

Analyzing the complexity of decision making in broadband network upgrading & roll out

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1 Introduction

Although broadband has been on the academic research agenda for quite some time now, as yet this has not resulted in a unifying theory combining technical, economic and policy/regulatory factors with regard to an evolutionary, flexible approach of network upgrading. There is no insight into the way technological, economic or regulatory factors affect broadband rollout in the local loop. The purpose of our research is to create insight into how technological, economic or regulatory factors affect broadband rollout in the local loop in order to develop a conceptual model that will allow us insight into critical relationships between these factors and the decision to invest in broadband infrastructure and to implement and rollout broadband in the local loop.

To develop a conceptual framework, (see figure 1) three research methods have been used (Bouwman et al., 2006). First, Meta-analysis to collect and analyze relevant existing literature that discusses broadband rollout in the local loop. The aim of this Meta analysis was to develop a conceptual model that allows insight into critical relationships between technical, economic and policy factors and the decision to engage in broadband infrastructure investments, implementation and broadband rollout in the local loop. Second, content analysis was used on hypotheses and propositions and finally network analysis has been applied on the data extracted from the literature. The combination of these three research methods has resulted in a first conceptual model that describes the path from decision making about broadband roll out upon the revenues generated with this roll out. This conceptual model is shown in Figure 1.

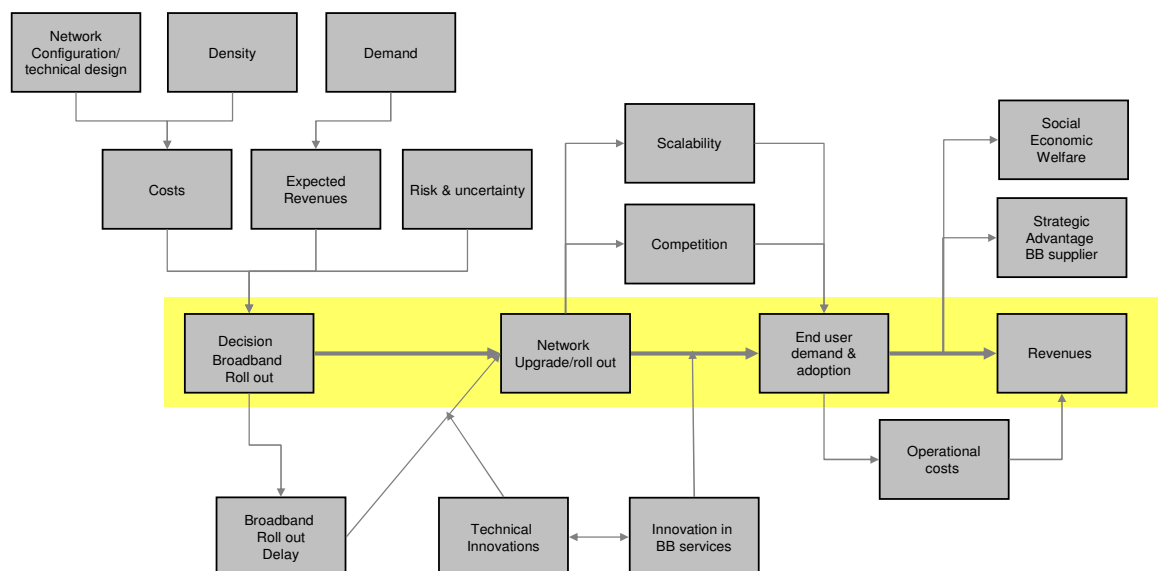


Figure 1: Conceptual model

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Within the process of rolling out a broadband network (upgrade), four different phases can be distinguished (see the frame in Figure 1). In the first phase, analysis and comparison of the different technological alternatives for broadband upgrade and roll out, together with the related financial and risk analysis are the key activities. At the end of this phase the actual choice for one or more directions (technology paths) is being made. After this decision the actual network roll out or upgrade will take place. This is mainly an operational phase. In the third phase, after the roll out has started, the adoption and use of the network by broadband consumers will start and develop. Phase 3 basically is the phase in which all kind of exploitation issues are central. Most of the times, phase 2 and 3 are overlapping because some geographical areas will be connected earlier than others and adoption can take place as soon as a connection has technically been realized. Finally, adoption will result in actual revenues for the providers because customers will pay for their broadband subscription. Overlap can also be seen between phase 3 and 4, because revenues start immediately as soon as adoption takes place.

2 Qualitative data analysis

To validate the conceptual model two research methods have been applied. First, a quantitative method by means of a survey among national and international decision makers, researchers and consultants, followed by statistical analysis of survey results (Bouwman, Fijnvandraat, 2007). Second, a qualitative research method of in-depth expert interviews and qualitative data analysis. This paper will get into the results of this qualitative validation.

As a start of the qualitative validation, 13 in depth interviews have been held with decision makers within telecom companies in The Netherlands. The interviewees are employed in the two biggest cable companies of The Netherlands, being UPC and Essent Kabelcom (@Home), the Dutch incumbent telecom company KPN and Tele2-Versatel, the biggest Dutch alternative provider that uses the incumbent's network by means of local loop unbundling (LLU) but has its own core fibre network. The interviewees are all part of the middle management of these companies and are all directly involved in the decision making process regarding the roll out or upgrade of the telecom network of the concerning companies. With these companies, we covered the largest part of the Dutch telecom market, being operators with a copper TP, cable and 'virtual' local loop. To ensure internal consistency within companies and to cover our whole area of interest (economic, organisational, regulatory and technical issues) three decision makers have been interviewed per company. All interviews were taped, transcribed and the reports have been reviewed and approved by the interviewees.

As a next step all interviews are analyzed with Atlas.ti v5.0, a scientific software programme for visual qualitative data analysis. This software makes it possible to create causal or concept maps. This research methodology will be explained in the next paragraph.

Concept mapping

Within this research concept maps are used as a means of representing the conceptual structures underlying the process from decision making about network upgrade/ roll out until the moment of actual revenues.

Concept mapping is a technique for visualizing the relationships between different concepts. Concept maps are a graphical two-dimensional display of knowledge that is comprised of concepts (usually represented in boxes or circles), connected by directed arcs enclosing brief relationships (linking phrases, mostly verbs) between pairs of concepts (Canas et al., 2005). Together, nodes and labelled or named links define propositions, assertions about a topic, domain, or thing (Alpert & Gruenberg, 2000). Linking phrases are not limited to a defined

set and can express any type of relationship. Figure 2a shows the theoretical representation of a concept map. Figure 2b gives an example: “Digging has impact on the roll out costs”.



