Tutorial

Valuing flexibility in telecom infrastructure projects using real options thinking

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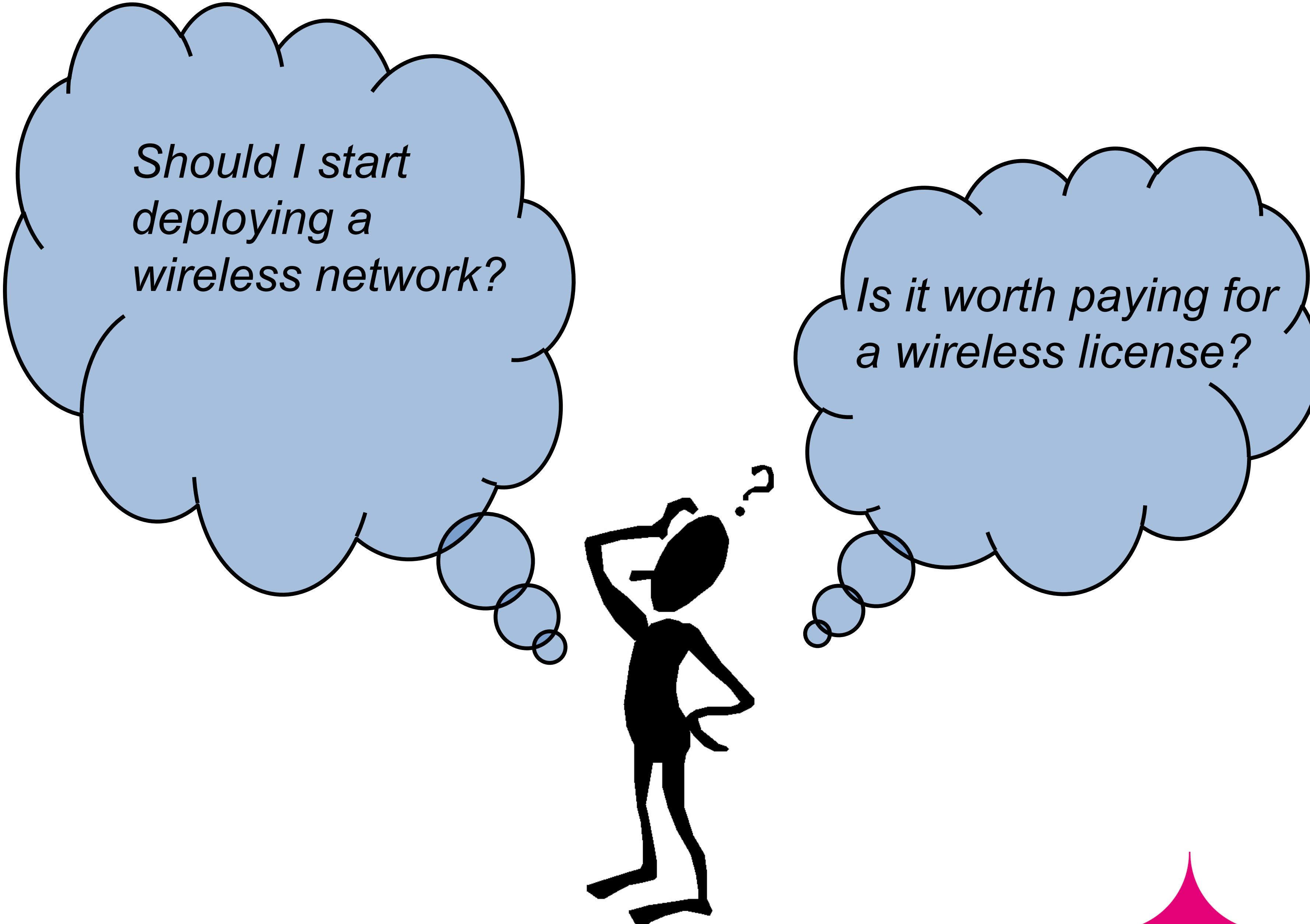

Should I start deploying a wireless network?
Is it worth paying for a wireless license?

Deployment of a wireless network

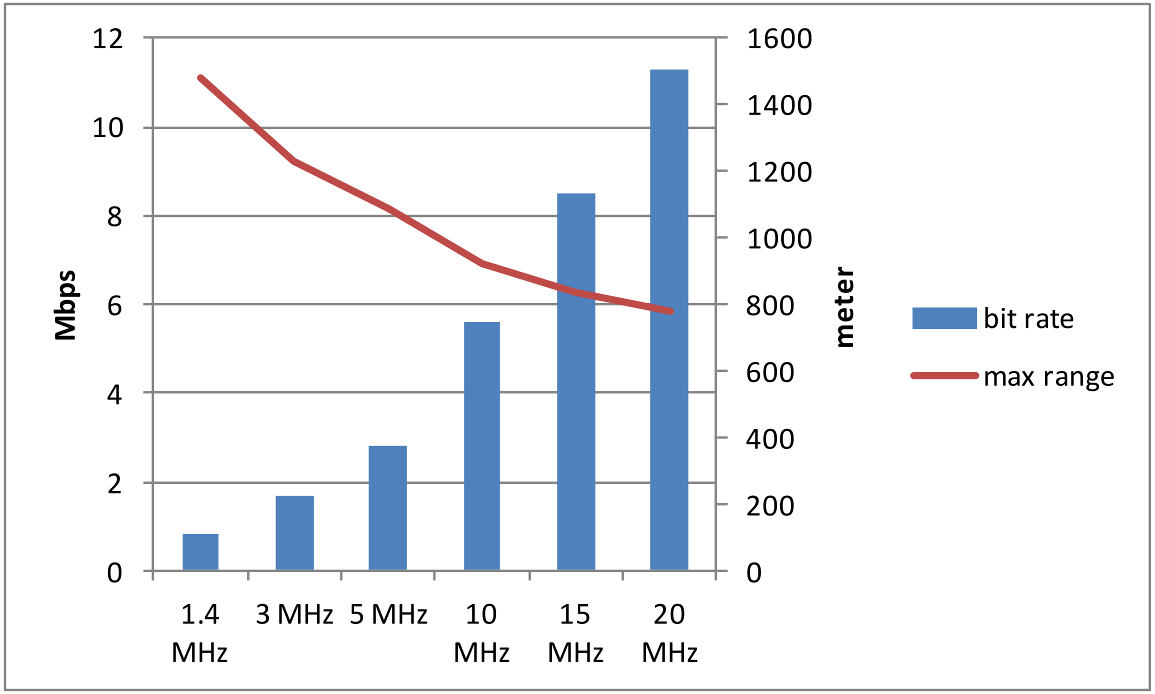
Example case of investment problem with inherent flexibility

LTE deployment
Some background

- Peak rates
  - 300 Mbps downlink
  - 75 Mbps uplink
- Scalable carrier bandwidths
  - From 1.4 MHz to 20 MHz
- FDD and TDD

LTE technology
Features

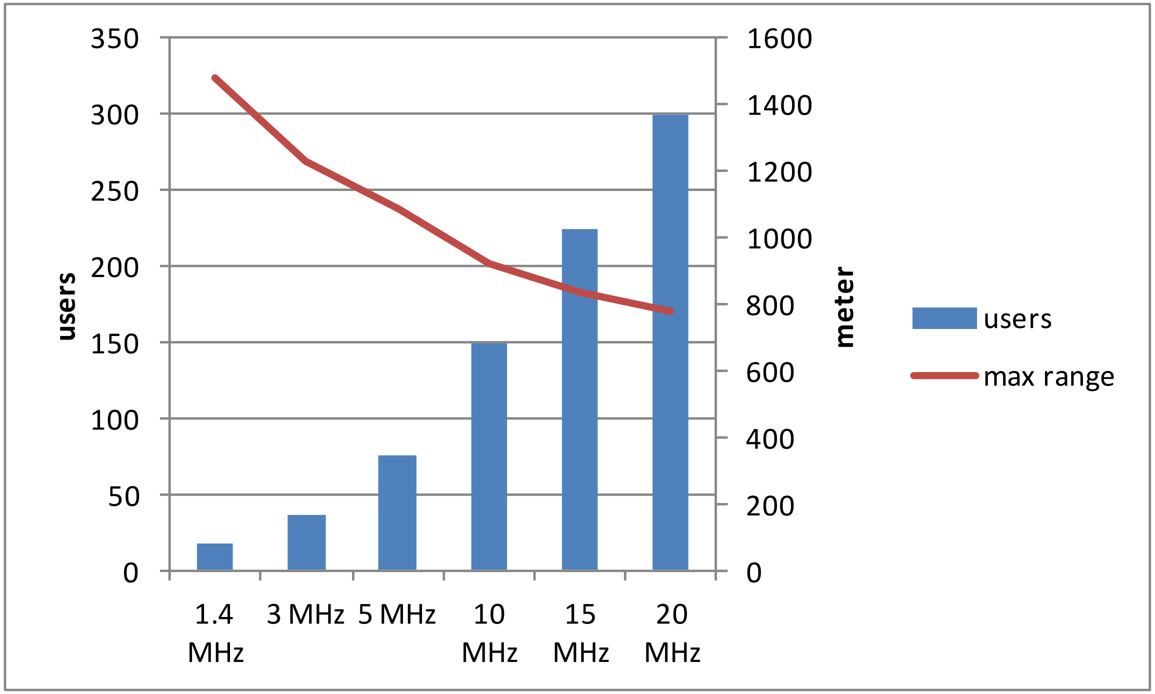
Different bandwidths
- Higher bandwidth
  - Higher bit rate
  - Lower range



LTE technology
Features

Different bandwidths

- Higher bandwidth
  - Extra users
  - Lower range



Case study

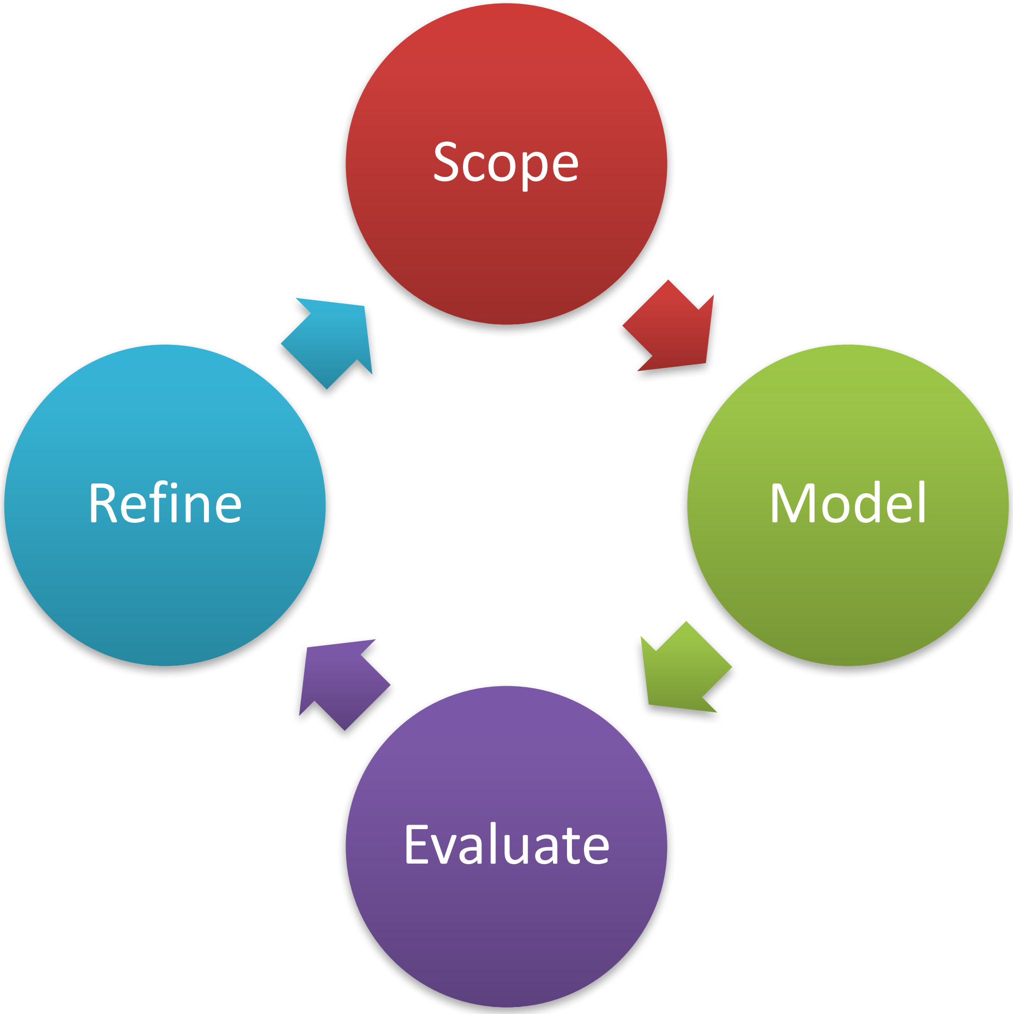
Deployment of LTE

- In 20 MHz band
- Offering 11.3 Mbps (in DL)
- BS reach = 780 m

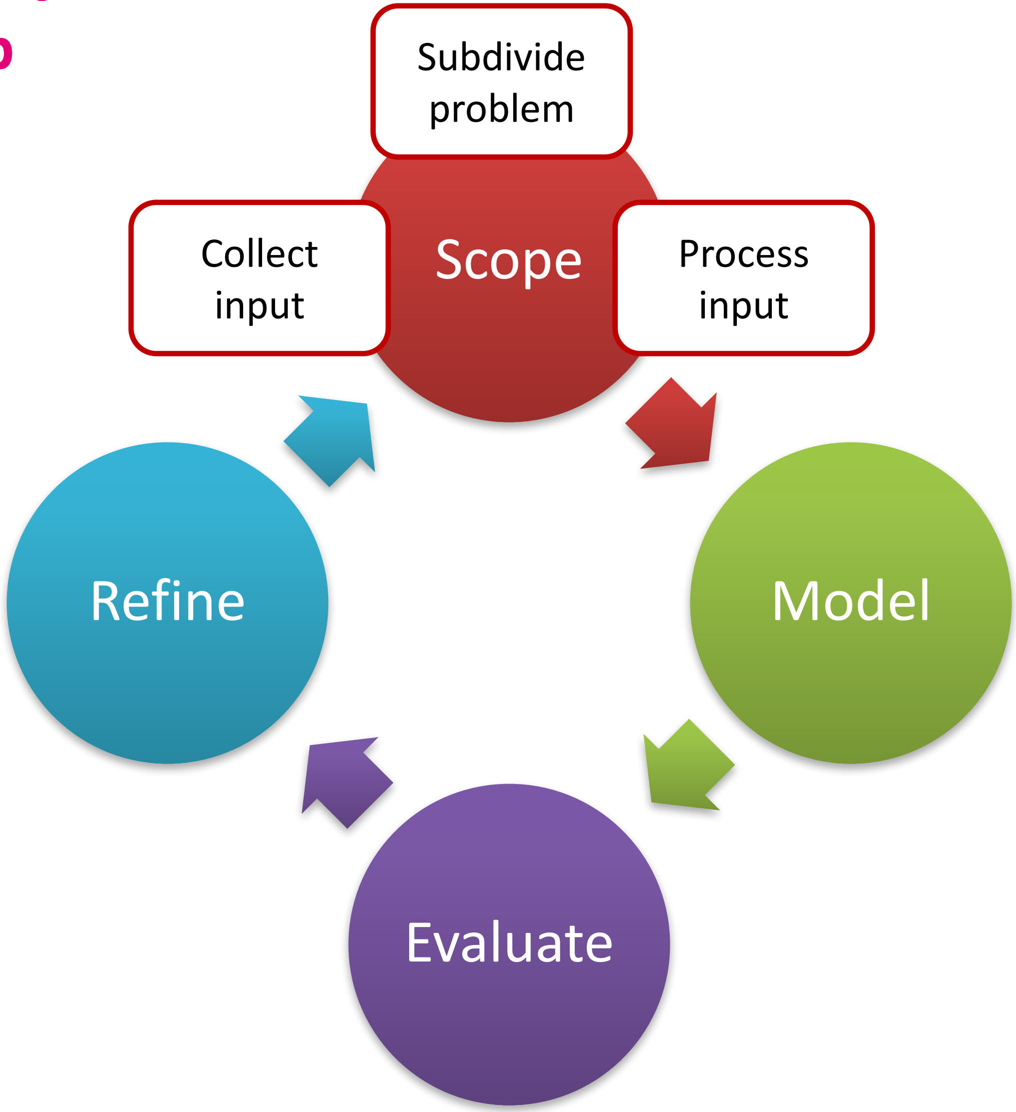
in Ghent

- 243.366 inhabitants
- 156.2 km^2

Techno-economic methodology
analysis of an investment decision in 4 steps



Scope the problem
as a first step



Collect input
for the investment problem at hand

Area input

- 243.366 inhabitants
- 156.2 km^2

Technology input

- In 20 MHz band
- Offering 11.3 Mbps (in DL)
- BS reach = 780 m

Cost input
for wireless technology

Parameter	Cost	unit	Reference
License cost	€2	Per inhabitant	[1]
Base station	€50.000	Per BS	[2]
Installation cost	€4.000	Per BS	[2]
Rent location	€3.000	Per BS	[2]
Maintenance	€5.000	Per BS	[2]

[1] BIPT. (2012). PRESS RELEASE BIPT makes the results of the 4G auction public, (November 2011), 1–2. Retrieved from http://www.bipt.be/ShowDoc.aspx?objectID=3639&lang=en
[2] J.Verstuyft (2011) Selection and evaluation of the optimal wireless technology for a mobile network operator

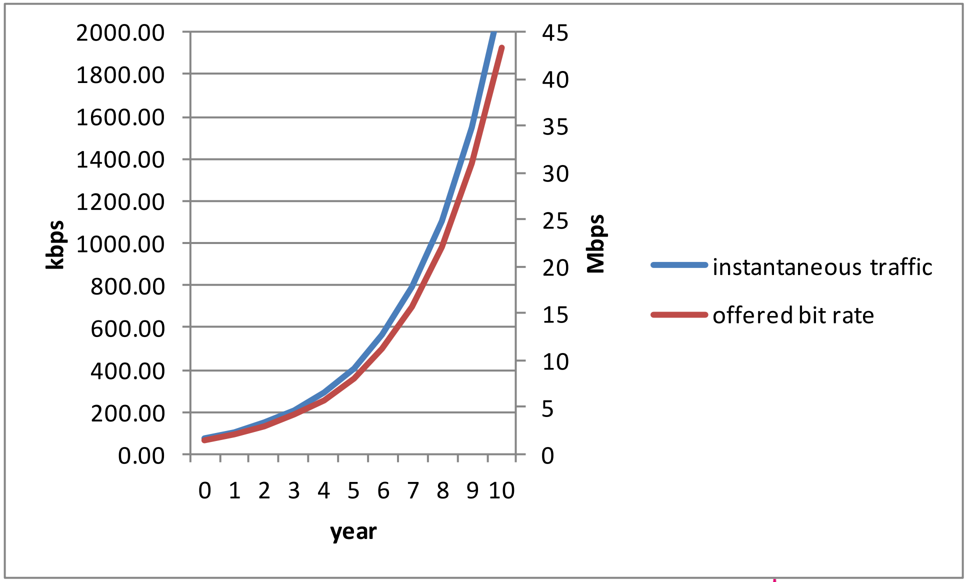
Traffic model

indicates how many traffic we expect on the network

Initial bit rate offered	1,5 Mbps
Overbooking ratio	1:20
Expected traffic growth	40%

