well as electricity and labor costs (Services Catalogue), available **financing methods** and conditions, (Financing Catalogue) and, finally, a collection of **broadband products**, which differ inter alia in the available bandwidths, prices and offered services for either business or private customers (Product Catalogue).

Figure 7: Database format (example)

Input assumptions which are related to data within any of the four databases can be extended and updated according to changes in the respective parameters. New Equipment can be considered by simply adding an entry. As the structure of each database is standardized, it can be reused for several projects requiring only a moderate number of changes. Each module has access to either of the databases, indicating that methods are strictly separated from input assumptions.

4.3.2 Externally and internally calculated Input

External calculated input refers to data which needs preprocessing that possibly has to be adapted to local conditions. Furthermore, such data may have several dimensions, if the values of variables differ according to several criteria, as e.g. values of “product distribution”, would depend on “time” as well as on “product type” and “subscriber type”. Even though there are no changes in the data format, it allows for alternative ways of calculation due to specific local conditions – which are not part of the framework and thus allow for a sufficient degree of flexibility. For the given example this would be necessary, if certain broadband products were not planned to be offered within an area. The present model approach comprises inputs that can be adapted with respect to project conditions with regard to:

- The **distribution of broadband products**, which may change over time and may be different for different types of subscribers. For individual projects the method of assignation may change.
- **Take up curves**: Describe the development of subscriptions once the network is available in an area. They specify the percentage of all potential subscribers that has signed contract after a certain time (lag).
- **Geographic distribution of subscribers**. For each location the subscriber type (business or residential) is indicated.
- **Existing Infrastructure**: Needs to be mapped onto the geographic distribution of subscribers.

Internally calculated Inputs have been calculated by other modules of the framework and therefore the respective methods are standardized and cannot be customized according to special project requirements. The respective outputs serve as an input for other model components as well as for the final evaluation module. Based on the outputs of the different modules, figures can be combined in order to derive customized profitability indicators and by that such framework permits the implementation of multiple of forecast features which are consistent, robust and manageable with reasonable effort.

5. SUMMARY

This paper has provided an overview on relevant features of fiber investment projects including relevant project phases as well as a functional grouping of participants. It has pointed out that – at the cost of some accuracy, though – TCO-modeling may concentrate on costs and revenues incurred by a hypothetical operator that can be seen as a virtual entity which is responsible for planning, deployment and operation of the network. As further aspects that emerge in the context of cooperation between different actors are neglected, an assessment of possible impacts of the latter on the obtained quantitative results is mandatory.

With respect to potential investment risks, cost- and demand-related risks require to be addressed within viability assessment by means of reliable forecasts, whereas operational risks would rather be subject to an evaluation in the course of detailed network and project planning – i.e. by assessing the skills of potential sub-contractors. The multitude of uncertainties that are characteristic for infrastructure projects, create room for either unintended or intended (i.e. strategic) misinterpretation of facts and figures by responsible authorities. In order to avoid such perception bias, the introduction of reference classes has been suggested, which relies on the statistical evaluation and classification of former projects and thereby serves as a basis for parameter estimation of future projects.

Forecasts on the basis of reference classes can be facilitated considerably, when business case models have a modular structure, as it allows for combining input data from different reference projects, when appropriate – that is when the considered parameters are not related to common features, which would require the selection of identical reference projects. If a modular framework is pursued, interfaces have to be defined, which enable the interoperability of individual modules and permit independent improvement, development and replacement of single modules as well as the enhancement of the entire framework.

Furthermore, an exemplary design of such framework has been provided. Relevant modules have been illustrated as well as the structure of information that is exchanged between them. As regards the inclusion of information, it is crucial how it enters that calculation process. Some data needs structural manipulation (i.e. preprocessing), whereas other can be stored in databases which only require updates – but no structural changes.

In combination with a sufficient qualitative assessment, modular business case models that consider data from reference projects are promising to facilitate the implementation of infrastructure investment profitability forecasts, which are consistent, robust, manageable and extendable with reasonable effort.

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