Figure 2a: Theoretical representation of a causal map and 2b: example of causal map

In our research the used relationships are "A has (strong) impact on B", "A is cause of B", "A is part of B", "A and B are mutually influencing" or "A is a B".

Concept maps are used to structure argument forms and express relationships between ideas (Gaines and Shaw, 1993). They are useful to understand complex issues that can have multiple consequences or multiple explanations (Limkeatcherdchoo, 2006). The ability to measure a particular person’s knowledge about a given topic in a specific context is the major strength of concept maps (Canas et al., 2005). Due to variations in mapping conceptual structures, a variety of other terminologies is used for concept maps, i.e. ‘cognitive maps’, ‘knowledge maps’, ‘network maps’, or ‘mind maps’ (Tergan et al., 2005). For consistency, in this paper the term concept mapping will be used.

Novak and Gowin (1984) mention several characteristics of concept maps. First, concept maps must have a structure, which is, by definition, hierarchical. Second, concept maps are based on propositions and every two concepts (A and B) and their linking phrase must be propositional coherent, which means that they form a ‘unit of meaning’. Third, concept maps have a specific context, a particular domain of knowledge within which all concepts and linking phrases must be interpreted.

Putting the concept maps in this research to these criteria, they do not meet the first criterion, due to the complexity of the concept maps in this research. The concepts in our maps have many interrelationships and are for that reason so complex that they cannot be fitted in a structured, hierarchical tree lay out.

The strict criteria the “Novakian standard concept mapping format” demands are, however, questioned by other researchers. Åhlberg (2004) mentions that although Novak & Gowin (1984) and Novak (1998) argue that concept maps should always be hierarchical, this is not always logical or economical. The fact that the world is a system implies that the best presentation of the world and its subsystems are conceptual systems, which are not always hierarchical (Åhlberg, 2004).

The high complexity and many interrelationships in this research can be explained by the fact that these concept maps do not show the concepts and relations mentioned by one person but by 13 persons. It was consciously chosen to bundle all concepts and relationships of all decision makers we interviewed into one dataset for concept mapping. The objective of using concept mapping is to generate general, sector wide insight in concepts and the relations between them to create a general conceptual model. By eliminating concepts that are mentioned only a few times, individual opinions are filtered out, which leads to more generic but broadly covered concepts. This makes it, however, very hard to create structured and hierarchical maps. The fact that there are so many interrelationships between the concepts shows how complex the decision making process is and how many variables are involved in this process.

The other two characteristics of concept maps, propositional coherency and being part of a particular knowledge domain are very well applicable to the concept maps concerned in this research. The specific knowledge domain is 'decision making around upgrading and roll out of fixed broadband networks'.

The advantage of concept mapping software

All interviews have been analyzed with Atlas.ti v5.0, a scientific software programme for visual qualitative data analysis. This package enables segmenting a text into passages (words, (parts of) sentences, paragraphs) to be indexed with codes. The software makes it possible to visually "connect" selected passages, memos, and codes into diagrams which graphically outline complex relations. The use of a software program like Atlas ti. has the advantage that all interviews and the concepts (named 'codes' within Atlas ti.) are linked to each other. The used concepts are listed and for every word or sentence that must be coded as a new concept, this list can be used to pick an already used concept for this word/sentence. As a result, links with these concepts out of several interviews are linked automatically, because they have the same concept name. For example, when concept A is linked in interview 1 with concepts B and C and in interview 5 with concept D, the software links these concepts and shows a concept map for concept A with relationships to B, C, and D. This way, the answers from 13 decision makers are combined in concept maps which results in concept maps with a more generic character, covering the opinion of the biggest part of the Dutch telecom market in stead of the opinion of one company.

In the following part of this paper, the concept maps of the four phases of our conceptual model (see phases in the frame in Figure 1) will be discussed in detail. For every phase, the additions to the conceptual model, based on the concept maps will be shown and explained.

3 Validating and adjusting the conceptual model

The four- phase base model

As a first step this paragraph discusses the basic four phase model, as shown in the black frame in Figure 1. The concept map shows that the four phases, which form the core of the conceptual model, are impacting each other in the way the causal model shows, which indicates that this basis model is validated by decision makers in the field. The concept map shows, additional to this, 2 feedback loops that are not mentioned in the first conceptual model. These are a feedback loop from end user demand and adoption phase towards the decision making phase and a feedback loop from revenues to the decision making phase. These loops are very well explainable: in case end user demand exceeds expectations, a decision must be made about further upgrading the network or in case demand is disappointing, maybe roll out must be delayed. The same counts for revenues. Disappointing as well as revenues above expectation lead to reconsideration of the original roll out strategy. Disappointing revenues are an immediate cause for delaying the planned roll out or entering a new round of the decision making process to upgrade the network. This is very well visible in Figure 3. The variable network upgrade delay is not, like in the conceptual model connected with phase 1 and 2 but with phase 3 and 4. Also disappointing end user demand will lead to a delay of the network roll out. We also see the relationship between end user demand and adoption and acceleration of roll out. This is a positive relationship: in case demand and adoption go by quicker than expected, roll out will be accelerated.

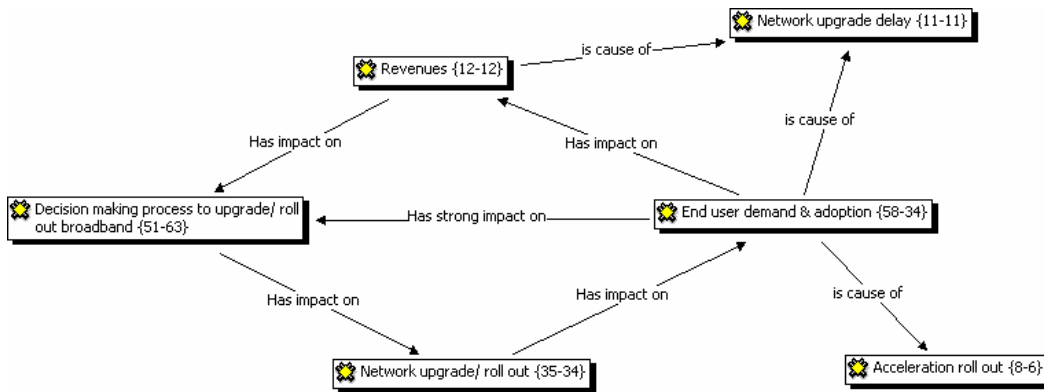


Figure 3: concept map of 4 phase model and network upgrade delay and acceleration

The numbers in brackets, shown after the concepts in Figure 3 indicate the number of times that the concept is mentioned and the number or relationships it has with other concepts (the density). For example, the concept ‘network upgrade/ roll out’ is mentioned 35 times by interviewees and has 34 relations (in- and outgoing) with other concepts. The concepts of figure 2 and their linking phrases are given in Table 1.