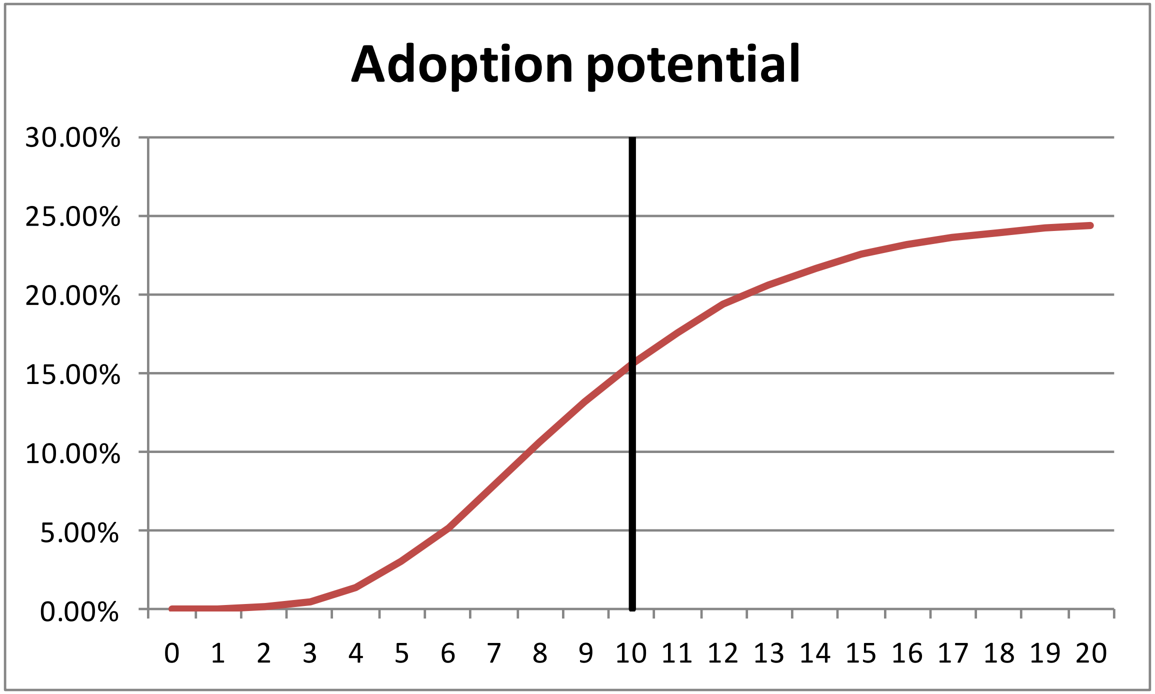
Implications:

- Traffic growth will result in extra BS
- Fiber lease cost will grow with traffic



Customer uptake
is modeled by Gompertz S-shaped adoption

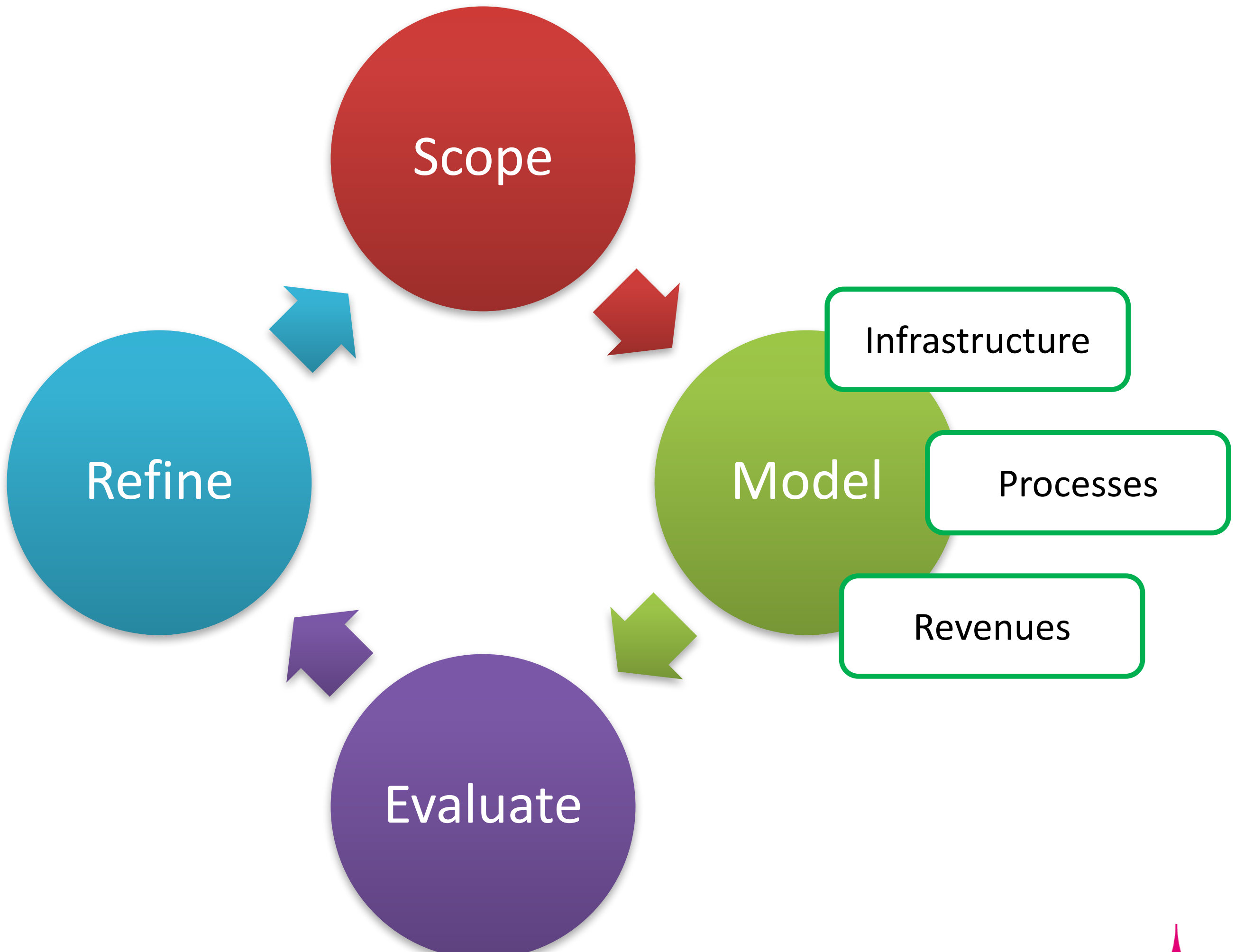
ARPU - €20 per month



[3] http://afr.com/p/business/technology/uptake_hanging_on_the_telephones_HhQoW6hT7Yy4sAnL6iOqWN

Model costs and revenues

as a second step

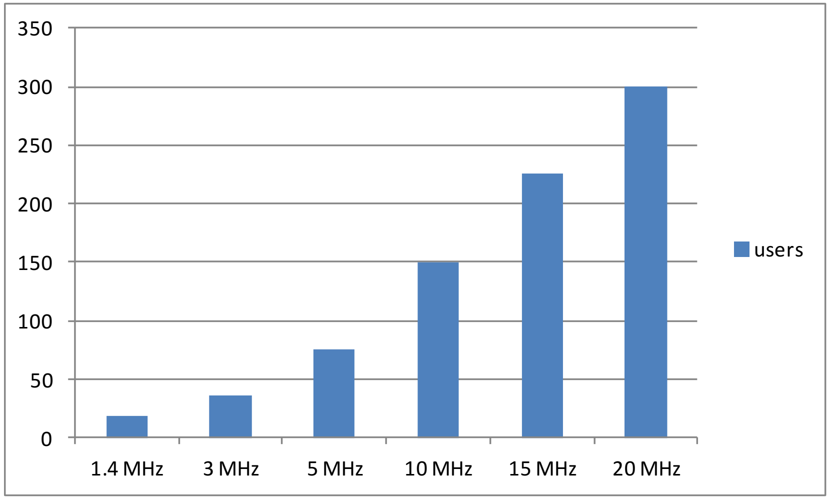


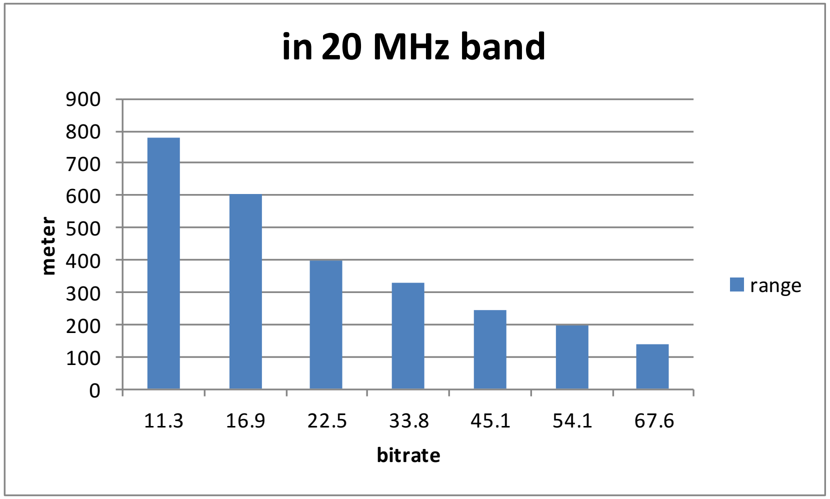
Base station dimensioning

indicates # base stations depending on areas and # customers

Customer dependent

Area dependent

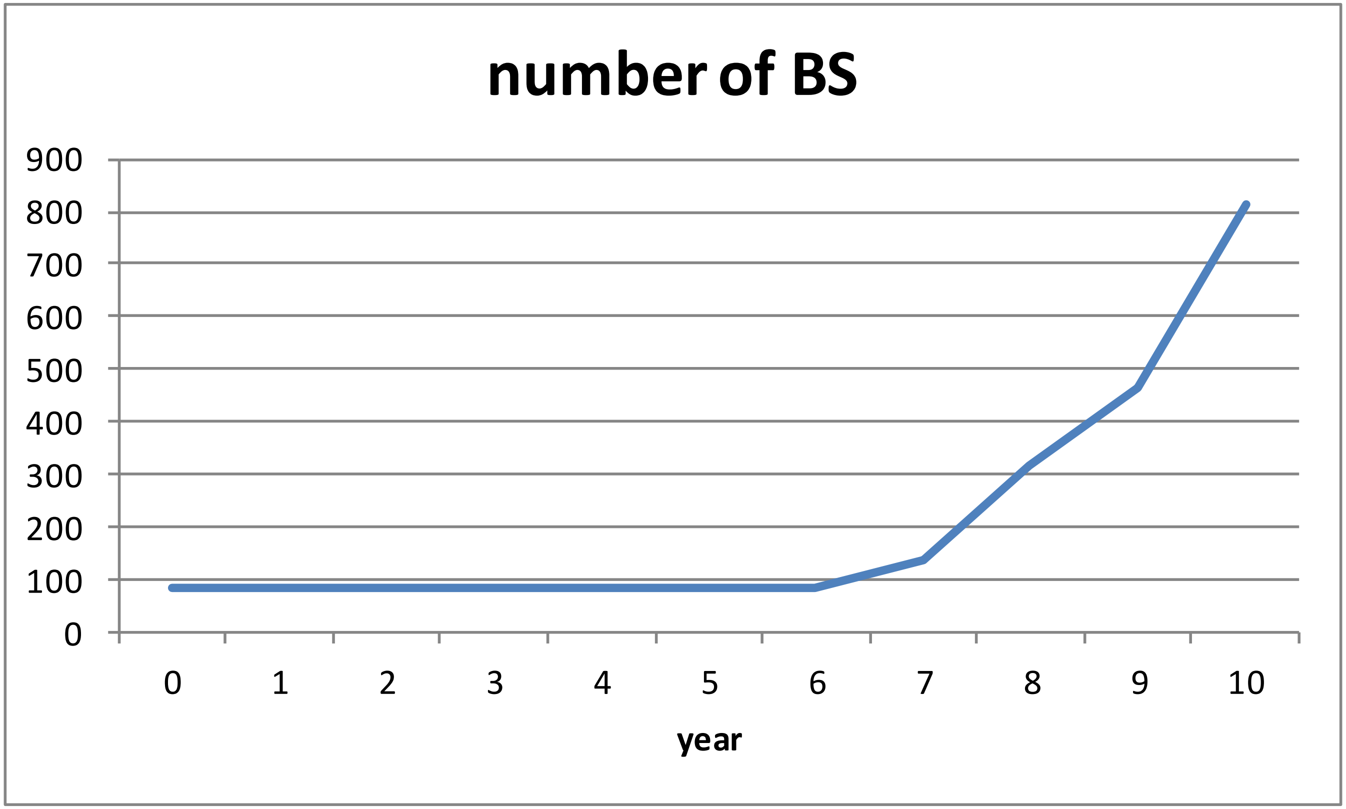




$$\#BS = MAX\left(\frac{area}{range_{BS}}, \frac{customers}{customers/BS}\right)$$

Base station dimensioning

results in total number of base stations installed

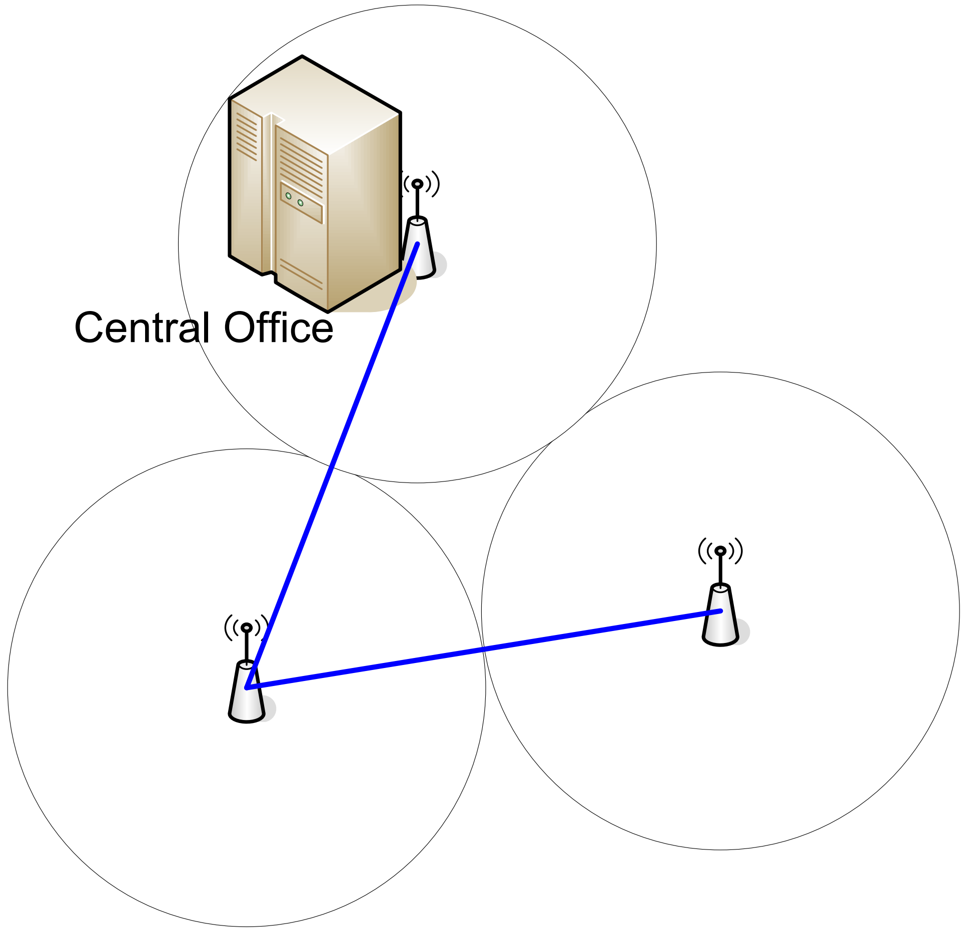


Backhaul dimensioning

results in required backhaul fiber length

$$(\# BS - 1) * range_{BS} * 2$$

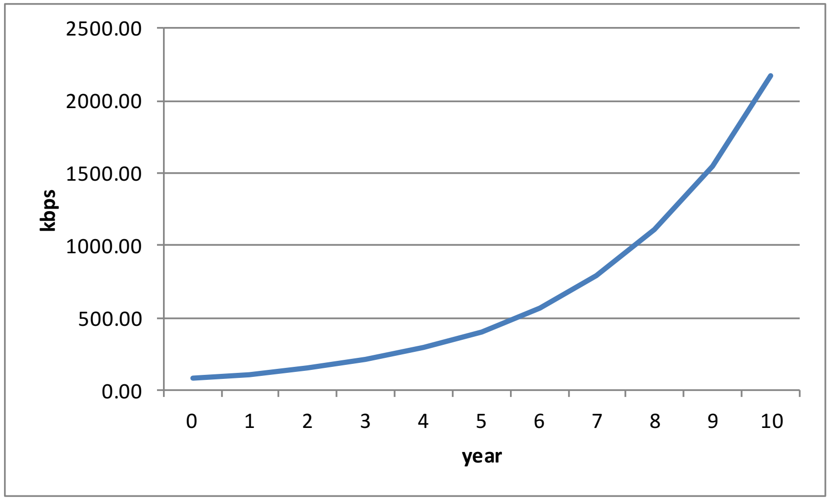
- CO located at BS
- Overhead length
- Lease cost
    - €1/Gbps/m/year



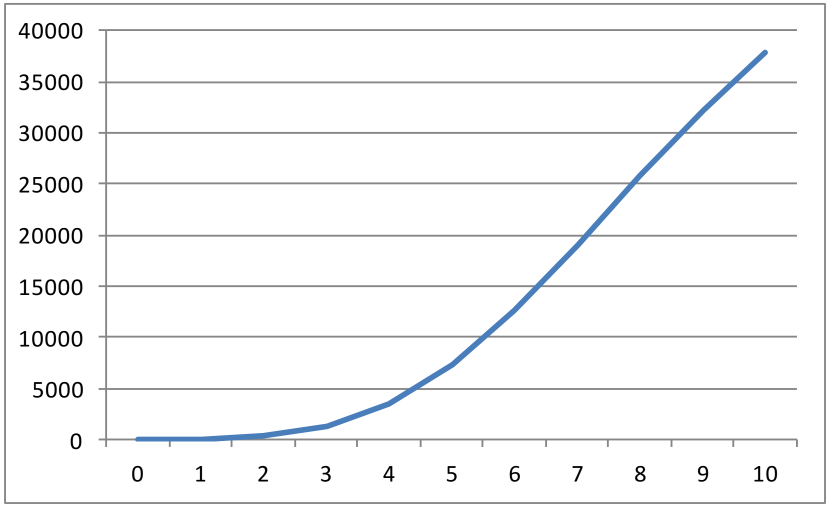
Backhaul traffic

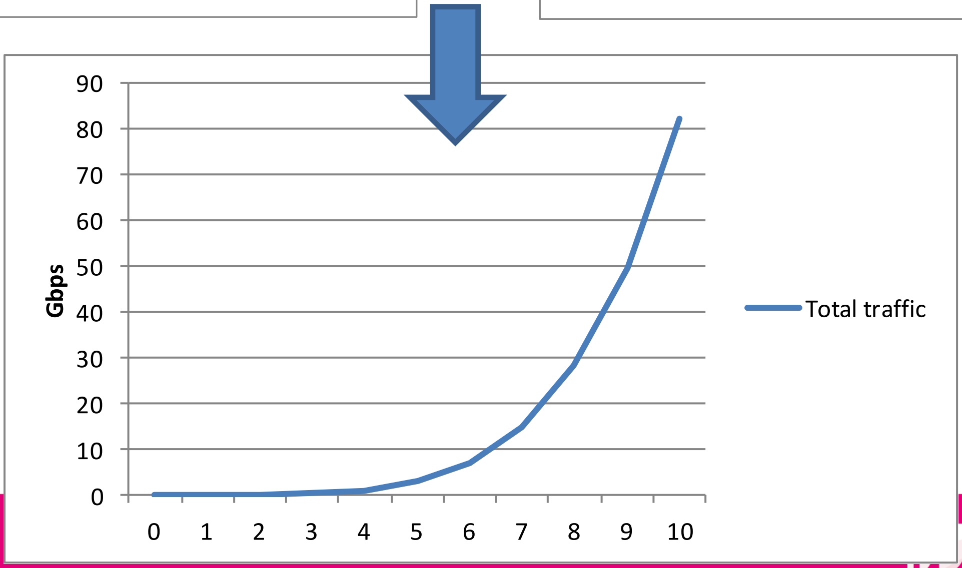
indicates required capacity over backhaul connections