Table 1: Relationships between the 4 main phases

Source concept	Relation (linking phrase)	Target concept
DM process to upgrade/roll out broadband	Has impact on	Network upgrade & roll out
Network upgrade & roll out	Has impact on	End user demand & adoption
End user demand & adoption	Has strong impact on	DM process to upgrade/roll out broadband (feedback loop)
End user demand & adoption	Has impact on	Revenues
End user demand & adoption	Is cause of	Broadband roll out delay
End user demand & adoption	Is cause of	Acceleration
Revenue (phase)	Has impact on	DM process to upgrade/roll out broadband (feedback loop)
Revenue (phase)	Is cause of	Broadband roll out delay

As a next step, we compare the concept map with the original conceptual model to validate the latter. Figure 3 shows the result of the adjustments to the original conceptual model (figure 1), based on the concept map of Figure 3. The adjusted model has 2 feed back loops that didn’t exist in the original model. Acceleration of roll out was not mentioned in the original model.

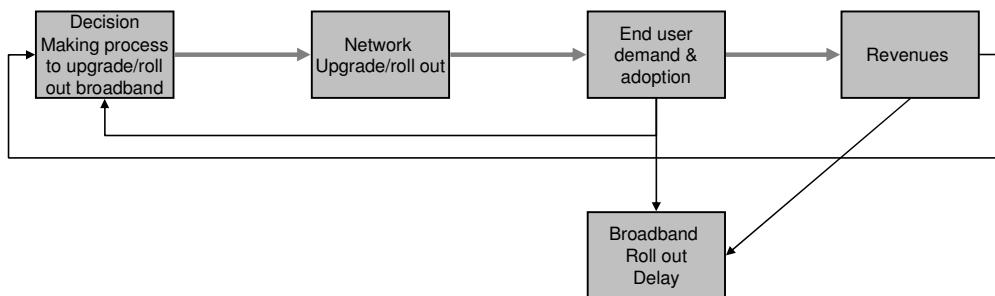


Figure 4: Adjusted base of the conceptual model (4 phases)

Having discussed the 4 phase base model, the next part of tis paper will discuss the 4 phases and their related concepts in more detail.

Phase 1: Decision making process to upgrade/ roll out broadband

The first phase of the upgrade- and roll out process of broadband networks is the decision making process to upgrade or roll out a broadband network. The concept map of phase 1 of

the conceptual model (the decision of broadband roll out) and all related variables show a non transparent 'blurb', caused by many and highly interrelating concepts. Within the concept maps the focus lies on relationships that concern causality, i.e. the relationships 'is cause of', 'has impact on' and 'has strong impact on'.

To make the 'blurb' of variables more insightful, the following criteria for variables have been formulated and will be taken into account in the concept maps:

- 'Causal' relationships (A is cause of B) are in all cases concluded in the concept map, because this relation is the strongest relationship between variables. When variable A is a cause of variable B it means that it is a *direct cause* of it.
- 'Strongly impacting' variables (A has strong impact on B) must be mentioned *at least 5 times* to be part of the model.
- 'Impacting relationships (A has impact on B) must be mentioned *over 10 times* to be part of the model.

In the concept map of phase 1 five variables are direct causes of the decision making process; 22 variables have strong impact on the process (and are mentioned over 5 times). These concepts and their linking phrases are shown in Table 2.

Table 2: Source and target concepts and relationships phase 1

Source concept	Relation (linking phrase)	Target concept
Incoming variables		
Sense of urgency (6)	Is cause of	DM process to upgrade/roll out broadband
Business strategy (27)	Is cause of	DM process to upgrade/roll out broadband
Driver for network upgrade (6)	Is cause of	DM process to upgrade/roll out broadband
Technological alternatives (23)	Is cause of	DM process to upgrade/roll out broadband
Technological developments (36)	Is cause of	DM process to upgrade/roll out broadband
Bandwidth development (6)	Has strong impact on	DM process to upgrade/roll out broadband
Business case (35)	Has strong impact on	DM process to upgrade/roll out broadband
Competition (46)	Has strong impact on	DM process to upgrade/roll out broadband
Cost rationalization (9)	Has strong impact on	DM process to upgrade/roll out broadband
Decision holding (7)	Has strong impact on	DM process to upgrade/roll out broadband
Demand forecasting (7)	Has strong impact on	DM process to upgrade/roll out broadband
End user demand and adoption (58)	Has strong impact on	DM process to upgrade/roll out broadband
Expected end user demand (developments) (13)	Has strong impact on	DM process to upgrade/roll out broadband
Financial analysis (11)	Has strong impact on	DM process to upgrade/roll out broadband
Financial resources (7)	Has strong impact on	DM process to upgrade/roll out broadband
Future proofness (12)	Has strong impact on	DM process to upgrade/roll out broadband
Individual actor behaviour (7)	Has strong impact on	DM process to upgrade/roll out broadband
Long term vision (5)	Has strong impact on	DM process to upgrade/roll out broadband
Market developments (25)	Has strong impact on	DM process to upgrade/roll out broadband
Regulatory issues (25)	Has strong impact on	DM process to upgrade/roll out broadband
Scalability (9)	Has strong impact on	DM process to upgrade/roll out broadband
Service development (18)	Has strong impact on	DM process to upgrade/roll out broadband
Shareholders (7)	Has strong impact on	DM process to upgrade/roll out broadband
Suppliers (15)	Has strong impact on	DM process to upgrade/roll out broadband
Uncertainty (7)	Has strong impact on	DM process to upgrade/roll out broadband
Vision, sense, and entrepreneurship (10)	Has strong impact on	DM process to upgrade/roll out broadband
Finance & control department (11)	Has impact on	DM process to upgrade/roll out broadband
Management (13)	Has impact on	DM process to upgrade/roll out broadband
Revenues (12)	Has impact on	DM process to upgrade/roll out broadband
Investments (24)	Has impact on	DM process to upgrade/roll out broadband
Outgoing variables		
DM process to upgrade/roll out broadband	Has impact on	Network upgrade/roll out (35)
DM process to upgrade/roll out broadband	Is cause of	Timing of upgrade/ roll out (8)

Figure 4 shows the concept map. It can be seen that there are many concepts and that all concepts are very closely interrelated with each other, which points at high complexity.