Instantaneous traffic



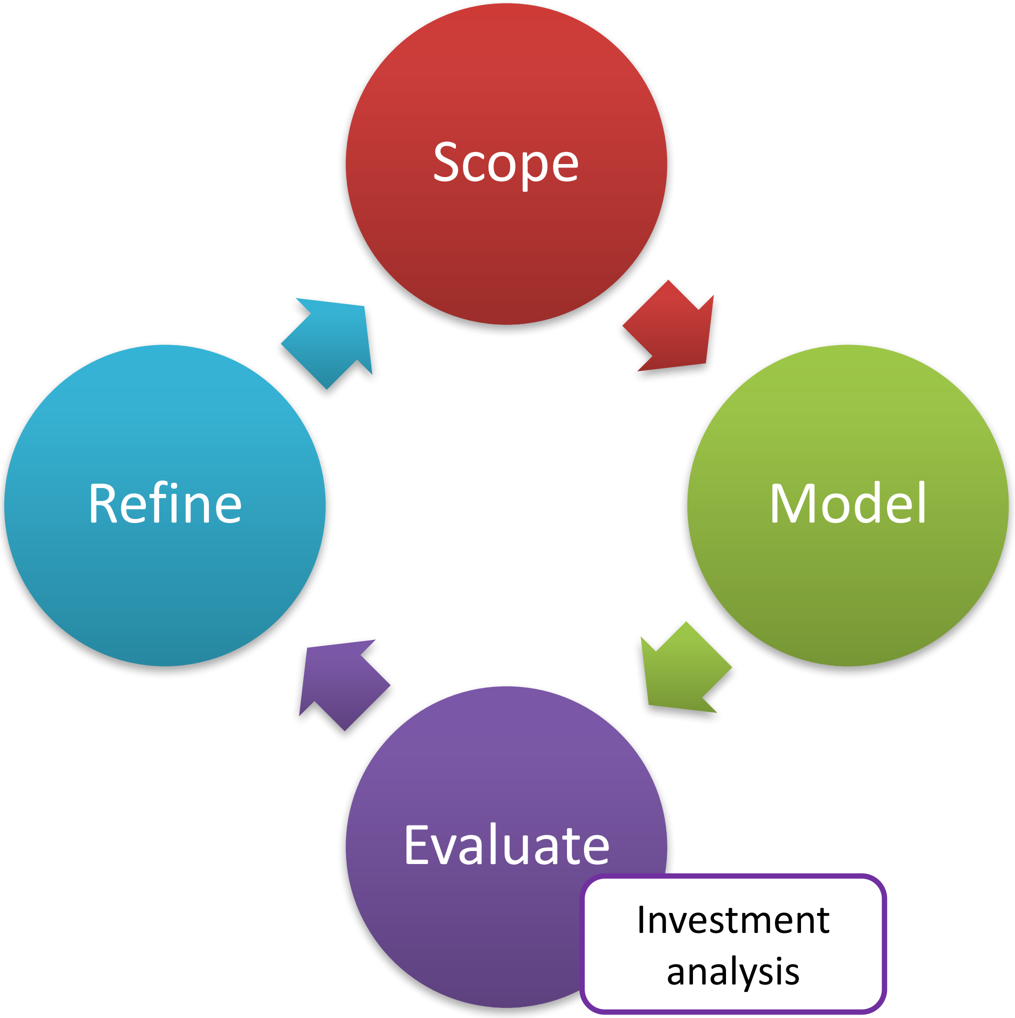
customers



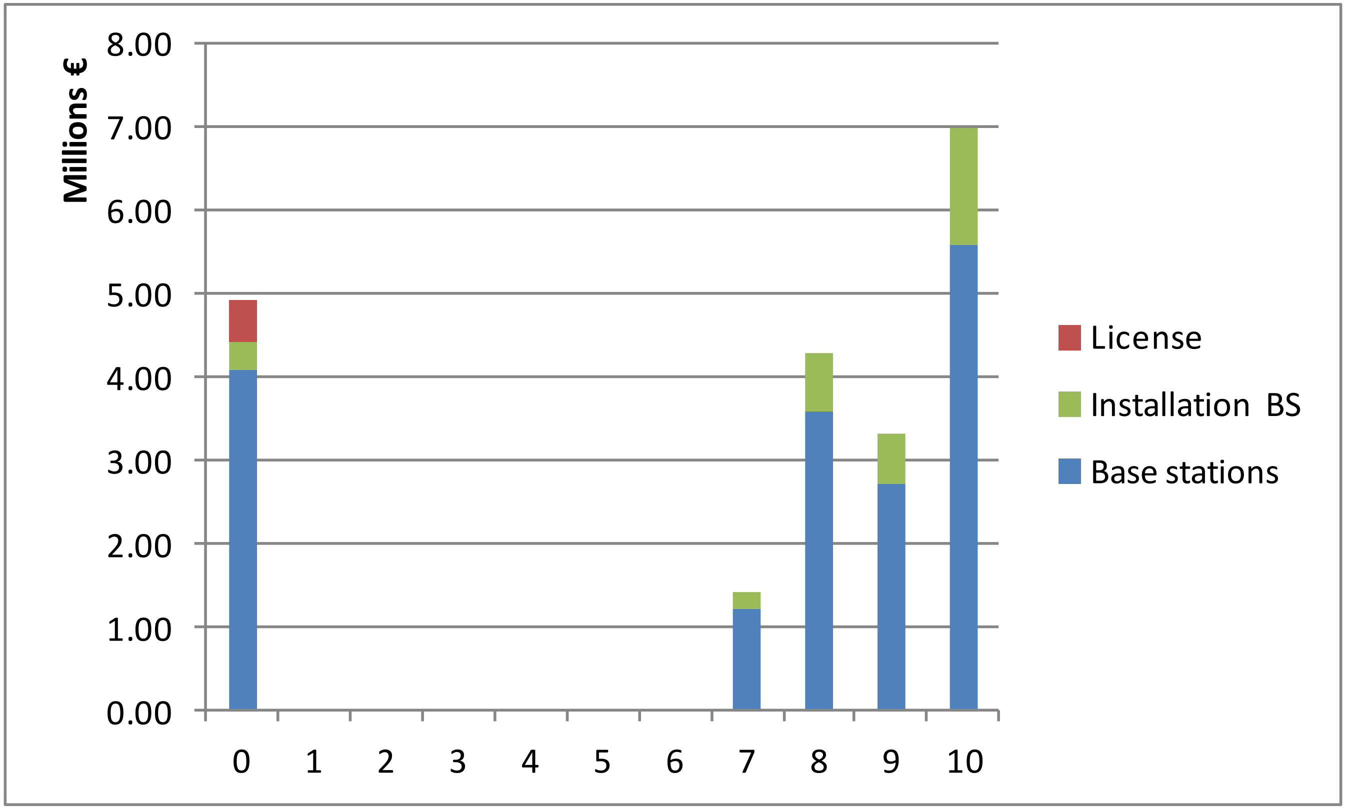


Evaluate cost versus revenues

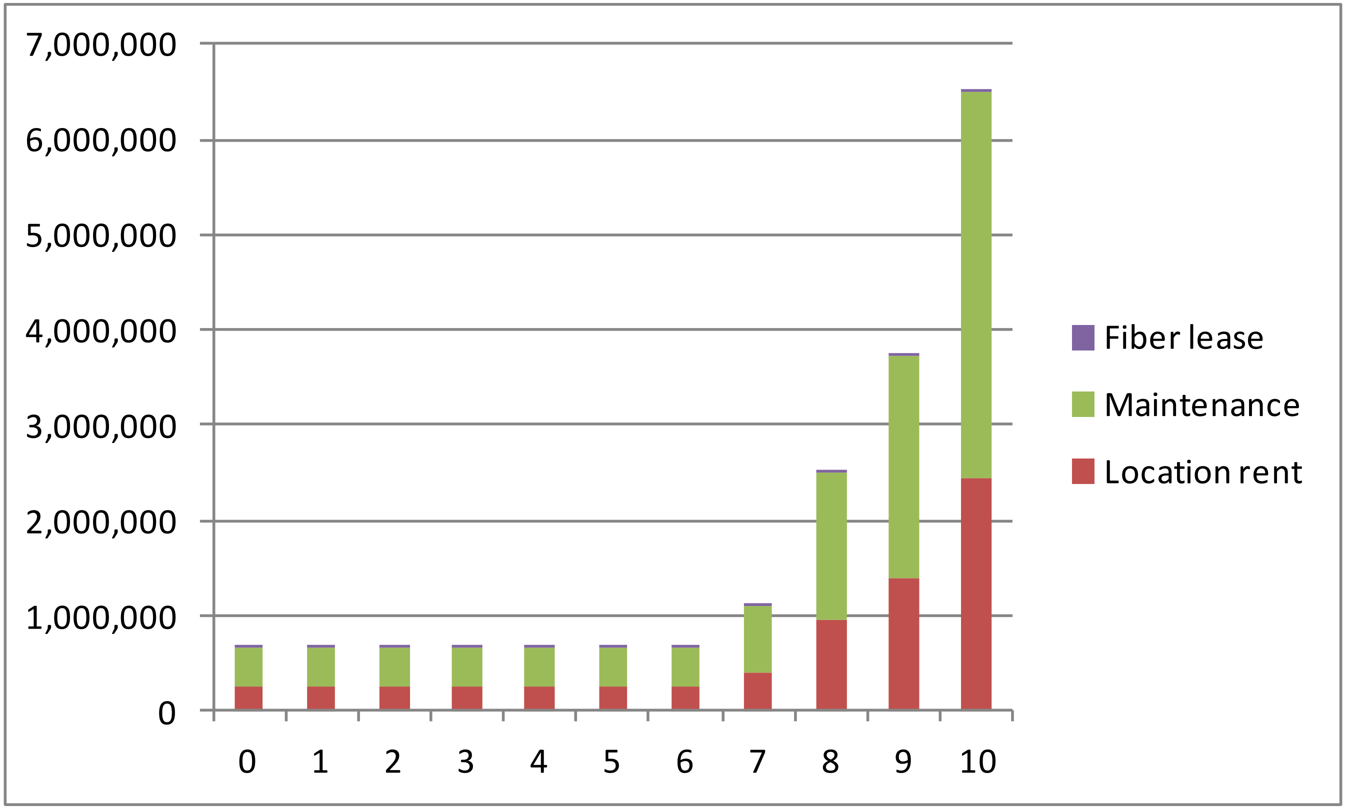
as a third step



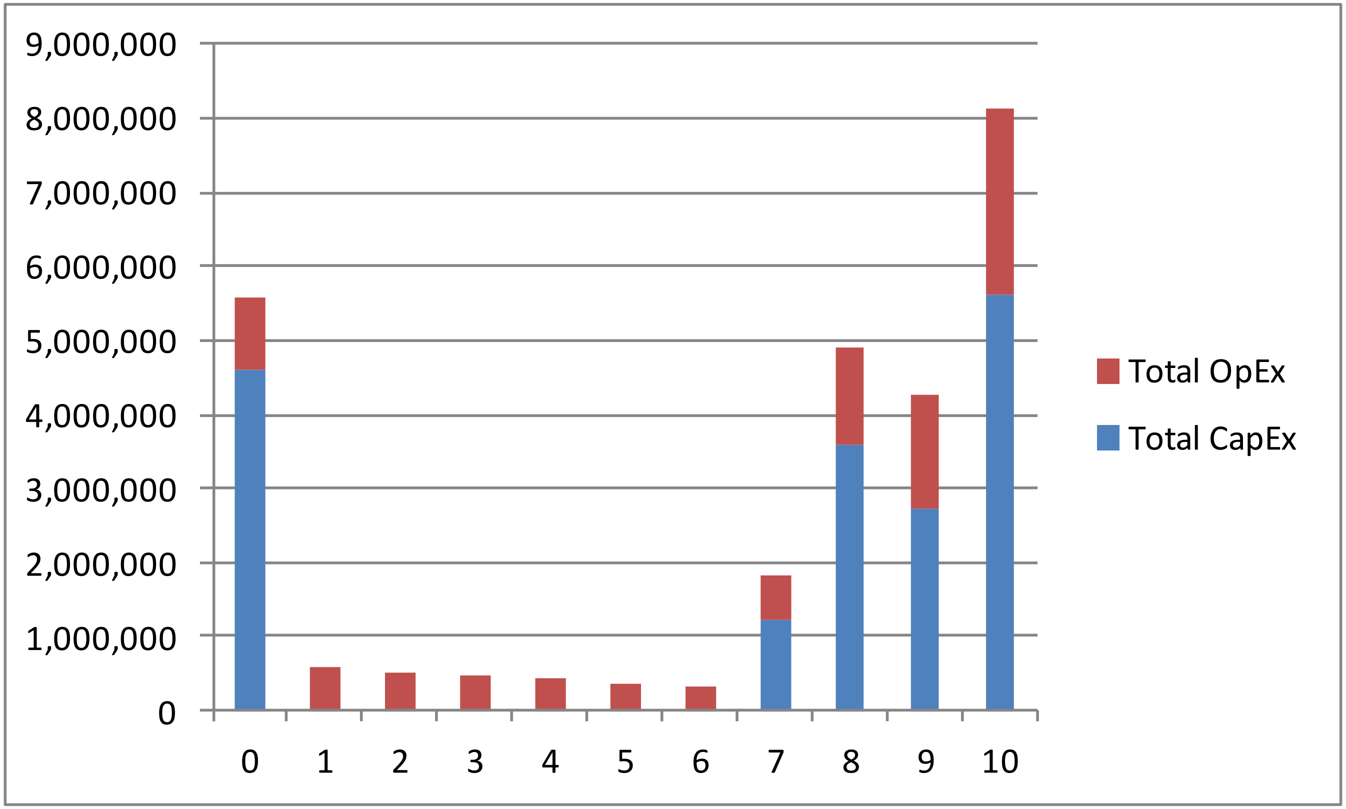
Capital expenditures
indicate depreciable investment cost



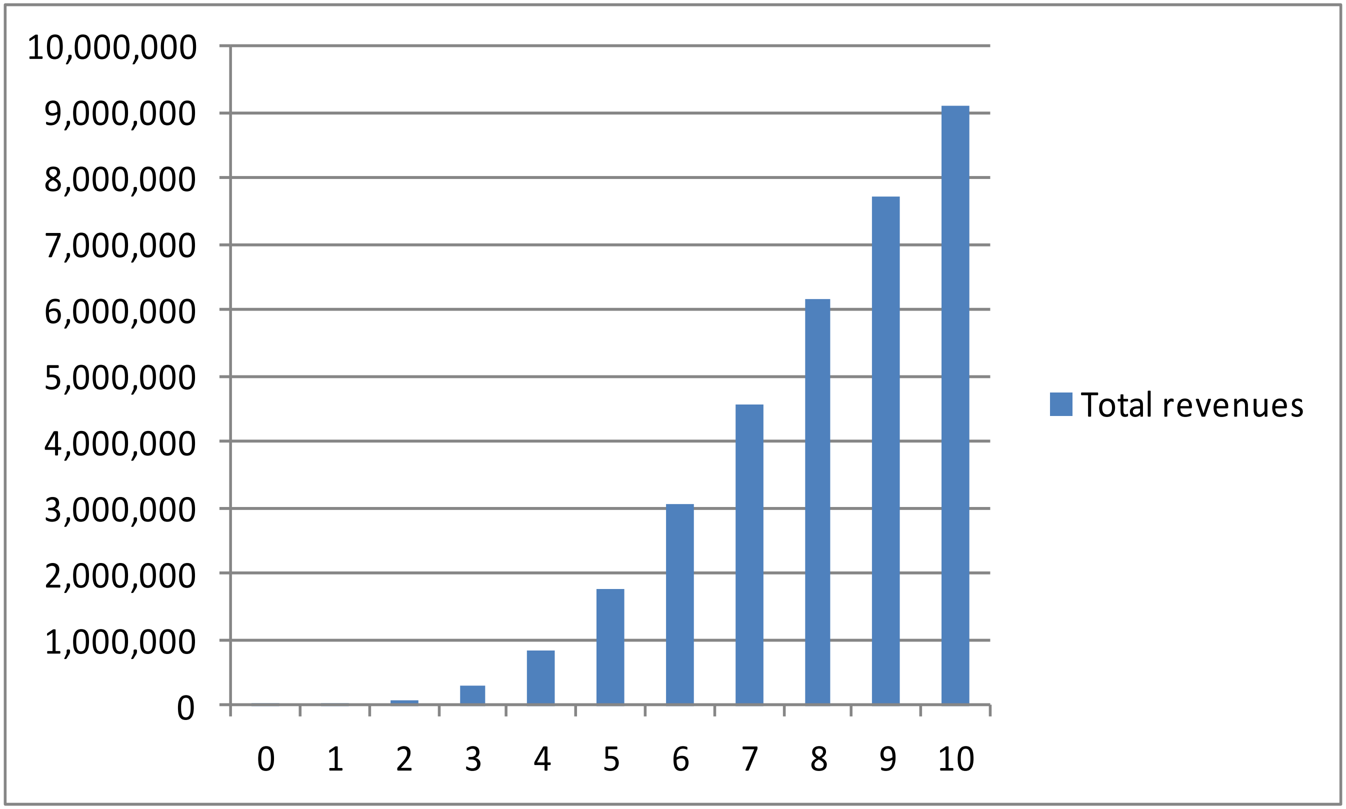
Operational expenditures
indicate recurring costs



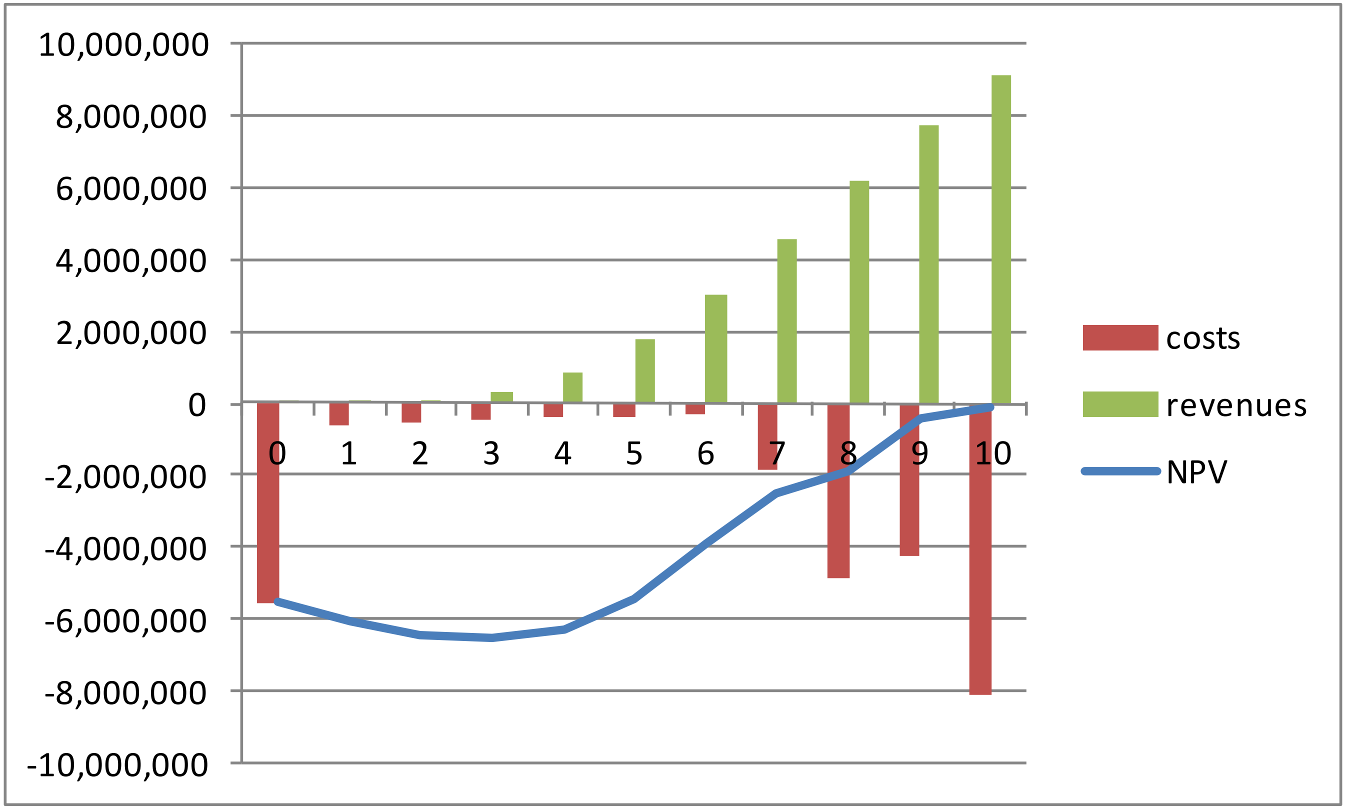
Total cost
sum CapEx and OpEx



Revenues
are related to the number of customers



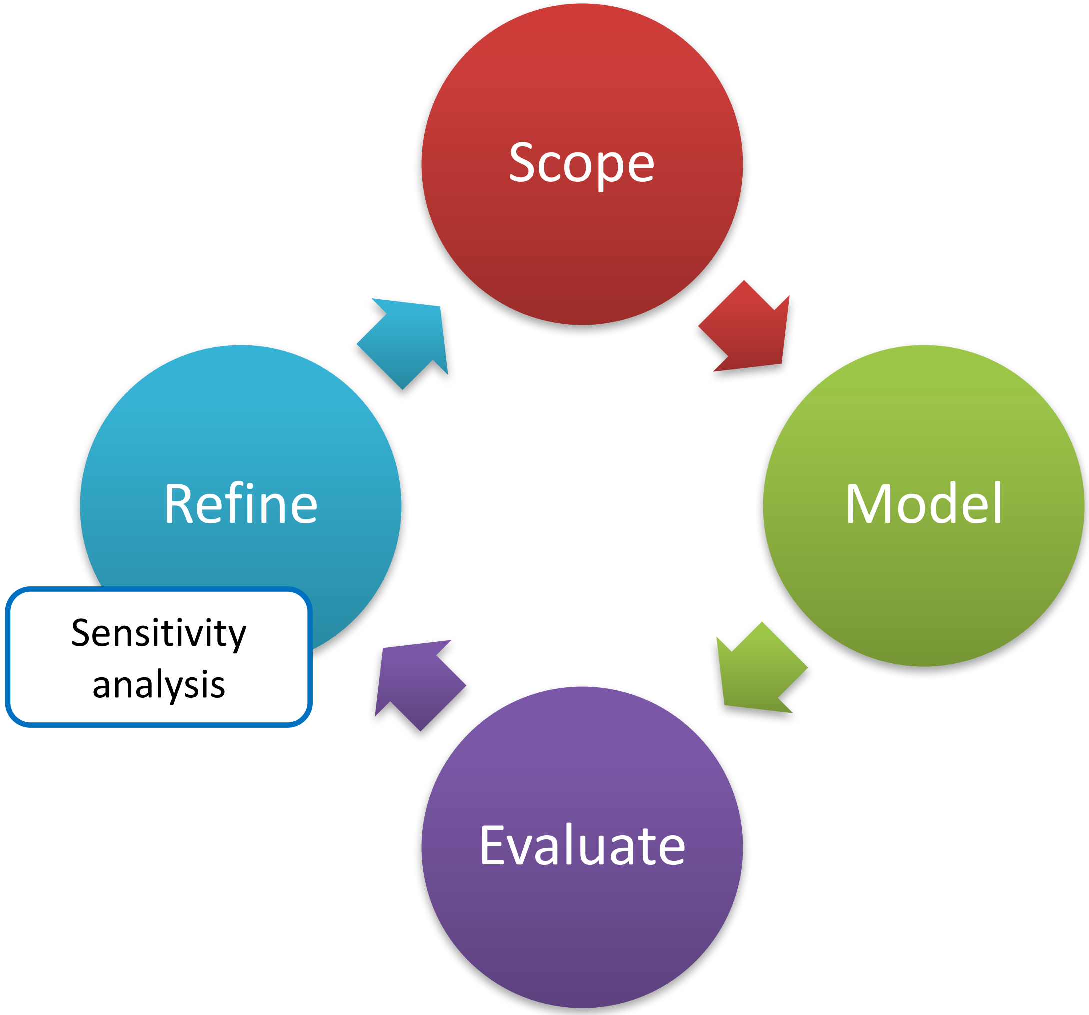
NPV analysis
sums discounted cash flows



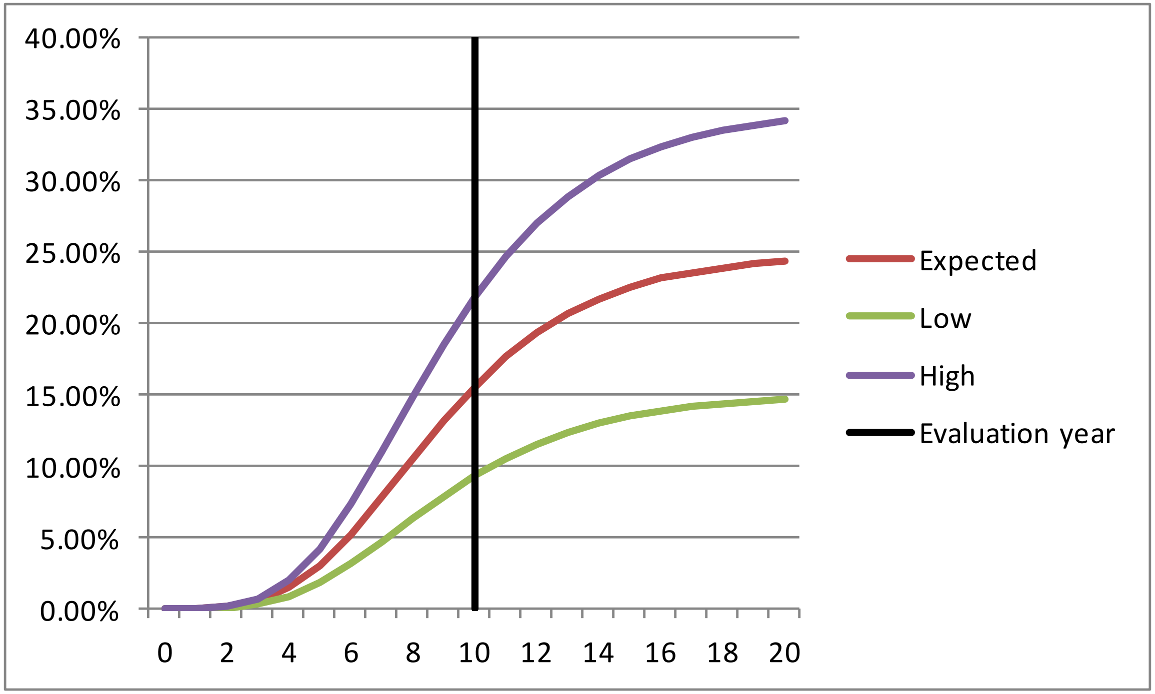
NPV at year 10 = €-84.999

Refine the analysis

as a fourth step



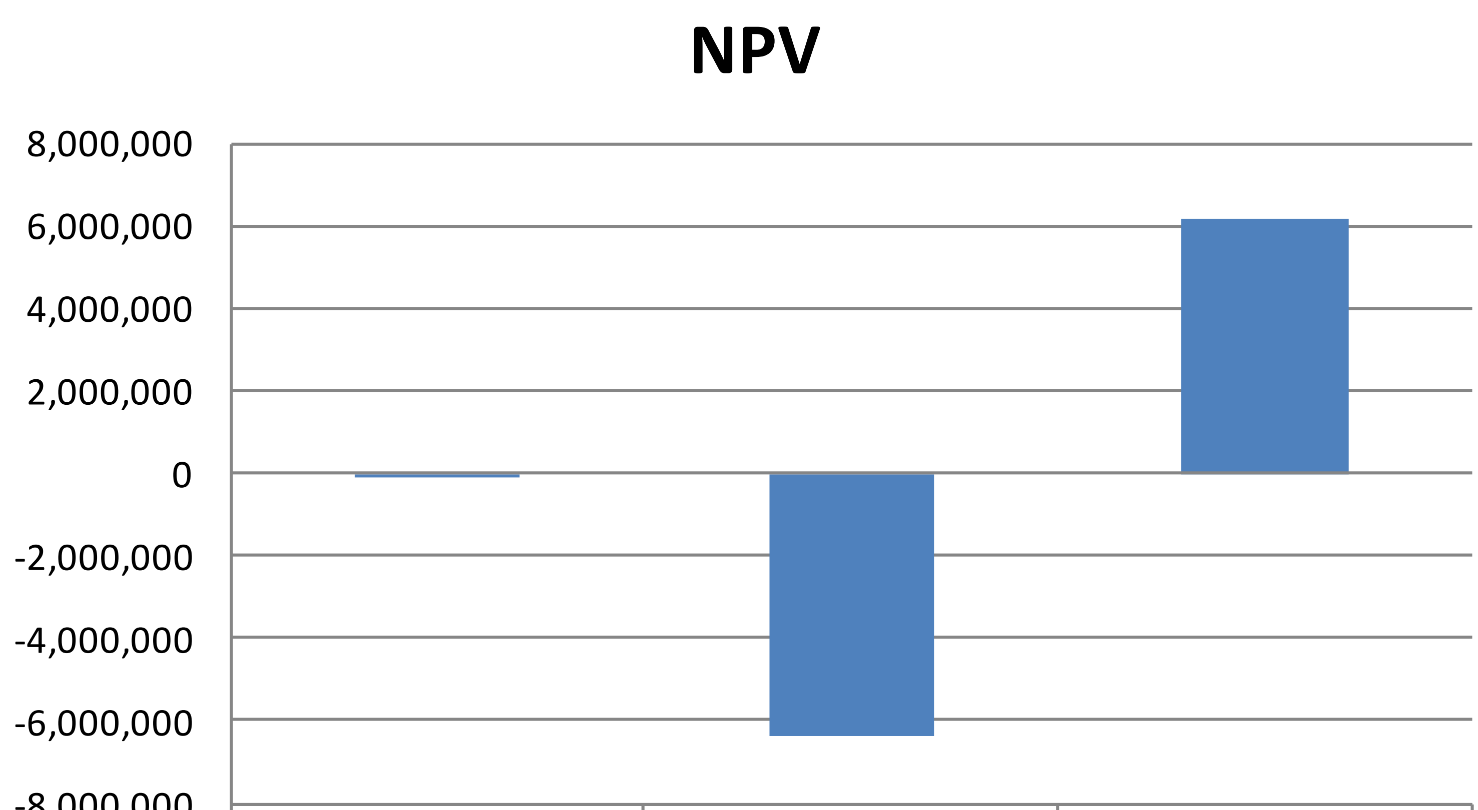
Impact of uncertainty
on expected market potential



Impact on

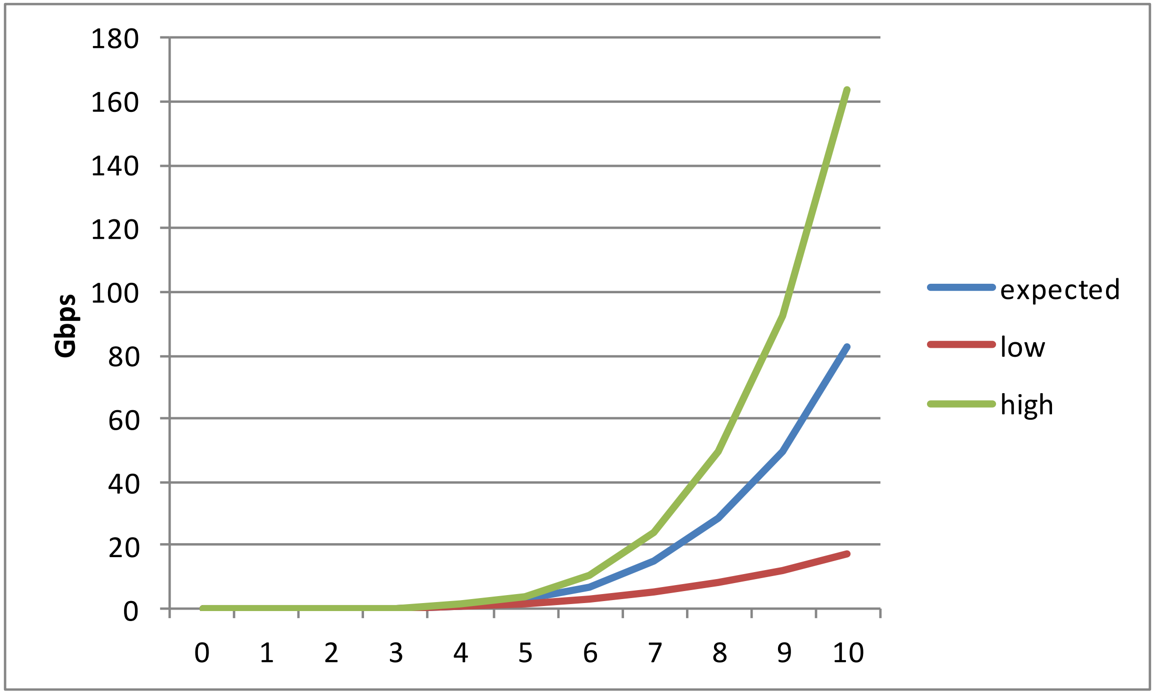
- # BS
- Traffic → fiber lease cost

Result can be very different
under different uptake assumptions



	Expected uptake	Low uptake	High uptake
NPV	-84,999	-6,354,806	6,184,640

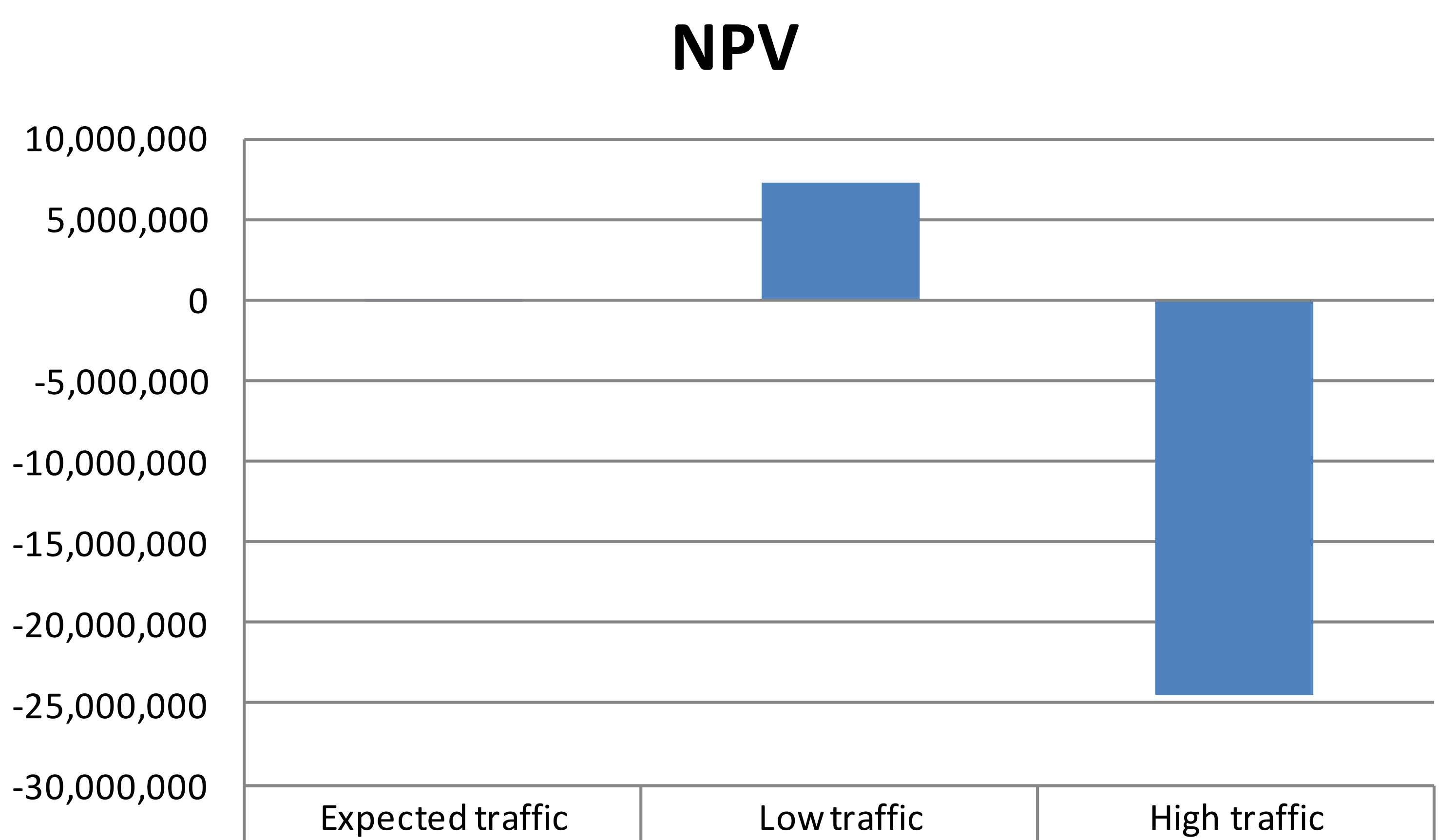
Impact of uncertainty
on expected traffic growth