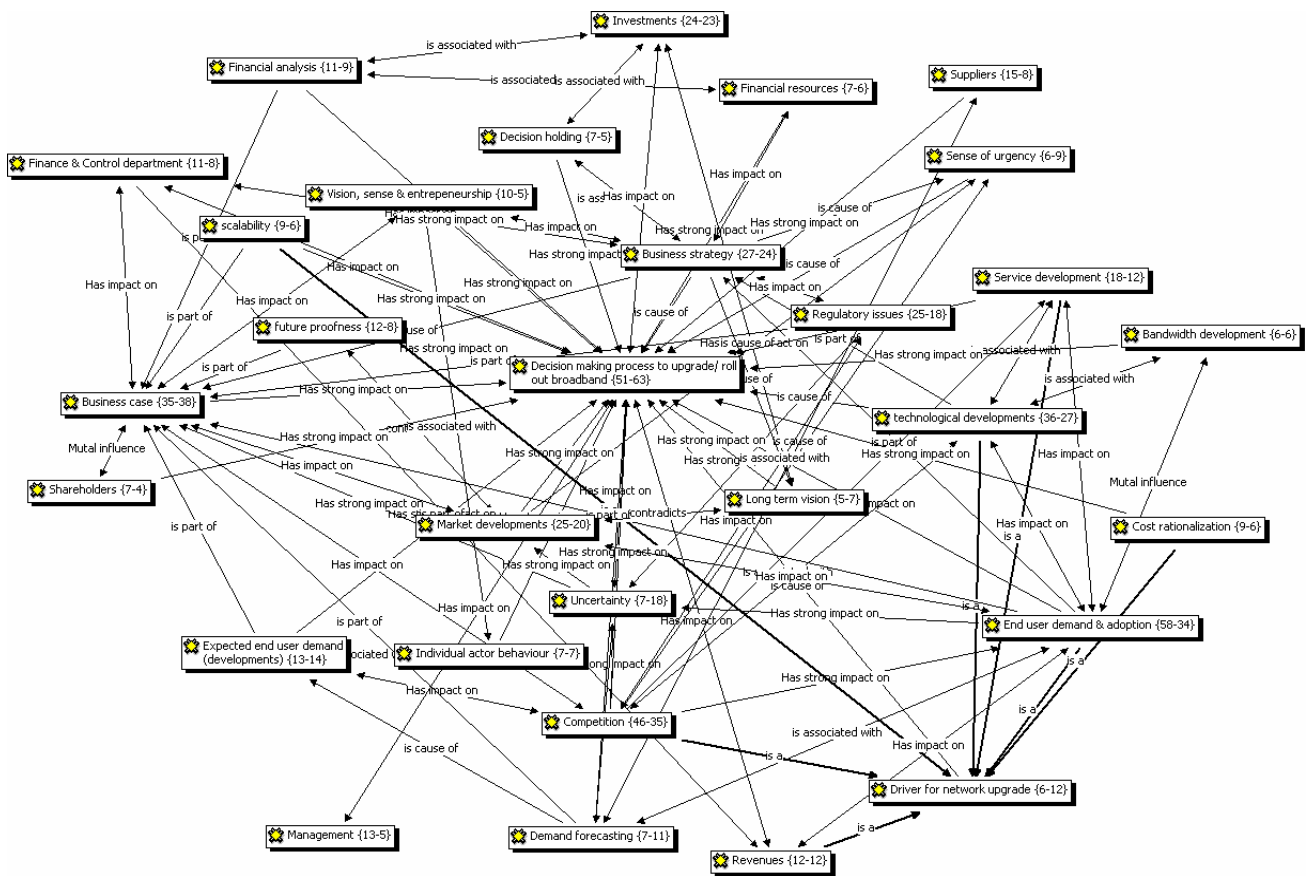


Figure 5: Concept map phase 1- decision making process to upgrade network (incoming and outgoing causing and strongly impacting variables)

One of the concepts in phase 1 is 'drivers for network upgrade'. Because this is not a concrete variable, but an accumulation of several other concepts (drivers), we will look into this variable one step further, which brings us the concept map of Figure 6.

Figure 6 shows the factors that are drivers for network upgrade. As drivers or incentives to upgrade the current network are mentioned: Cost rationalization, scalability, technological developments, service developments, competition, end user demand and adoption, revenues, technological network boundaries, and costs. Because these drivers are a direct cause of the decision making process to upgrade/ roll out a broadband network, we can state that these variables also are direct causes of this decision making process to upgrade the network. (A=B=C, so A=C).

Several of these factors have, however, also a direct connection with the variable 'decision making to upgrade network'. As a result, the variables 'costs', 'technological network boundaries' and 'revenues' can be added as additional factors influencing the decision making process to upgrade the network:

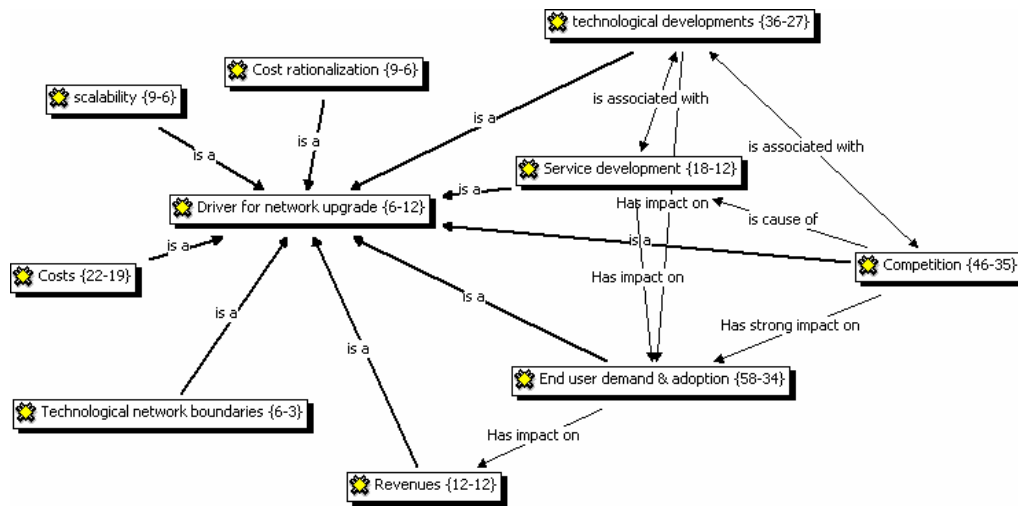


Figure 6: Concept map for “Drivers for network upgrade”