Impact on

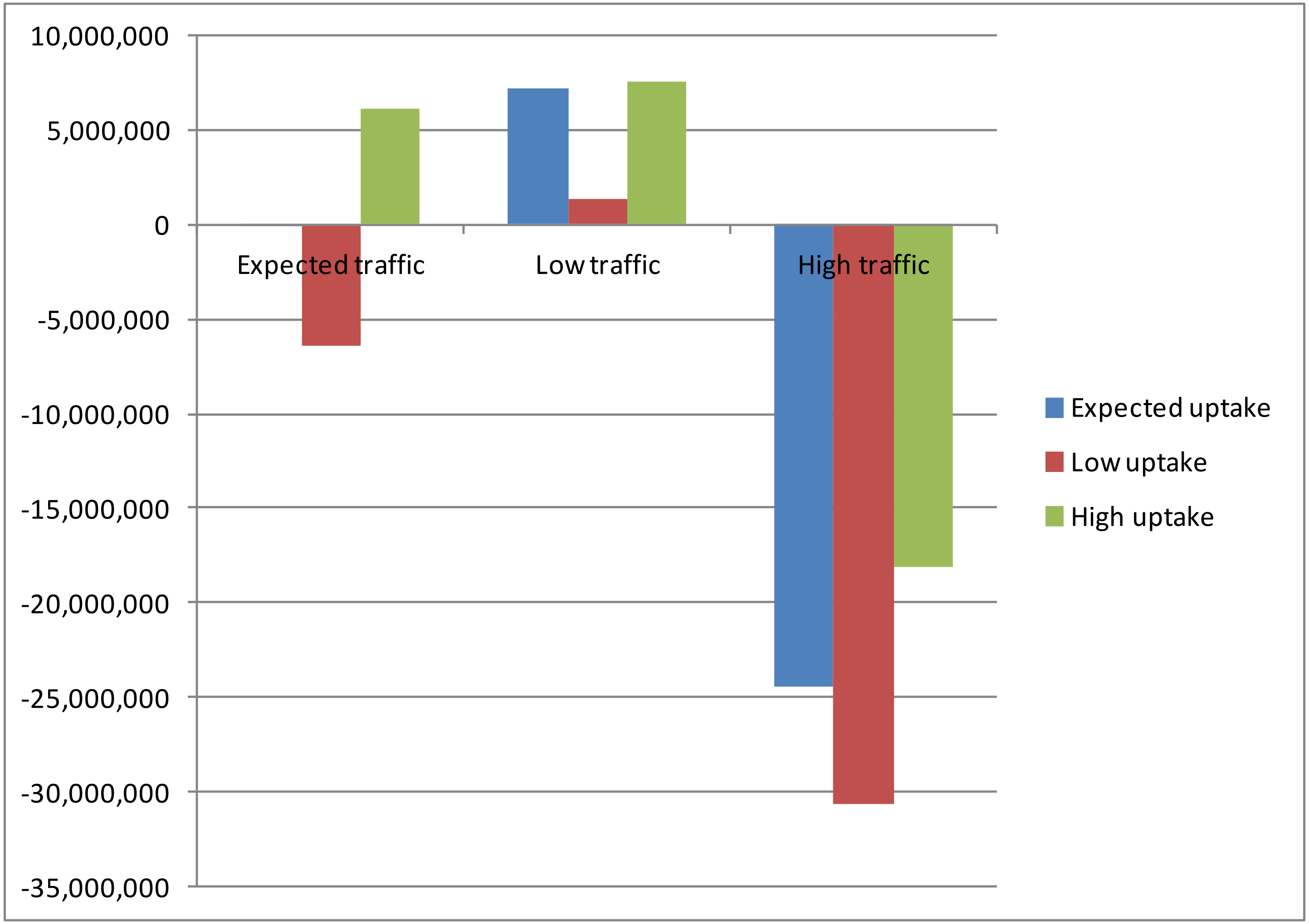
- # BS
- Fiber lease cost

Result can be very different
under different traffic growth assumptions

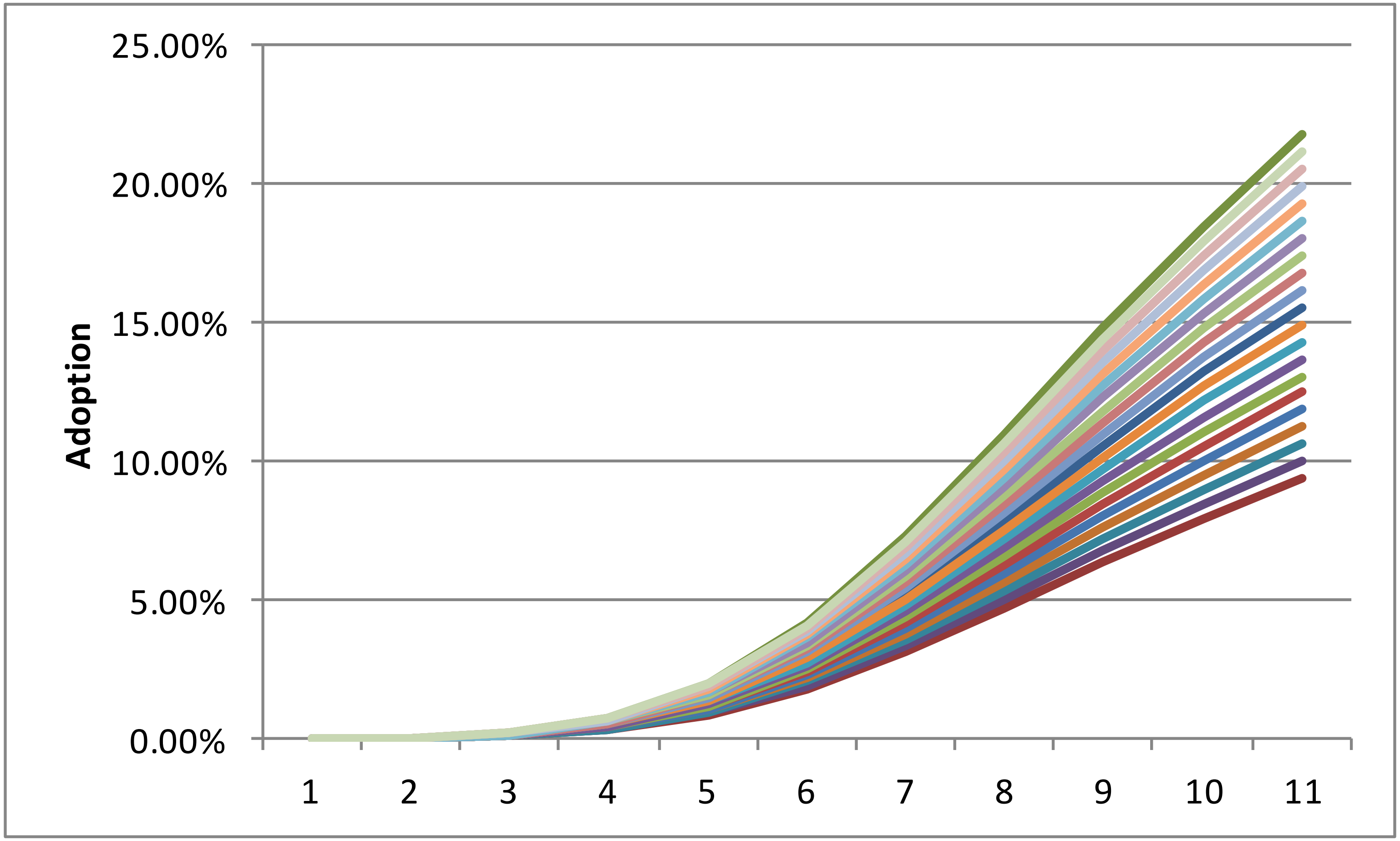


	Expected traffic	Low traffic	High traffic
NPV	-84,999	7,208,317	-24,448,085

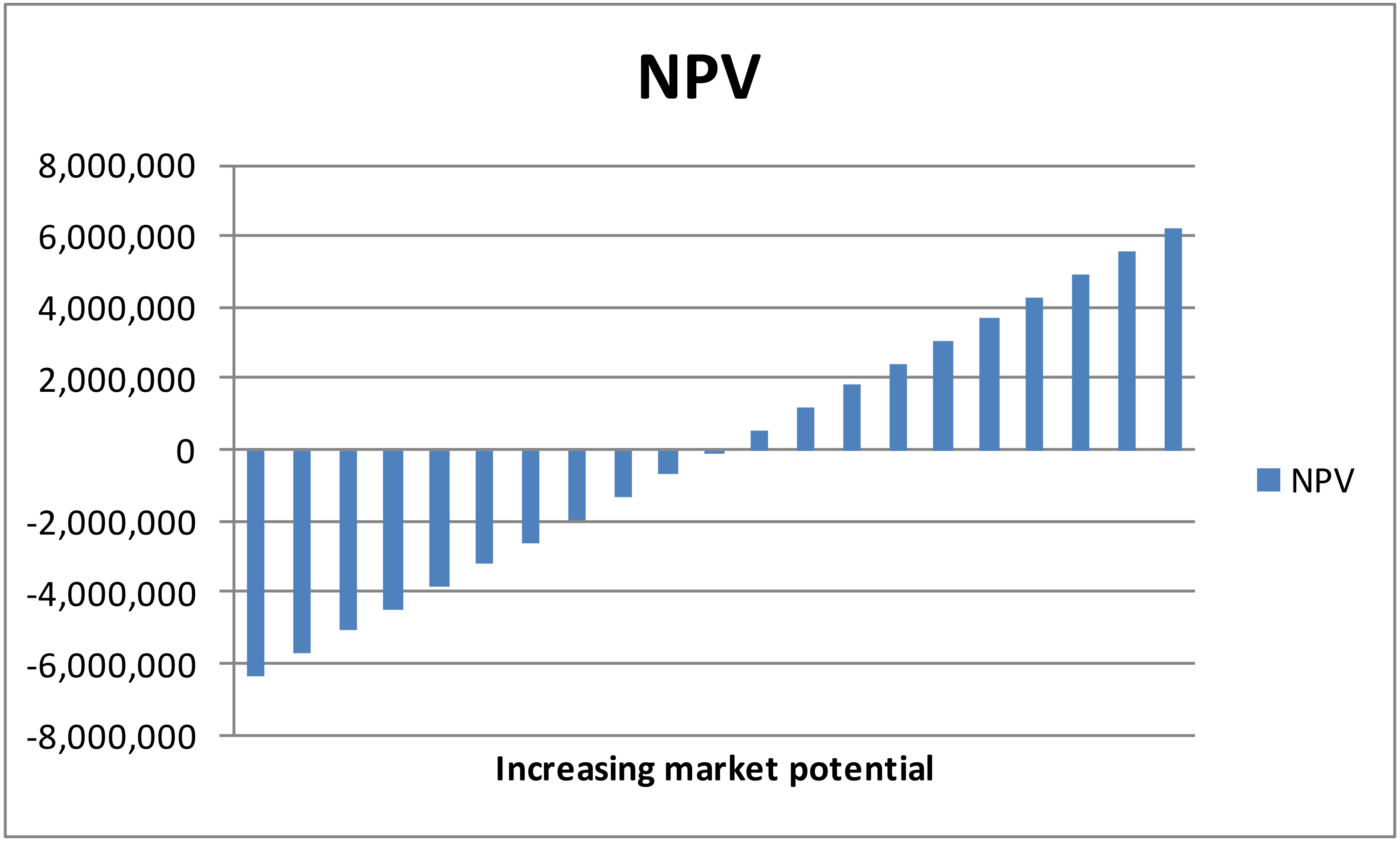
Results are even more different
under combined market potential and traffic growth assumptions



From discrete to continuous uncertainty
by adding big amount of scenarios

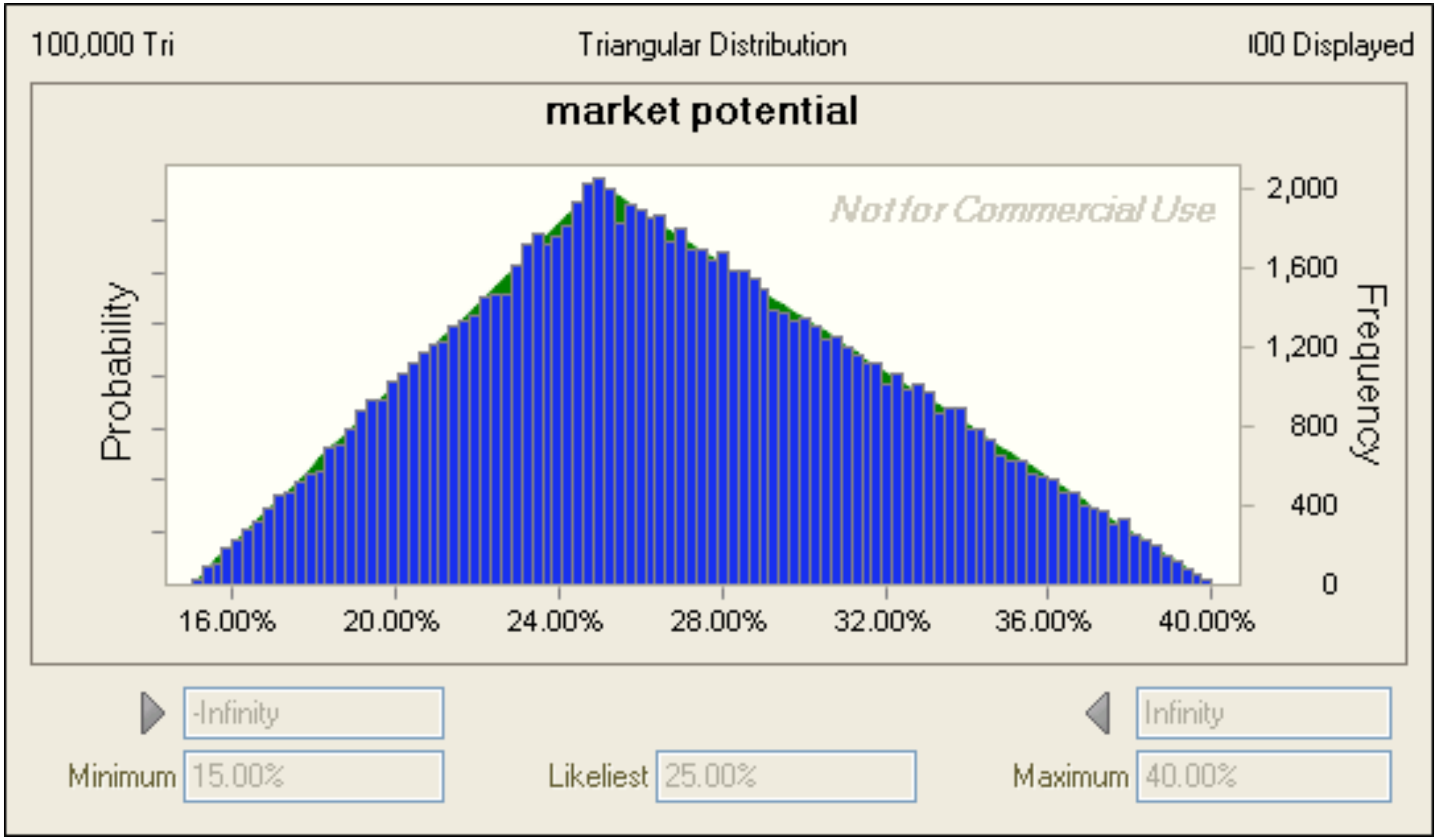


From discrete to continuous uncertainty
shows range of results, representing range of scenarios



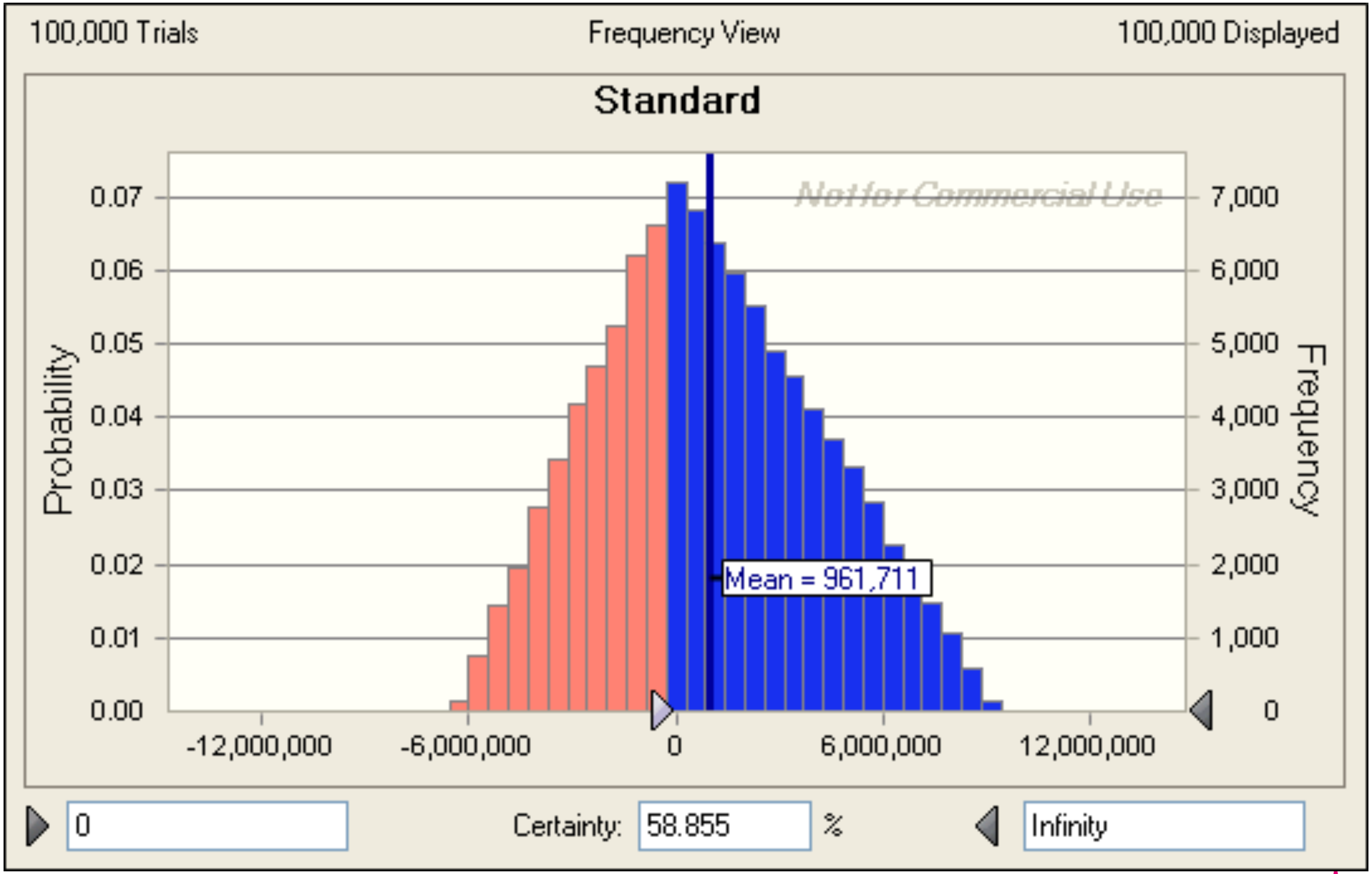
Density distribution of results

indicates mean value and deviations



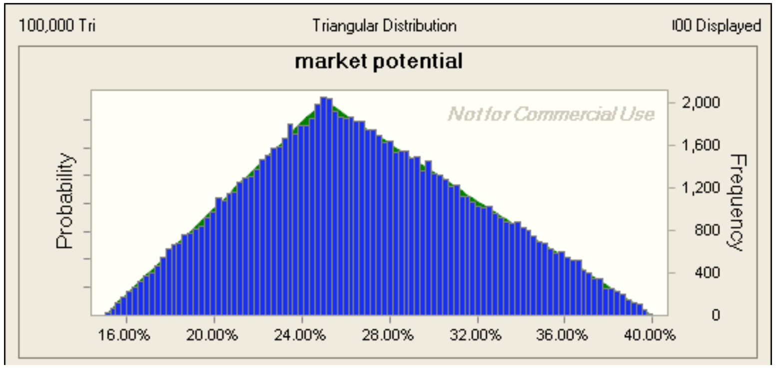
Density distribution of results

leads to helpful interpretations

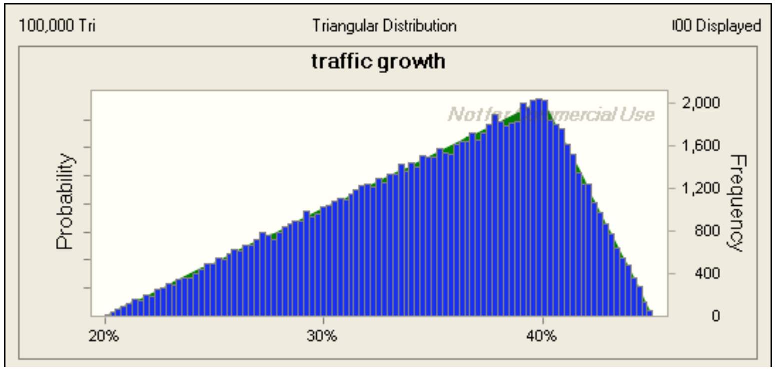


Combined uncertainties
on adoption and traffic growth..

Adoption

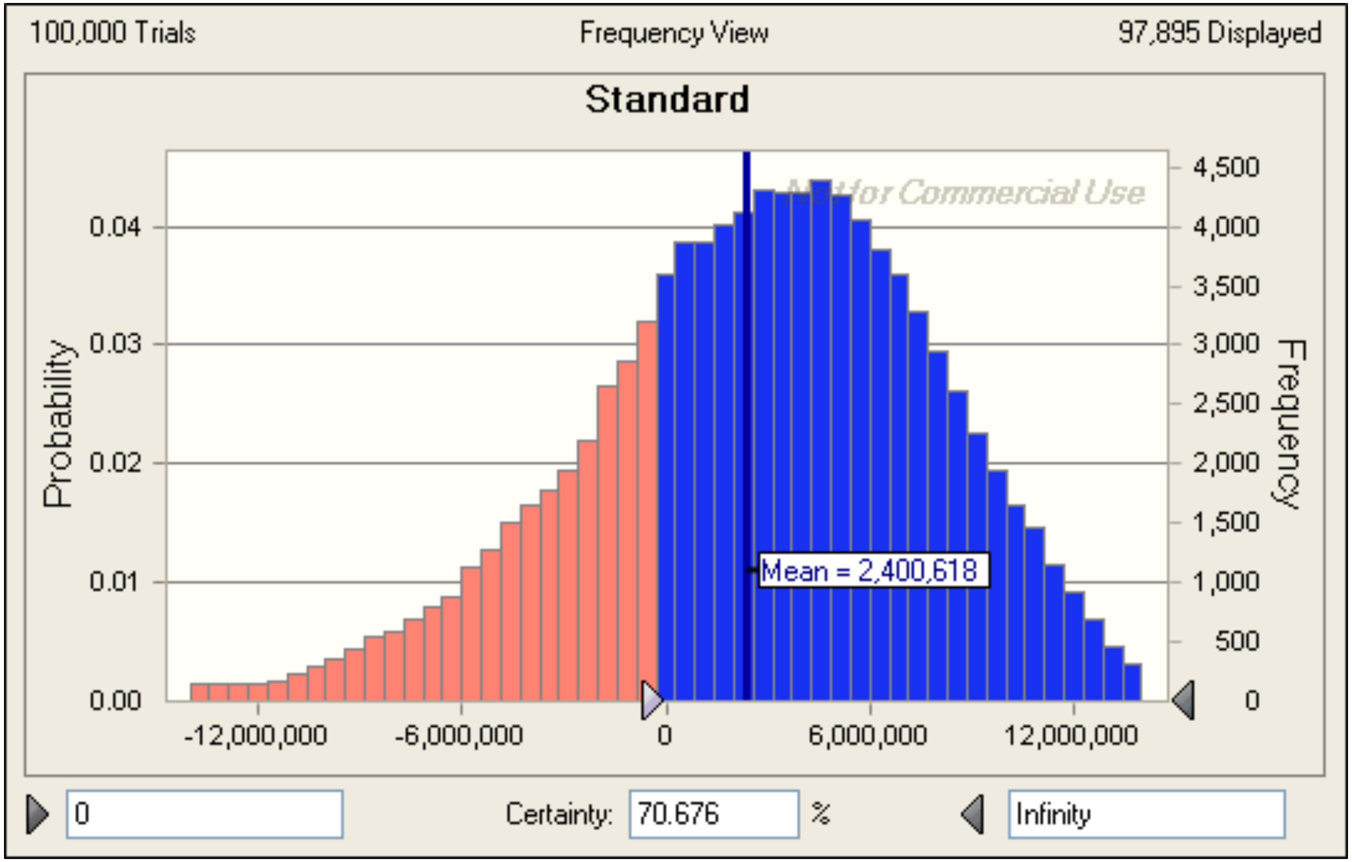


Traffic growth



Combined uncertainties

lead to combined impact on results..



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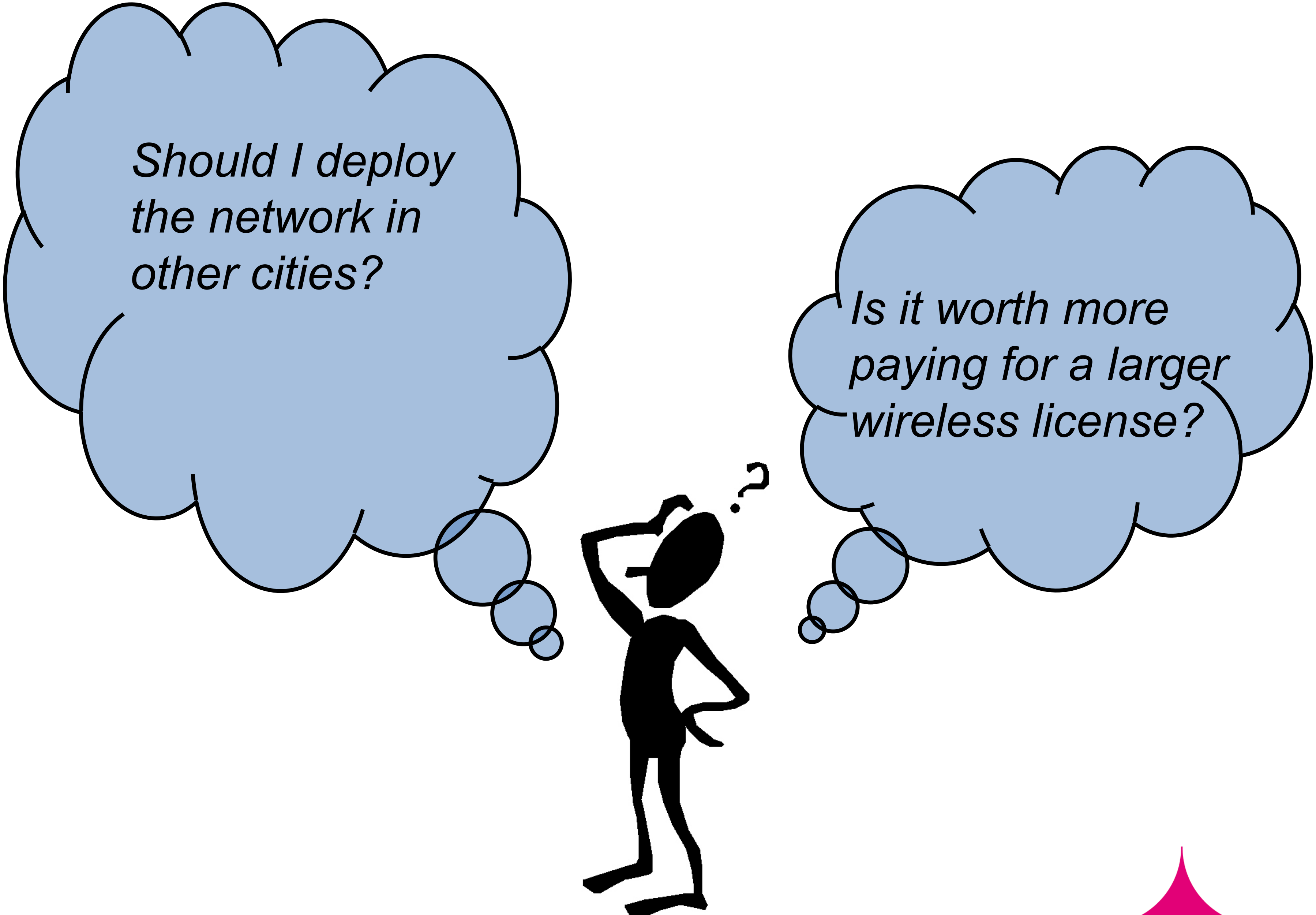
Conclusion
on the use case of LTE deployment in Gent

The project is unprofitable

- Negative payoff under initial conditions
- Very sensitive to input

But the operator has flexibility

- Deploy network in another city
- Stop project if it turns out unprofitable
- Offer differentiated services
- Use other technology

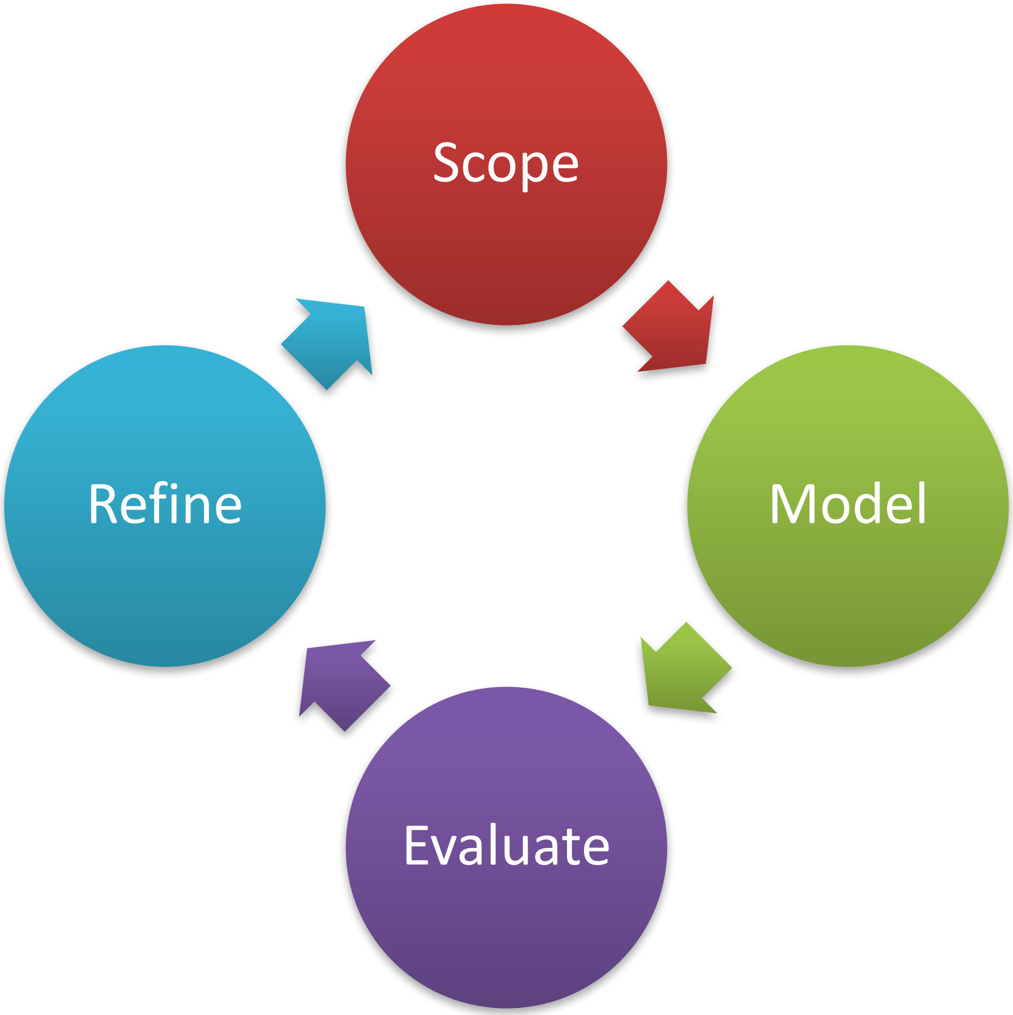

Should I deploy the network in other cities?
Is it worth more paying for a larger wireless license?

Deploy in other cities

in Antwerp

- 483.505 inhabitants
- 204.5 km^2

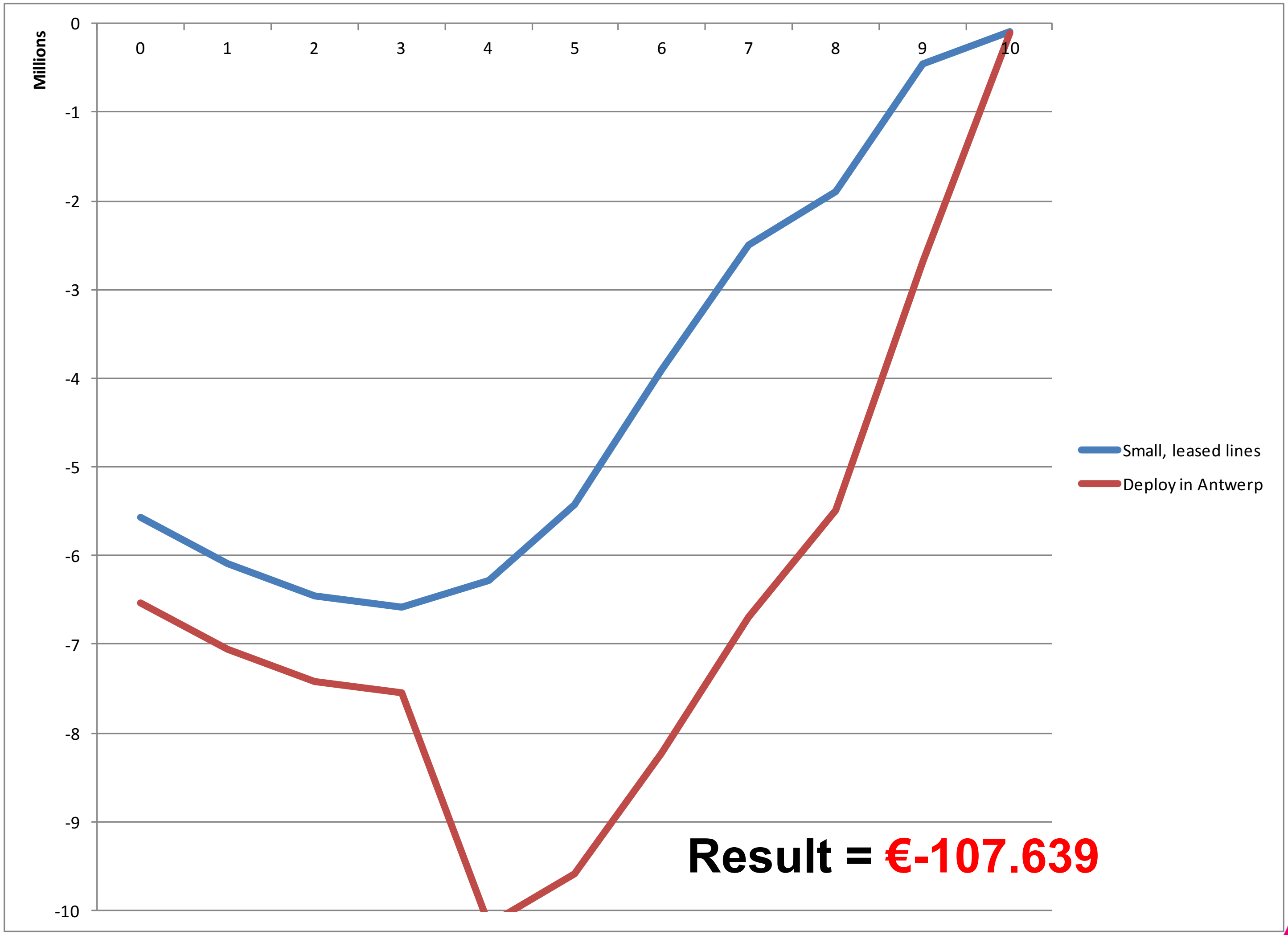
Following the same methodology



Minor differences with previous case

- Deployment in Antwerp in year 4
  - Higher initial license cost
  - Extra CapEx and OpEx
- But also larger market
  - Higher potential revenues

Result from deployment in other cities



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But what if operator has flexibility?

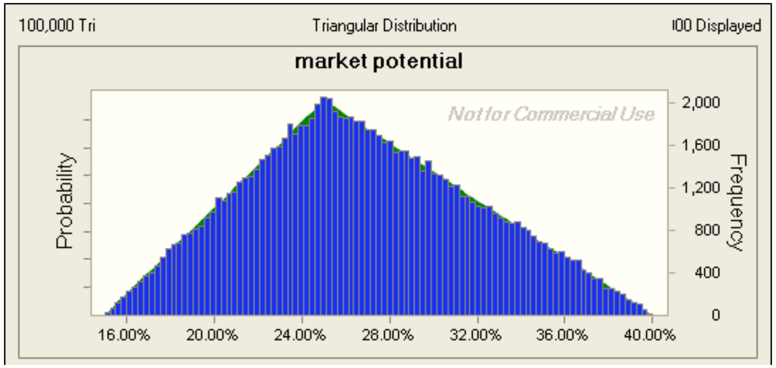
1. He can do an extra deployment/ expand the deployment

Extra deployment only

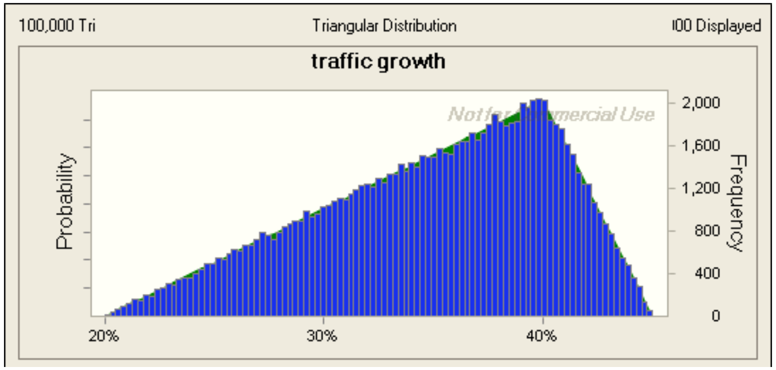
- If positive impact on case
- Impacted by uncertainty
  - Adoption
  - Traffic growth

Uncertainties

Adoption

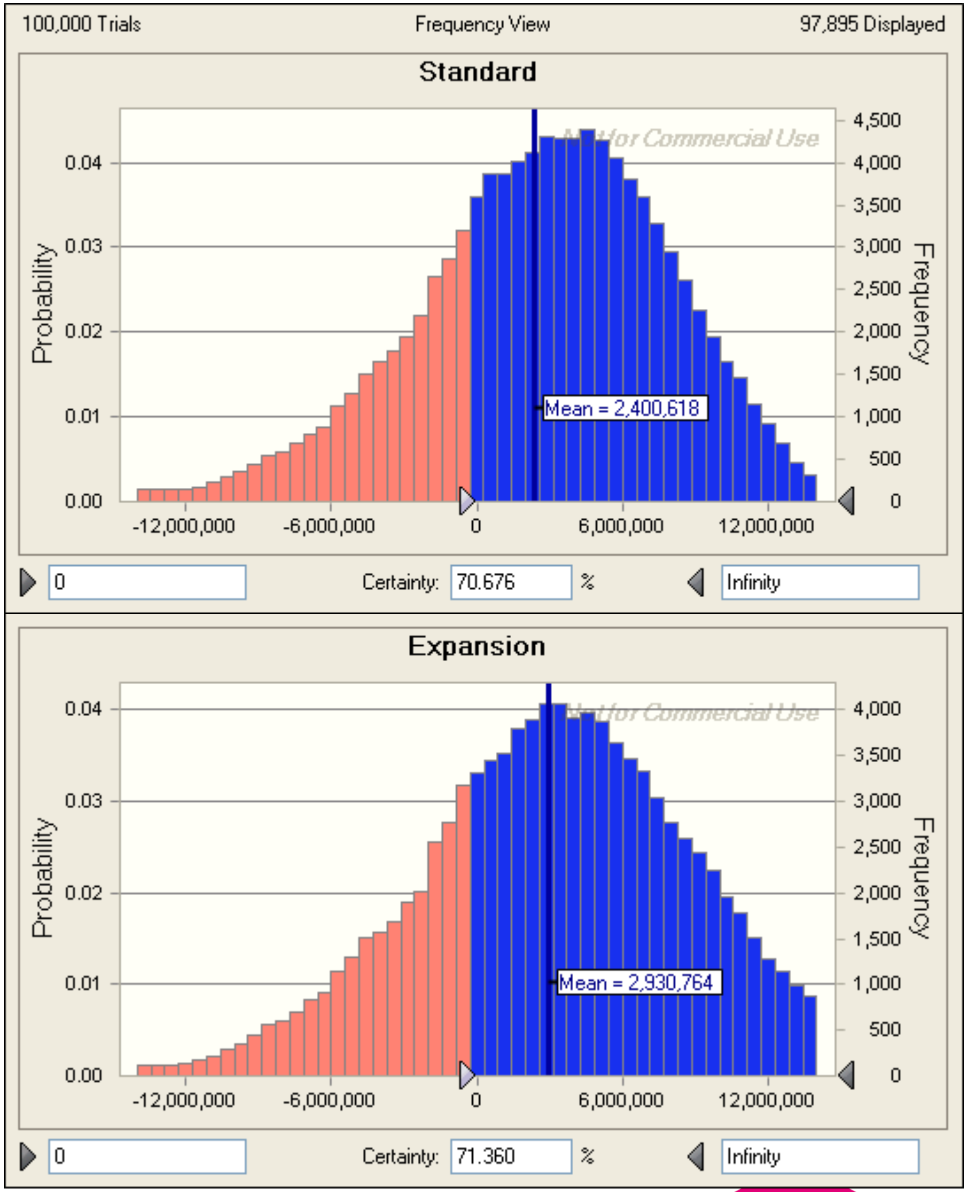


Traffic growth



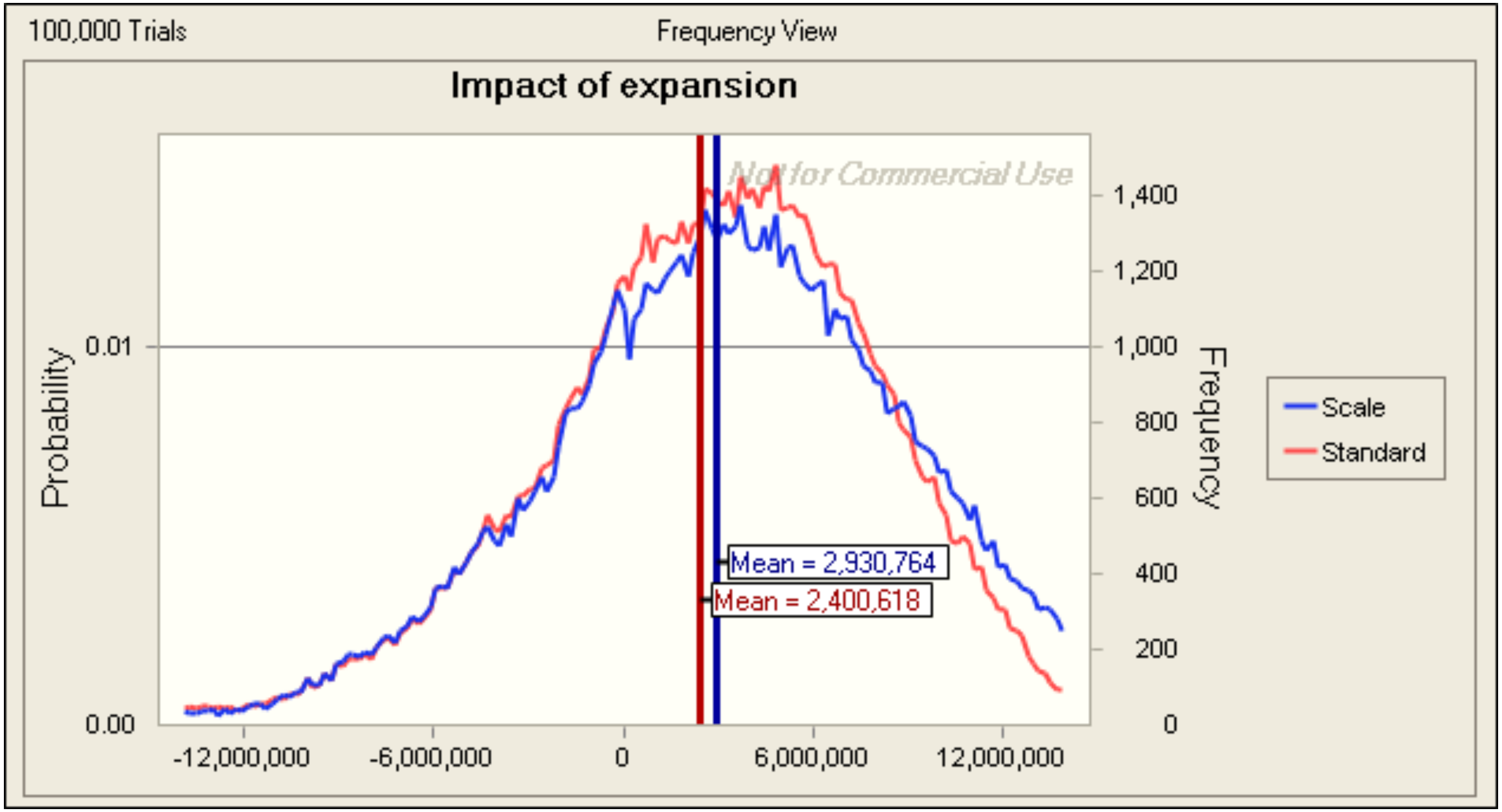
Flexibility to expand
has a positive impact

- Expected payoff
  - + 22%
- Risk
  - Higher probability of positive case +0.7%
  - Mean negative -3% (license cost)



Flexibility to expand

shows a shift to a more positive result



Do I continue with the operation of the wireless network?