Two other variables should be given more attention. The variables ‘sense of urgency’ and ‘business case’ are concepts that doesn’t give any insight unless you dig into the variables behind the concept.

Figure 7 shows the concept map for ‘sense of urgency’. It shows that several variables that also have a direct link with the decision making process have a stronger impact on this process via the concept ‘sense of urgency’. Competition, market developments, business strategy and the necessity to upgrade the network are four variables that cause a high sense of urgency to make a decision around an upgrade or roll out. For this reason, these variables will accelerate the decision making process by forcing decision makers to choose direction. The variable ‘technological network boundaries’, which is also a driver for network upgrade, is a direct cause of the necessity to upgrade the network, which appears to be logic, because when the network capacity is lagging behind on the market demand, an upgrade will be necessary to avoid subscribers from churning.

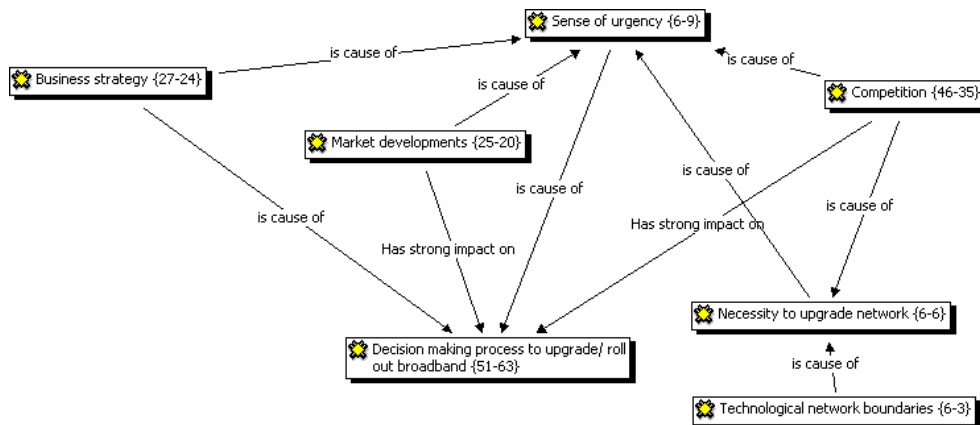


Figure 7: Concept map for “sense of urgency”

Thirteen variables that have strong impact on the decision making process are also impacting or part of the business case. These variables are shown in the concept map of Figure 8.

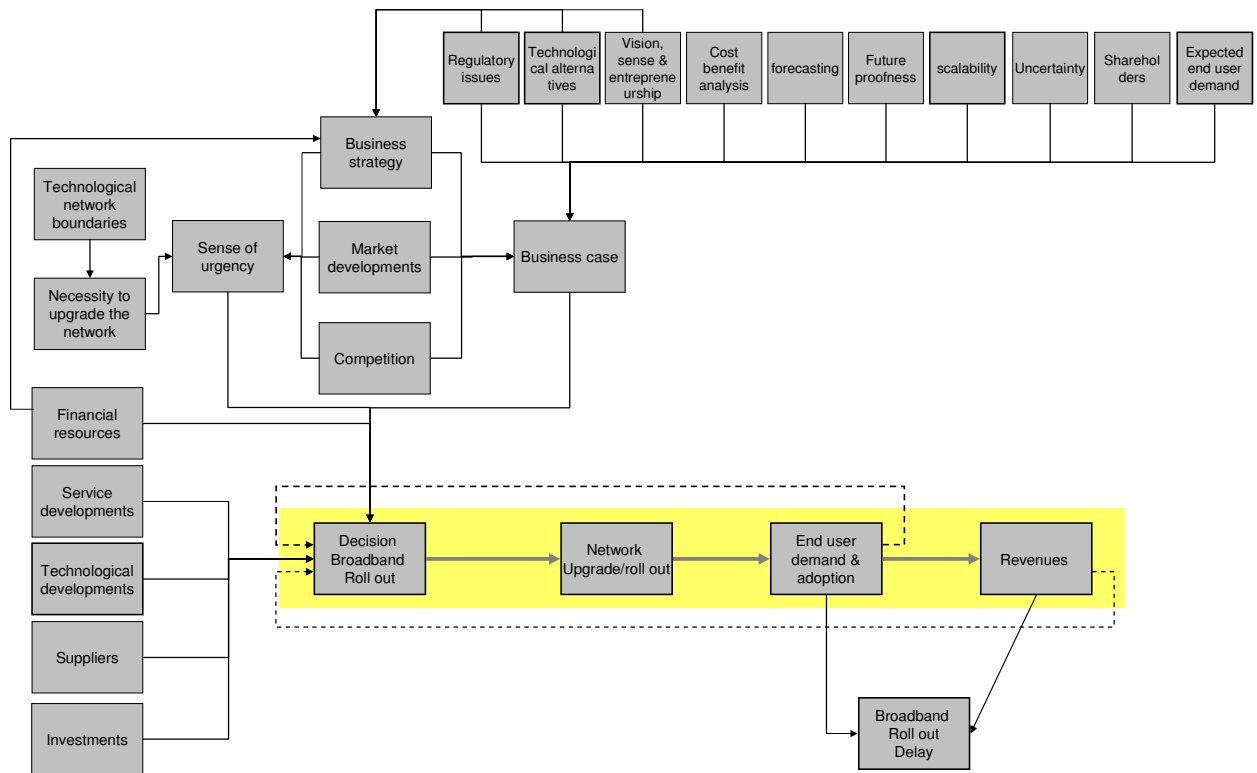


Figure 9: Adjusted model phase 1

Phase 2: Network upgrade/roll out

After the decision making process, a decision is made to roll out or upgrade the current broadband network by following one or more migration paths. This upgrade or roll out forms the second phase of the process and is mainly an operational phase. Within this phase, several decisions have to be taken around the operational progress, the speed of the roll out, the technology, the contracts with equipment suppliers, (sub) contractors, etc. The concept map of network roll out is less complex than the concept map of the first phase. Table 3 shows the variables that are included in the concept map.