Do I stop and sell my license if it is not viable?

What if operator has flexibility?

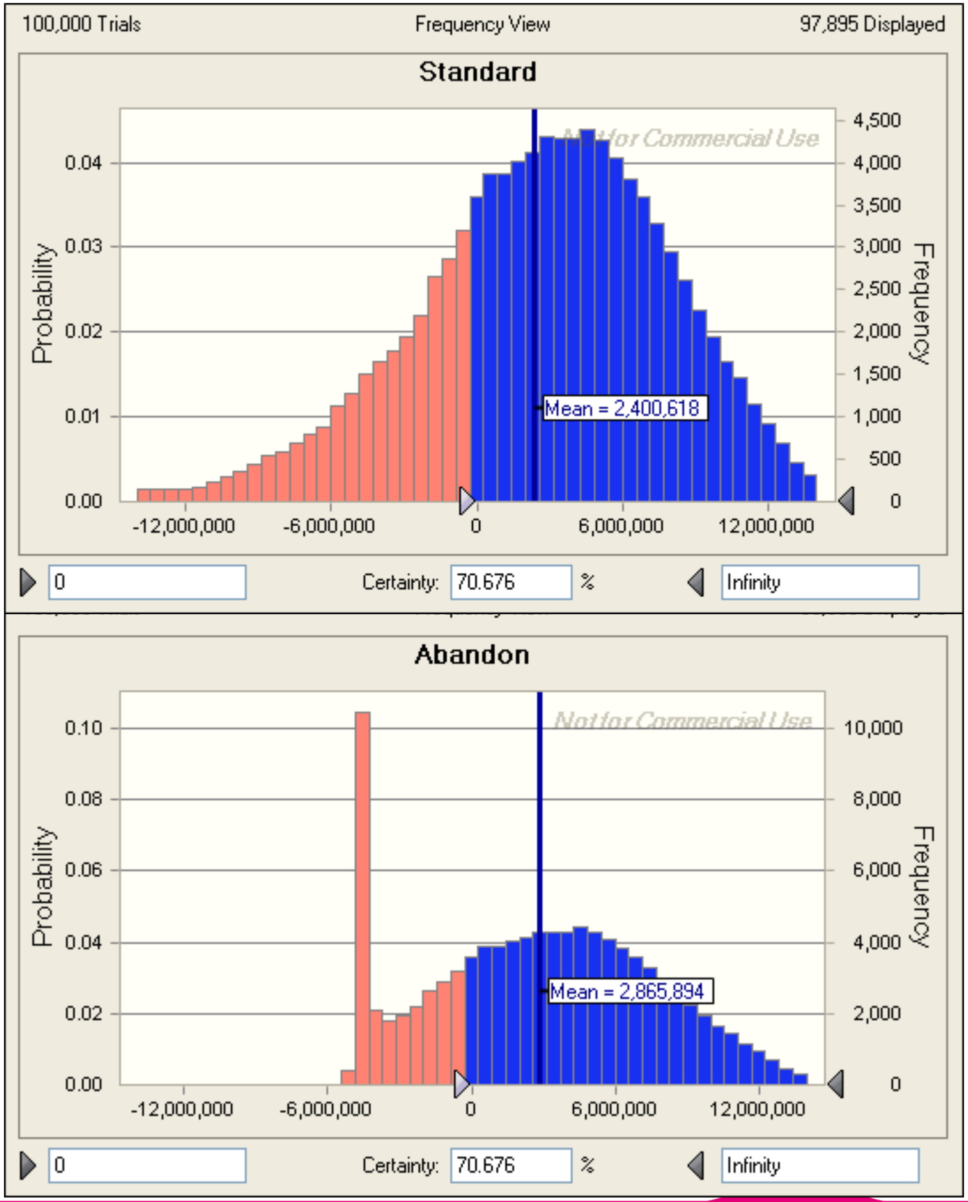
2. He can abandon the project

If outlook is negative

- Abandon the project
- Cut losses
- Gain revenues from
  - License sale
  - Scrap value of equipment (50%)

Flexibility to abandon

shows a dual effect on result



- Expected payoff
  - + 19%
- Risk
  - No impact on positive probability
  - Clear that tail is cut
  - Mean negative +20%

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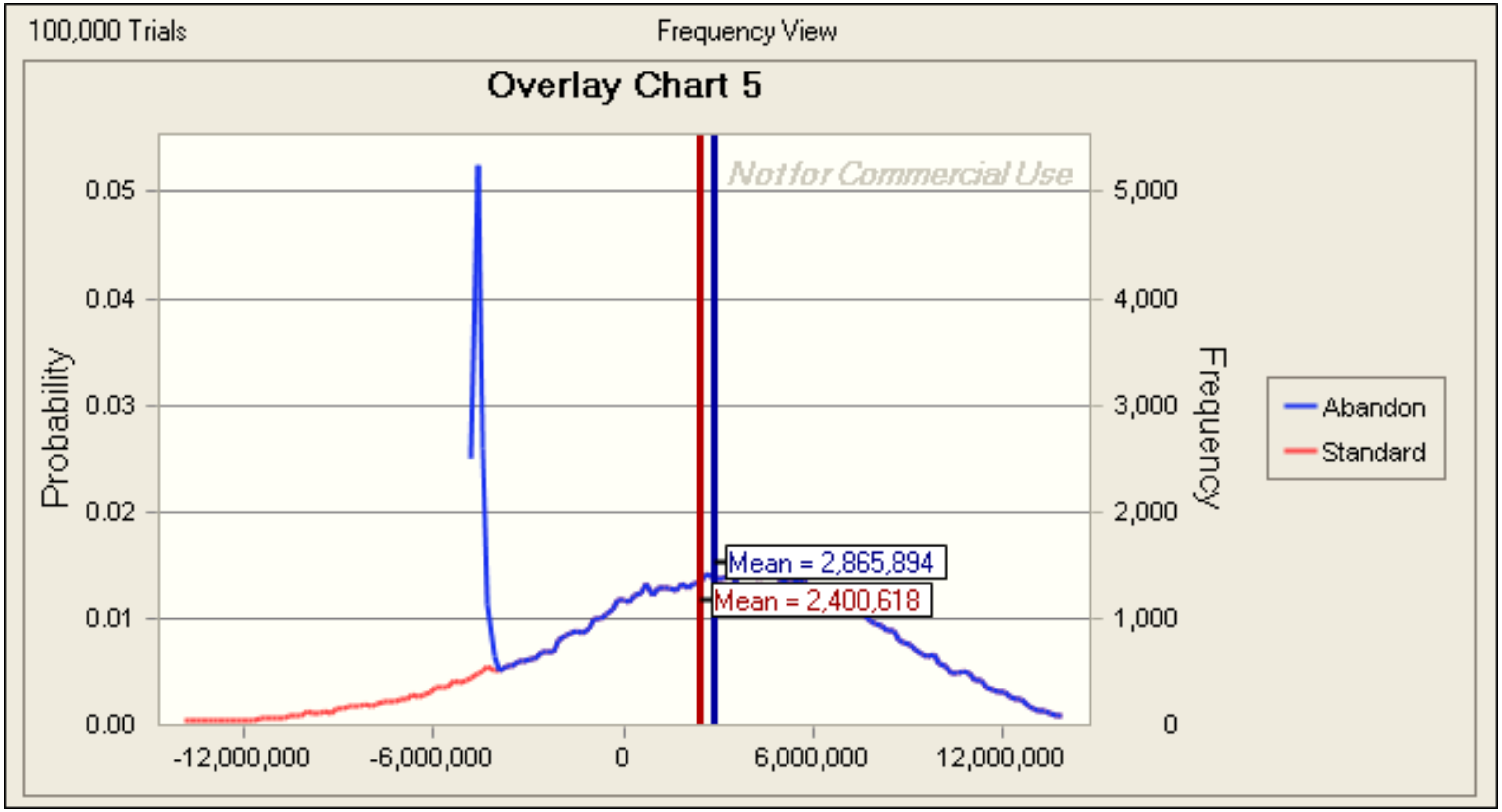
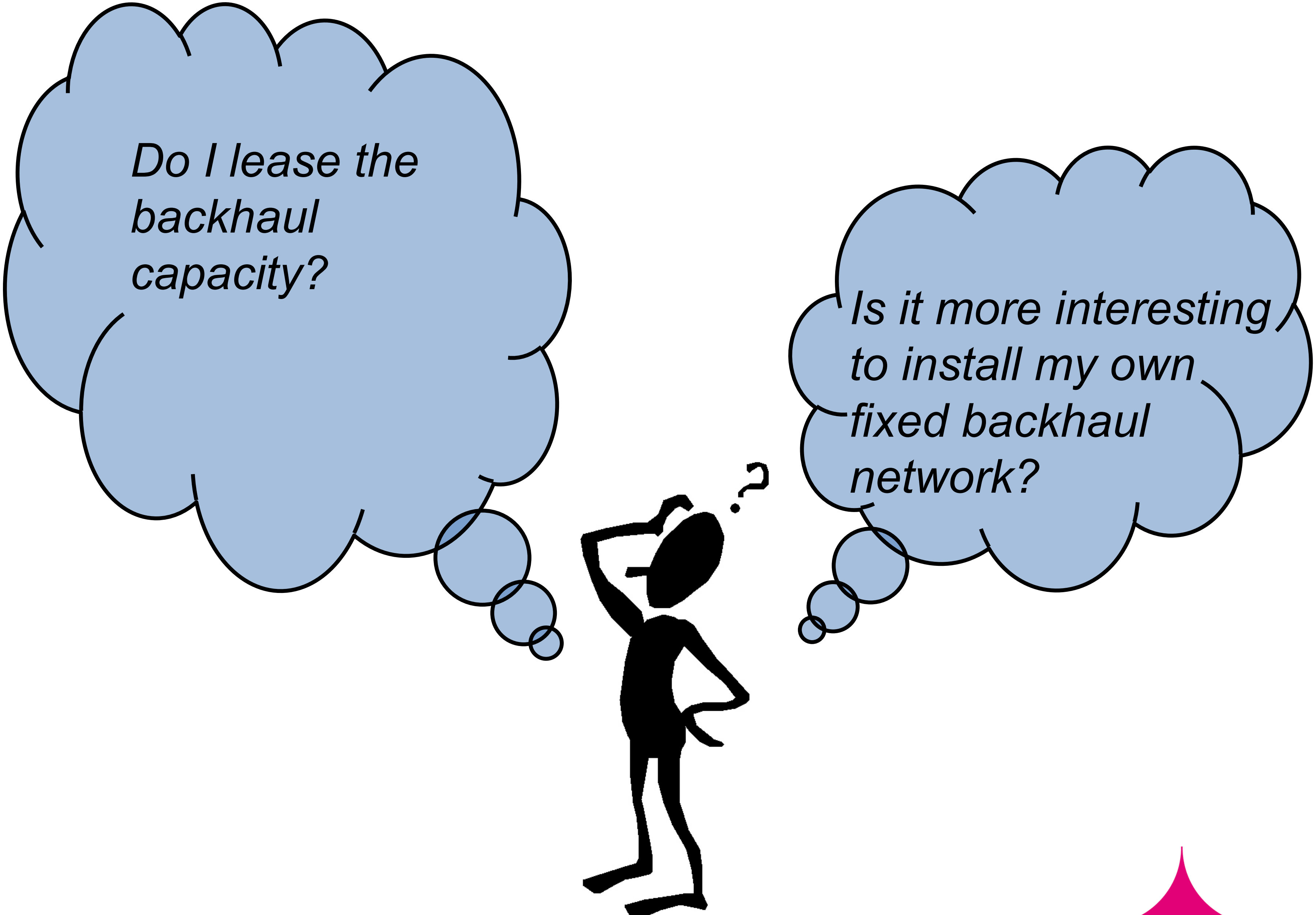
Flexibility to abandon

shows a cut in the negative tail in the expected result




Do I lease the backhaul capacity?
Is it more interesting to install my own fixed backhaul network?

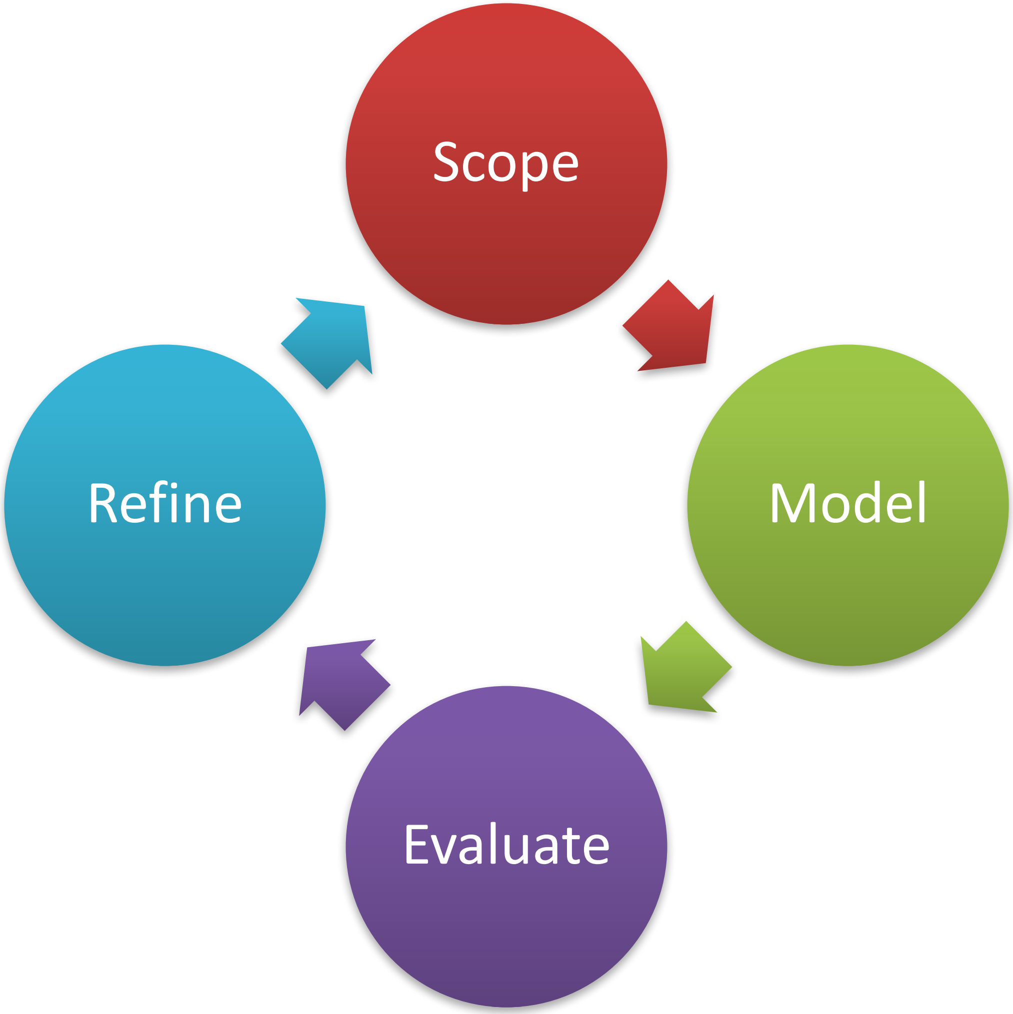
But what if operator has flexibility?

3. He can install his own backhaul infrastructure

Buy-or-lease decision

- Infrastructure installation is expensive
- Only interesting under large traffic volumes
  - High uptake
  - High traffic growth
- Requires fiber dimensioning
- Installation in Y4