Table 3: Source and target concepts and relationships phase 2

Source variable	Relation	Target variable
Incoming variables		
Suppliers (15)	Has strong impact on	Network upgrade & roll out
Bandwidth (7)	Is cause of	Network upgrade & roll out
Competition (46)	Is cause of	Network upgrade & roll out
Choice between technologies (32)	Has impact on	Network upgrade & roll out
Decision making process to upgrade/roll out broadband (51)	Has impact on	Network upgrade & roll out
Outgoing variables		
Network upgrade & roll out	Has impact on	End user demand and adoption (58)
Network upgrade & roll out	Has impact on	Operational costs (13)
Network upgrade & roll out	Mutual influence	Customer penetration (11)

These concepts and their interrelationships are visualized in the concept map of Figure 10.

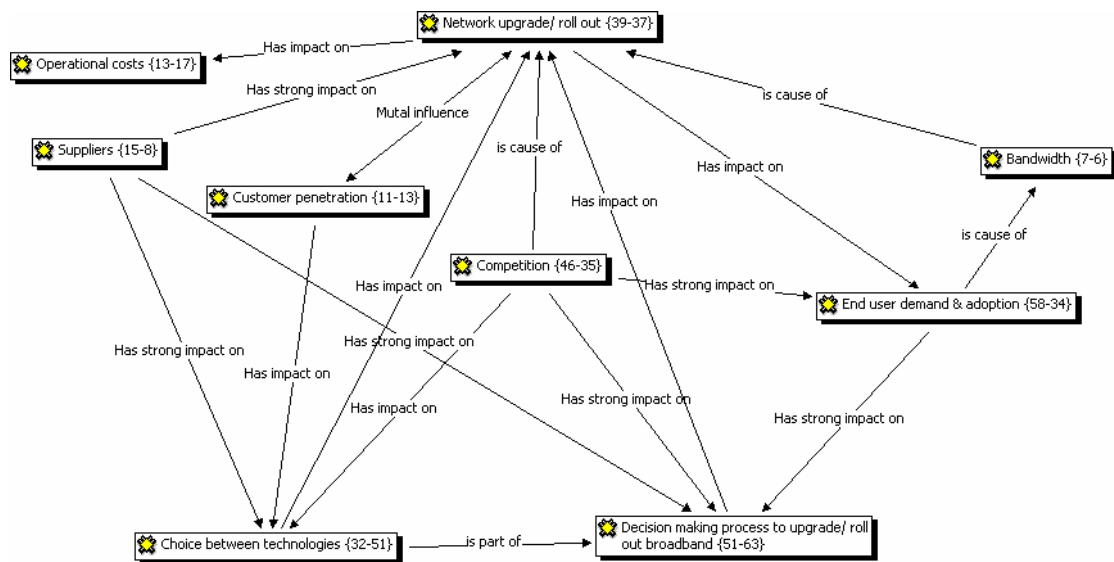


Figure 10: Concept map phase 2- network upgrade and roll out

Integrating these variables into the conceptual model, results into the model shown in Figure 11. Comparing this to the conceptual model (Figure 1) the following aspects are striking. The variable scalability doesn't appear in phase 2 but has appeared in phase 1. Competition appeared in the model as variable being influenced by network roll out. The variable comes back in the new model, however, as influencing variable: competition has impact on the network roll out, not the other way around. This is, however, a matter of point of view. For company A company B is competition but also other way around. As a result, when the network roll out of company A and company B are both influenced by competition, they automatically both must impact competition. For that reason, the variables 'network roll out' and 'competition' are mutually influencing each other. Interviewees indicate that competitive behavior has impact on how and with what pace they will roll out their own network. This partly explains both the delay in fiber roll out in the Dutch market but also the extremely high biddings on the UMTS frequencies: "It's better to go down all together than giving your competitor competitive advantage." Most operators adopt the strategy of being a 'quick follower' rather than being a first mover, because the first mover risks are too high. The variable roll out delay doesn't show in phase 2 of the new model but it will come back in phases 3 and 4. Operational costs are a logic consequence of rolling out a network as well as customer penetration. Customer penetration is on the other hand also a trigger for further roll out.

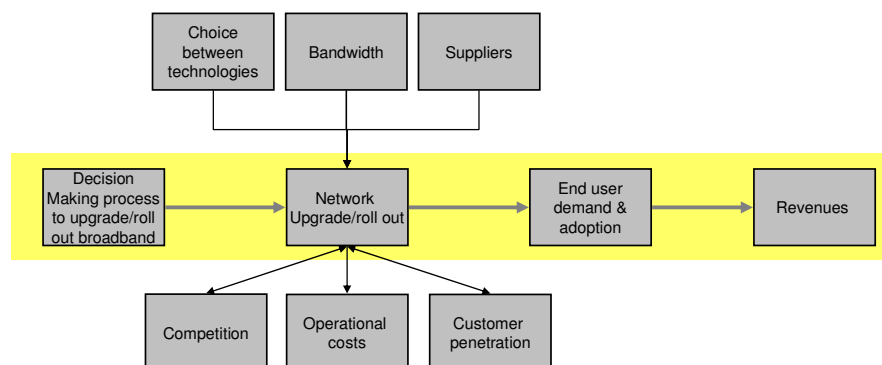


Figure 11: Adjusted model phase 2

and quick adoption will lead to acceleration of the current roll out, and on (necessary) upgrades of the existing network. Disappointing demand could make the company decide to delay the network upgrade. Demand and adoption also influences the strategy to follow evolutionary paths. This comes together with the fact that end user demand and adoption is a direct cause of uncertainty about market developments: in an uncertain environment, it's safer to opt for evolutionary upgrades instead of doing risky high investments in revolutionary upgrades.

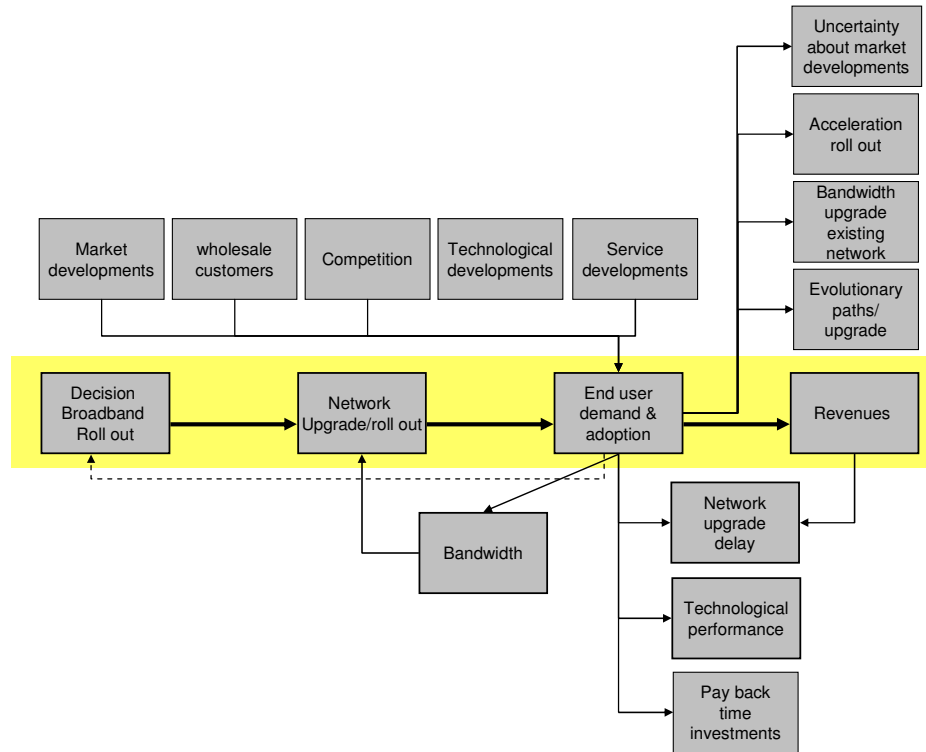


Figure 13: Adjusted conceptual model phase 3

Phase 4: Revenues

The final phase is the revenue phase. In this phase adoption will result in actual revenues for the providers because customers will pay for their broadband subscription and services. This phase goes by parallel to phase 3 because revenues start immediately as soon as adoption takes place. Table 5 shows the in- and outgoing variables of phase 4, together with their linking relationships.

Table 5: Source and target concepts and relationships phase 1

Source variable	Relation	Target variable
Incoming variables		
Broadband services (20)	Has impact on	Revenues
End user demand and adoption (58)	Has impact on	Revenues
Operational costs (13)	Has impact on	Revenues
Outgoing variables		
Revenues	Is cause of	Network upgrade delay
Revenues	Has impact on	Decision making process to upgrade/roll out

These concepts and relations together result into the concept map as shown in Figure 14.

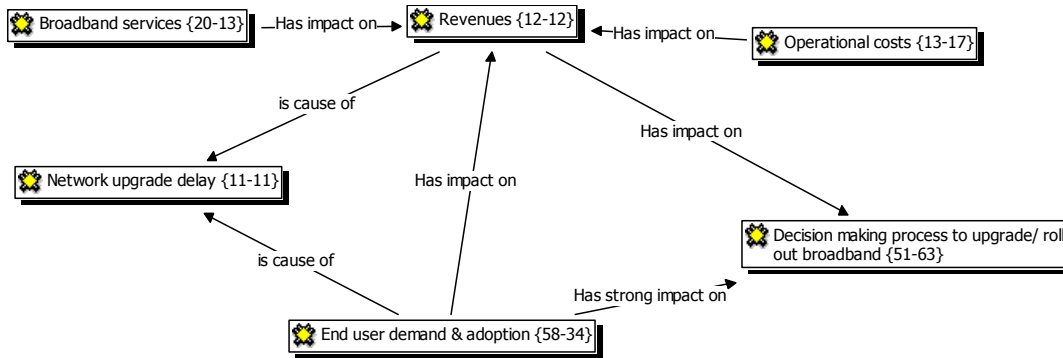


Figure 14: Concept map phase 4: Revenues

Comparing the relationships from this last concept map with the conceptual model, it can be seen that the variables ‘social and economic welfare’ and ‘strategic advantage broadband supplier’ are not mentioned in the interviews. The variable ‘operational costs’ has been validated as incoming variable of revenues. Striking is that Atlas ti also gives the relationship: “Revenues is a driver for network upgrade”, which implies that phase 4 also has a feedback loop with phase 2, which appears to be logic, because revenues bring in money that makes it possible to invest in network upgrades. These insights lead to the model of phase 4, shown in Figure 15.

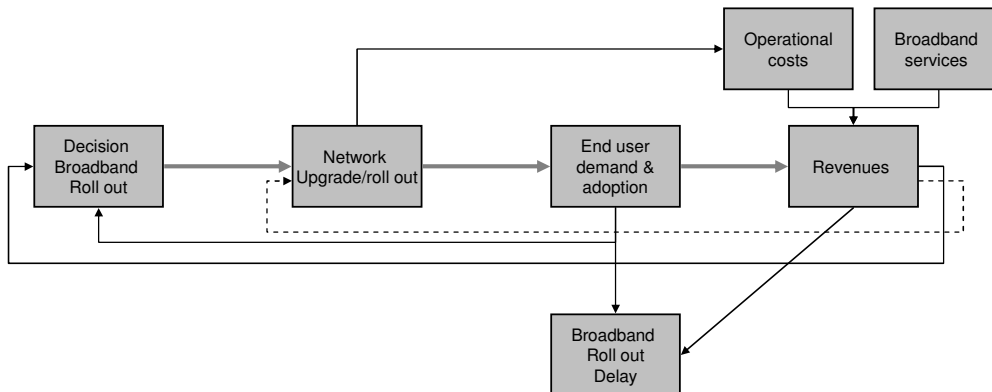


Figure 15: Adjusted conceptual model phase 4: revenues

4 Adjusted model

Combining these four adjusted phase models into one model gives us an adjusted model for the broadband network roll out process from decision making until revenues. This final model is shown in Figure 16.

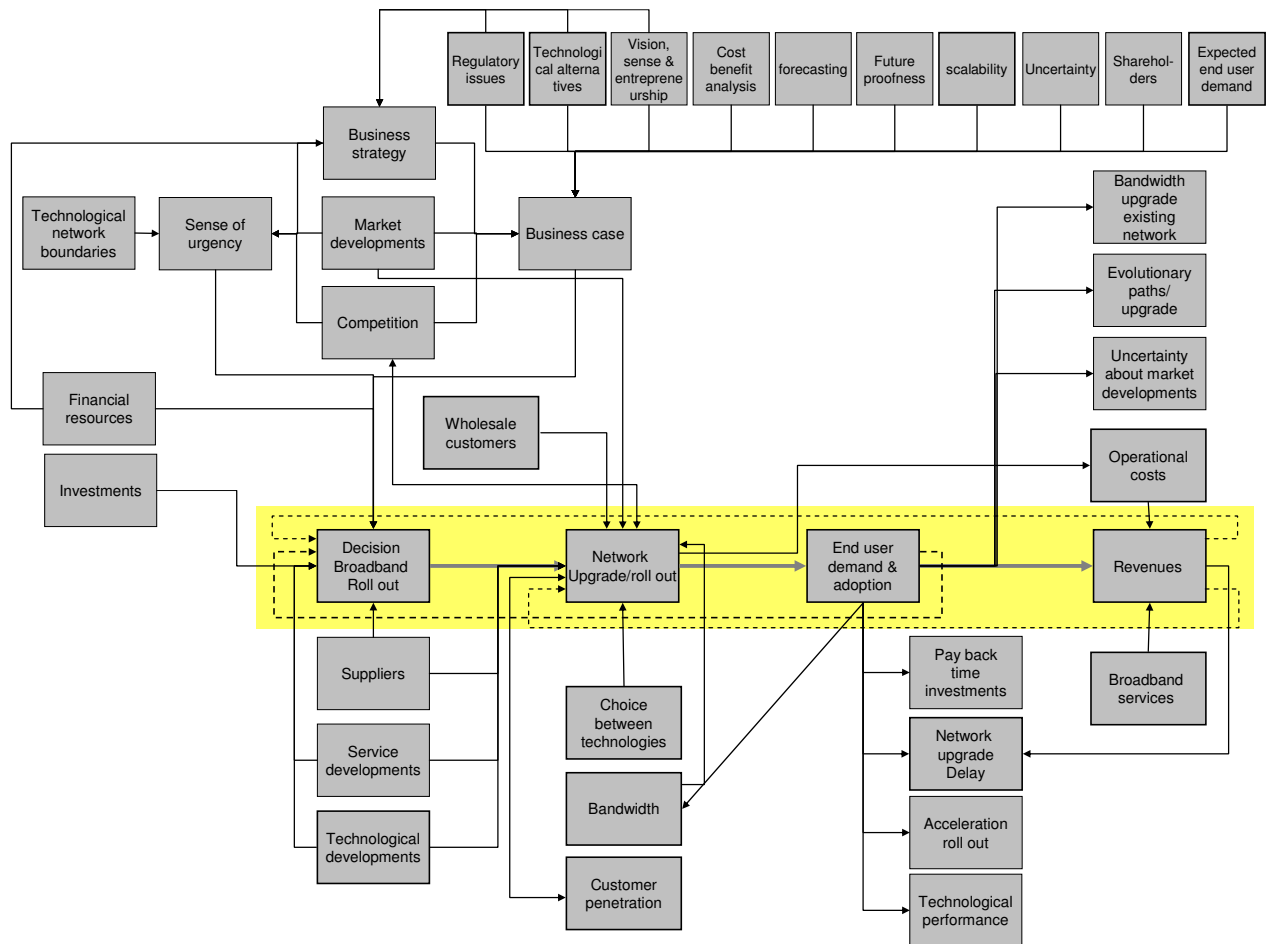


Figure 16: Adjusted conceptual model

5 Conclusions

From the four phases of the model, the first phase of decision making is clearly the most complex one. The decision making process includes the comparison of business cases, alignment with the business strategy, forecasting, reacting on all kind of developments in the surroundings, etc. Besides this, the feed back (results) from the following phases are also input for the first phase. After a decision for a migration path is made, the following phases are more operational and for that reason less complex. The decisions made in these phases are less strategic and more planning related.

Most variables of the original conceptual model have been validated by the qualitative data analysis, being not always at their original position in the model or at the same level of aggregation. Three variables, being social and economic welfare, density, and strategic advantage have shown not being relevant for the interviewees.

On the other hand, new information is gained by these interviews, which has resulted in additional variables in the model. Most noticeable are several feedback loops in the process, which imply it's an ongoing and repeating process, the importance of the 'soft side' of the decision making process, variables that lead to a high sense of urgency that can accelerate the decision making process and some concrete drivers for network roll out.

The final model as presented in Figure 10 is much more complex than the first conceptual model as presented in Figure 1. On the one hand, this can be explained by the fact that these models show more detail and aren't yet aggregated as much as the conceptual model. On the other hand the explanation lies in new information gained by the interviews that wasn't available in literature, which was the basis for the first conceptual model.

6 Limitations and further research

Atlas ti. has shown to be a very suitable tool for qualitative data analysis by means of concept mapping. Data resulting from interviews with 13 decision makers in telecom companies that together cover the market of copper TP, cable as well as local loop unbundled telecom infrastructure have been merged in generic and insightful concept maps.

A major drawback of the tool is, however, that it delivers insight into the number that variables have been mentioned but not into the number of relationships between concepts. The density of relationships remains unknown. For this reason, further validation of the relationships is necessary and will be done by means of statistical data analysis, based on surveys among decision makers.

A general risk of doing interviews with decision makers in companies is that they always have a hidden agenda and will never give insights in their business strategy, because this information is highly confidential. For our research, we, however, are searching for the variables influencing the several phases of the process and their relative importance, not for specific numbers. This makes that the answer "I cannot provide this information" was given very seldom during interviews.

The next research step is to test the relations from the new model with structural equation modelling with Lisrel. To make this possible, it will be necessary to reduce the number of model variables by clustering several variables into a higher level of detail. Although clustering will be necessary, insight in a more detailed level like the models in this paper provide is very useful to understand the complexity of the broadband roll out process.

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