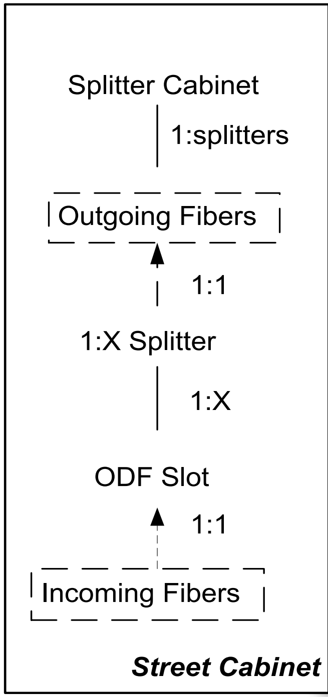
Following the same methodology

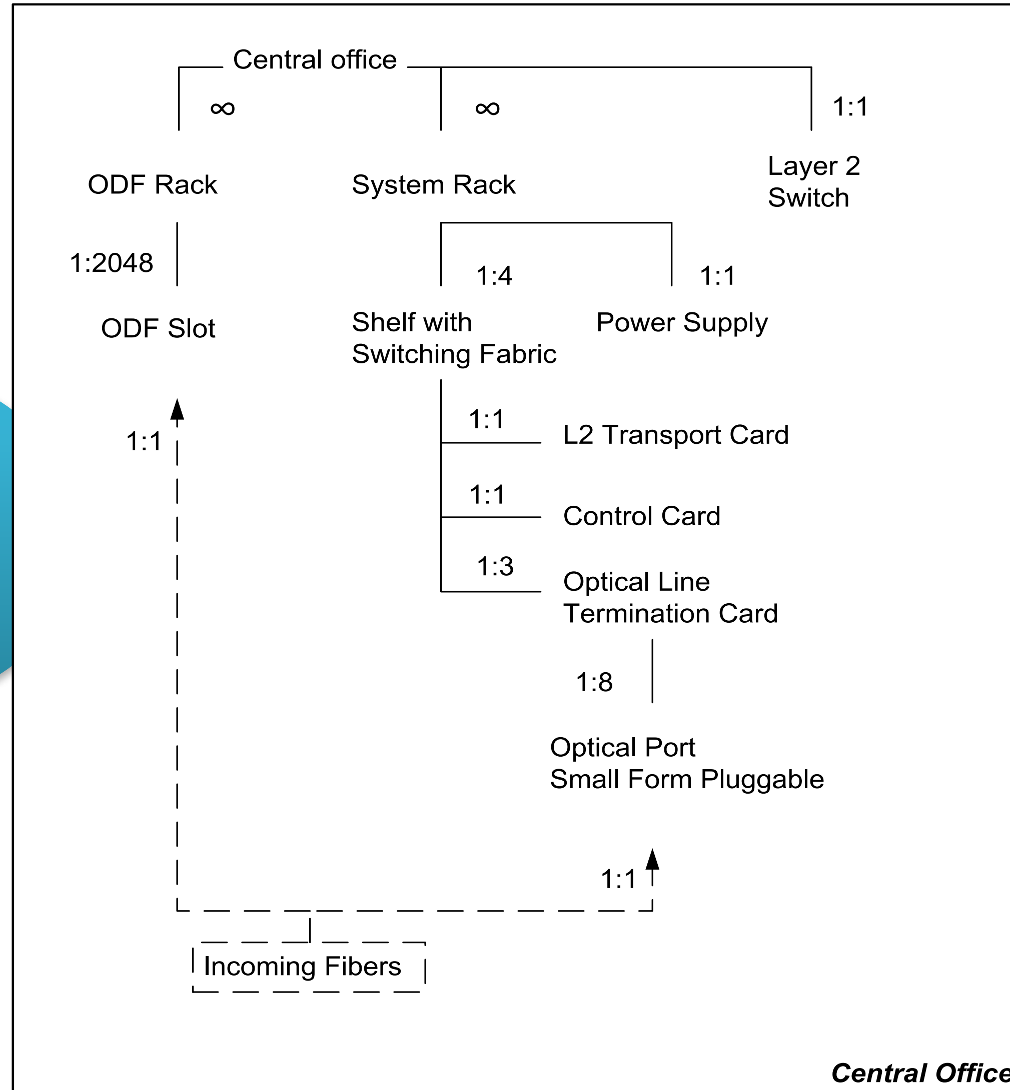


Following the same methodology

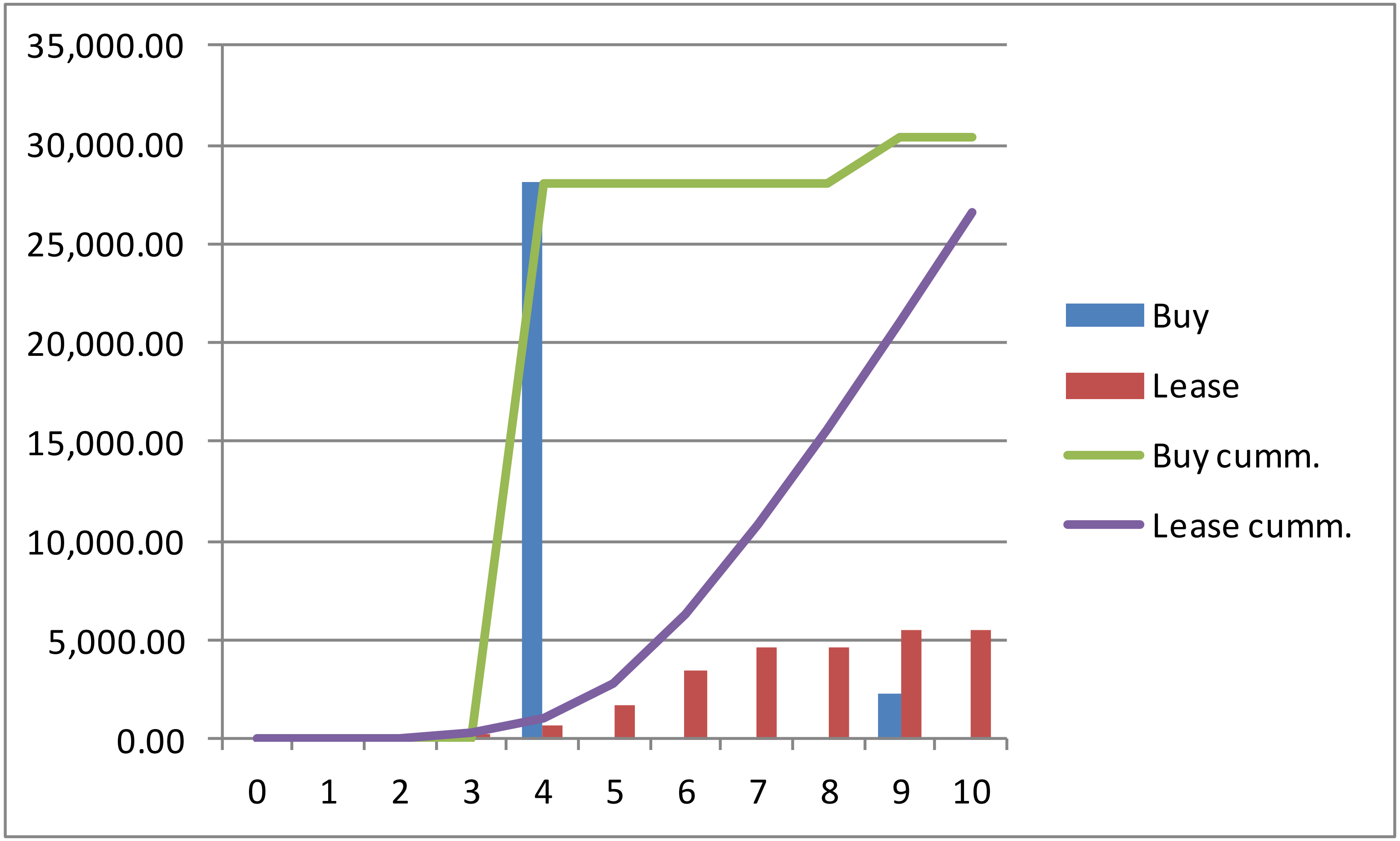
Parameter	Cost	Unit
Fiber	€0.20	Per meter
1:32 splitter	€500	Per 32 fiber
L2 switch	€650	Per Central Office
Power supply	€700	Per Central Office
Optical port	€15	Per splitter
OLT card	€2.000	Per 8 ports
Shelf	€5.375	Per 3 cards
System rack	€600	Per 4 shelves
ODF slot	€20	Per splitter
ODF rack	€800	Per 2048 slots

Following the same methodology





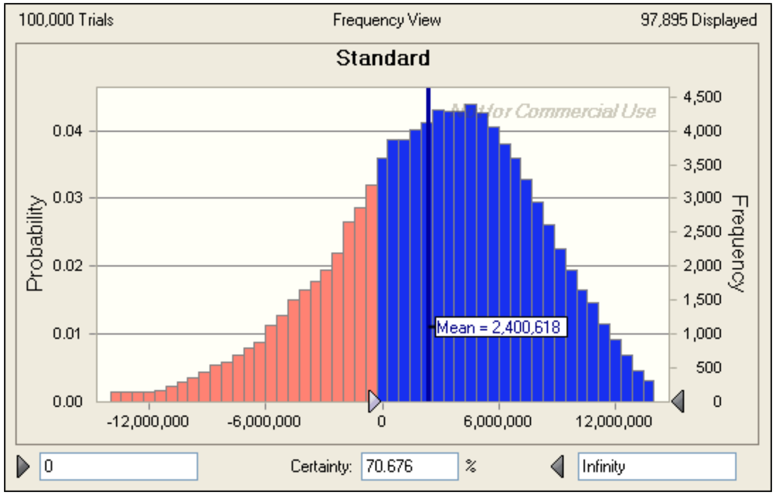
Buy-or-lease decision

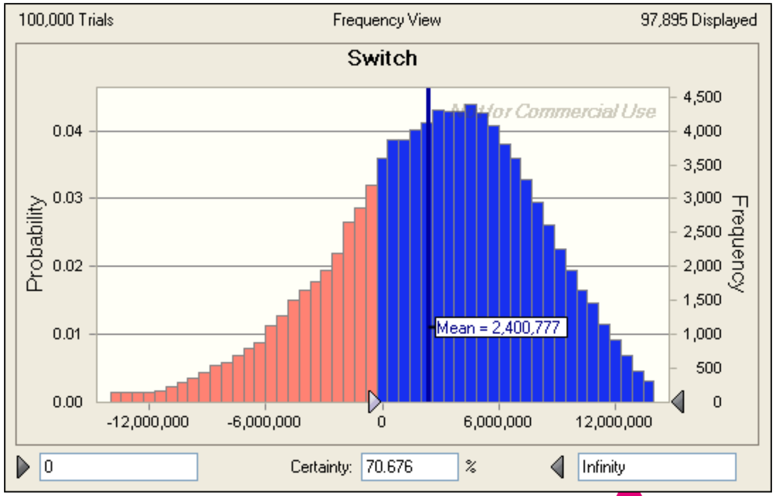


Flexibility to deploy on own backhaul

shows a negligible impact on result

- Expected payoff
  - + 0.007%
- Risk
  - No impact





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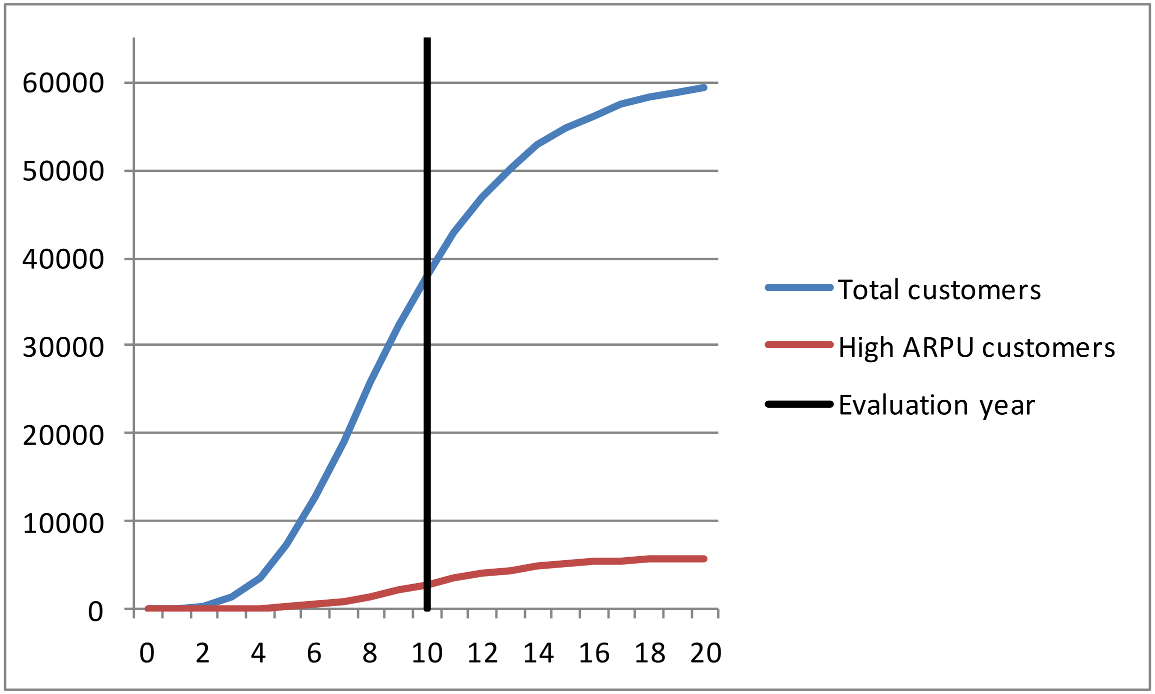
Are all customers buying the same service?

Or can I differentiate and sell different services?

But what if operator has flexibility?

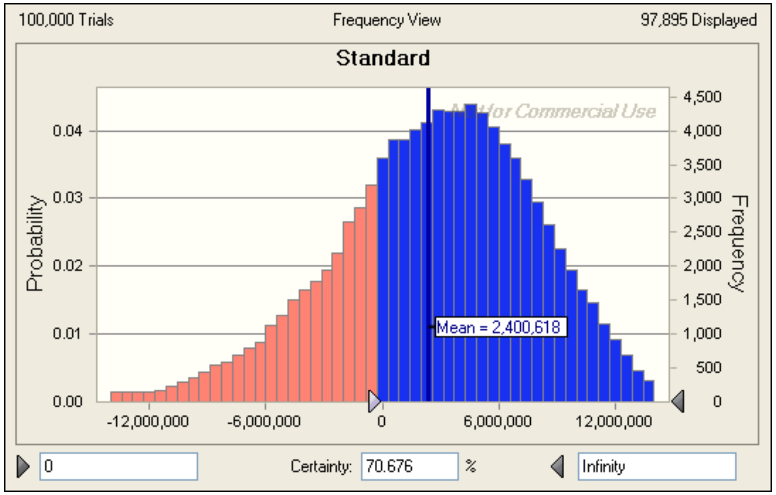
4. He can differentiate between customers

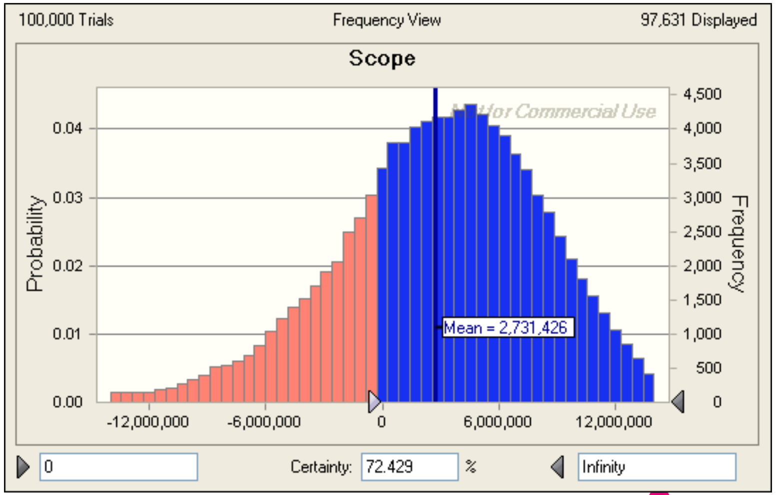
- Sell high-speed subscriptions
- Will require capacity upgrade
- Customers with higher ARPU
- Decide in Y4



Flexibility to differentiate between customers
shows a positive impact on the result

- Expected payoff
  - + 13.8%
- Risk
  - Higher probability of positive case (+1.8%)
  - No impact on mean negative (no option cost)





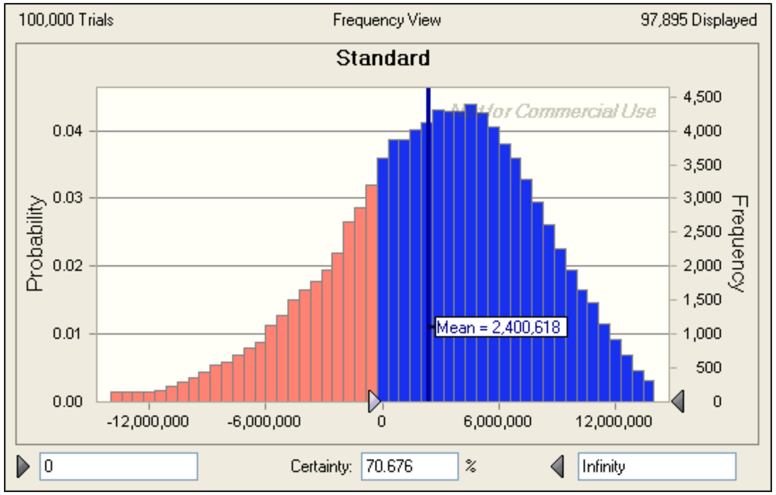
Do I expand my network to a larger area?

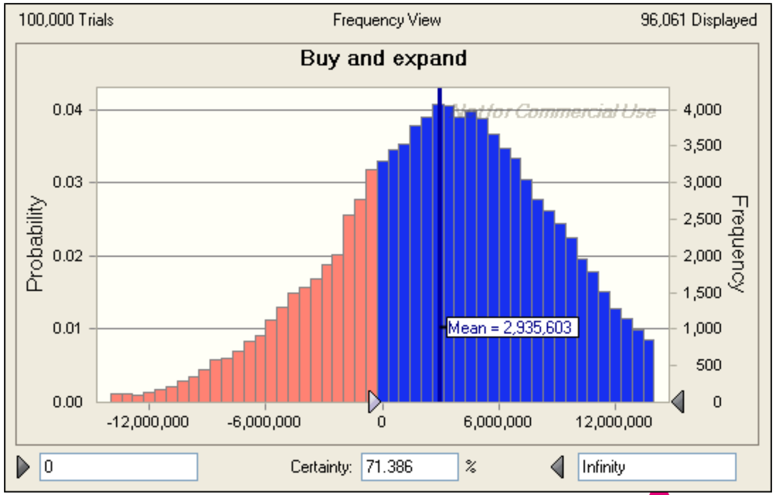
Is installing my own backhaul capacity more interesting?

Combined flexibility

to expand and switch to own backhaul

- Expected payoff
  - + 22.3%
  - Buying backhaul creates value
- Risk
  - Higher probability of positive case (+0.7%)
  - Mean negative -3% (license cost)





Uncertainty and Flexibility

are typical in real investment problems

Uncertainty in telecom planning: from case study

- Adoption
- Traffic growth

Uncertainty in telecom planning: more examples

- Technological change
  - alternative technologies
  - improved standards
- Competition uncertainty
  - competitor entry
- Adoption uncertainty
  - potential
  - timing
  - speed
- Regulatory changes
  - Licensing
  - Radiation limits
  - corporate governance standards
  - forced network unbundling
- Component price evolution
  - resource price inflation
- Traffic intensity uncertainty
  - OTT services
  - geographical concentration of usage (events)
- Equipment lifetime uncertainty
- Borrowing capability
- Willingness to pay/ARPU evolution

Sources of uncertainty in telecom planning

Compliance Threats

Uncertainty governing the institutional environment the telco operates in.

Operational Threats

Uncertainty concerning the operational aspects of the telco's core business processes.

Telecom Uncertainty

Strategic Threats

Uncertainty with regards to the product market.

Financial Threats

Uncertainty regarding the financial continuity of the telco operator.

Ernst & Young – 2012 – Top 10 Risks in Telecommunications 2012
Online: <<http://www.ey.com/GL/en/Industries/Telecommunications/Top-10-risks-in-telecommunications-2012>>

Sources of uncertainty in telecom planning

allow to classify typical uncertain parameters

Compliance Threats

- Regulatory change
- Corporate governance standards
- Radiation emission standards

Operational Threats

- Technological change
- Traffic Intensity uncertainty
- Equipment Lifetime uncertainty

Telecom Uncertainty

Strategic Threats

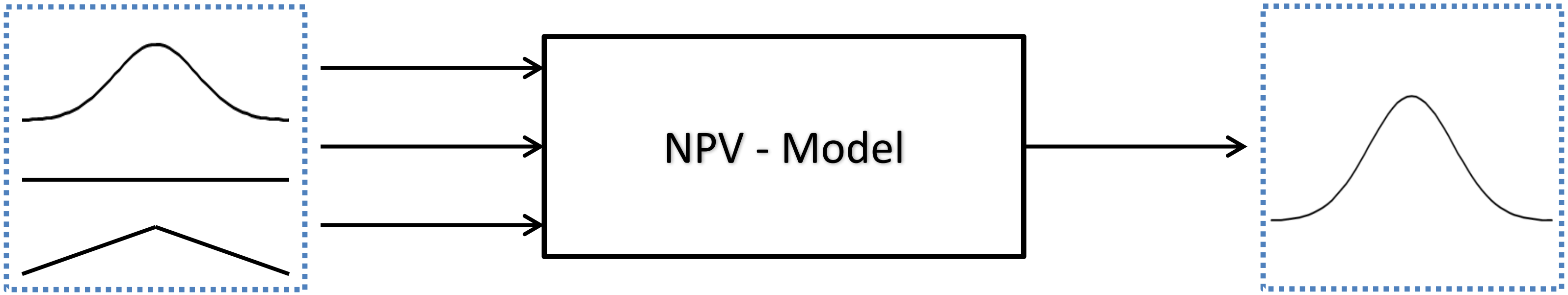
- Competition uncertainty
- Adoption uncertainty
- Willingness to pay evolution

Financial Threats

- Component price evolution
- Evolution of borrowing capacity

Impact of uncertainty on decision making

when the input is uncertain, the output is uncertain as well

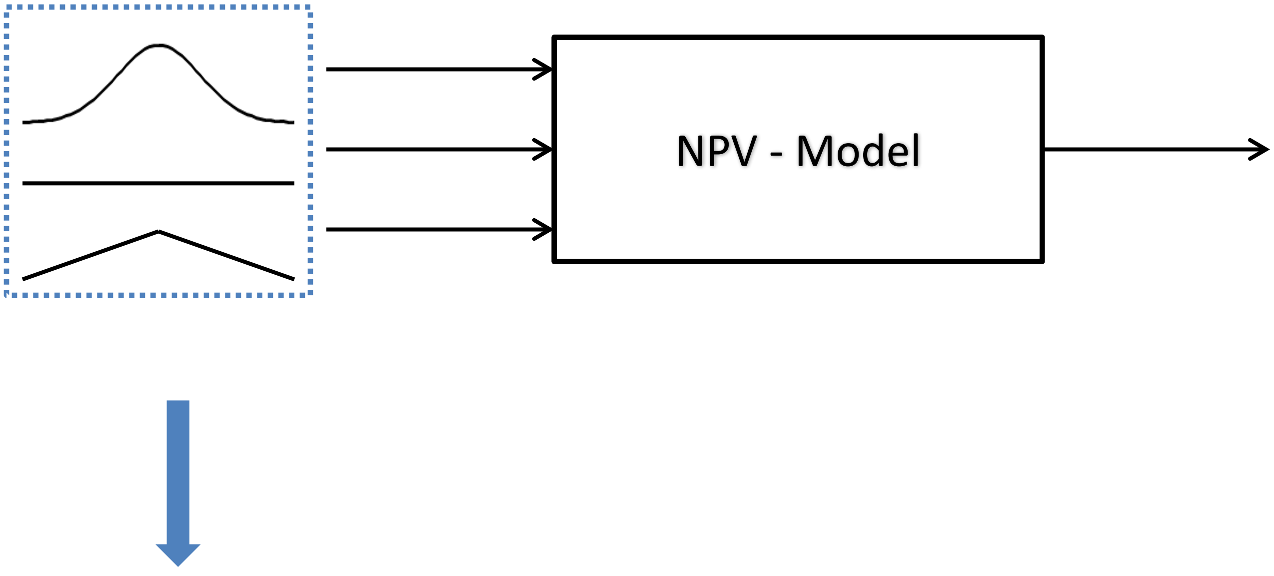


Input information is uncertain for different reasons

- Inherently
  - Aleatoric uncertainty
- Data unavailable
  - confidential
  - costly predictions
- Timing issues
  - Will become available at t>0

Impact of uncertainty on decision making

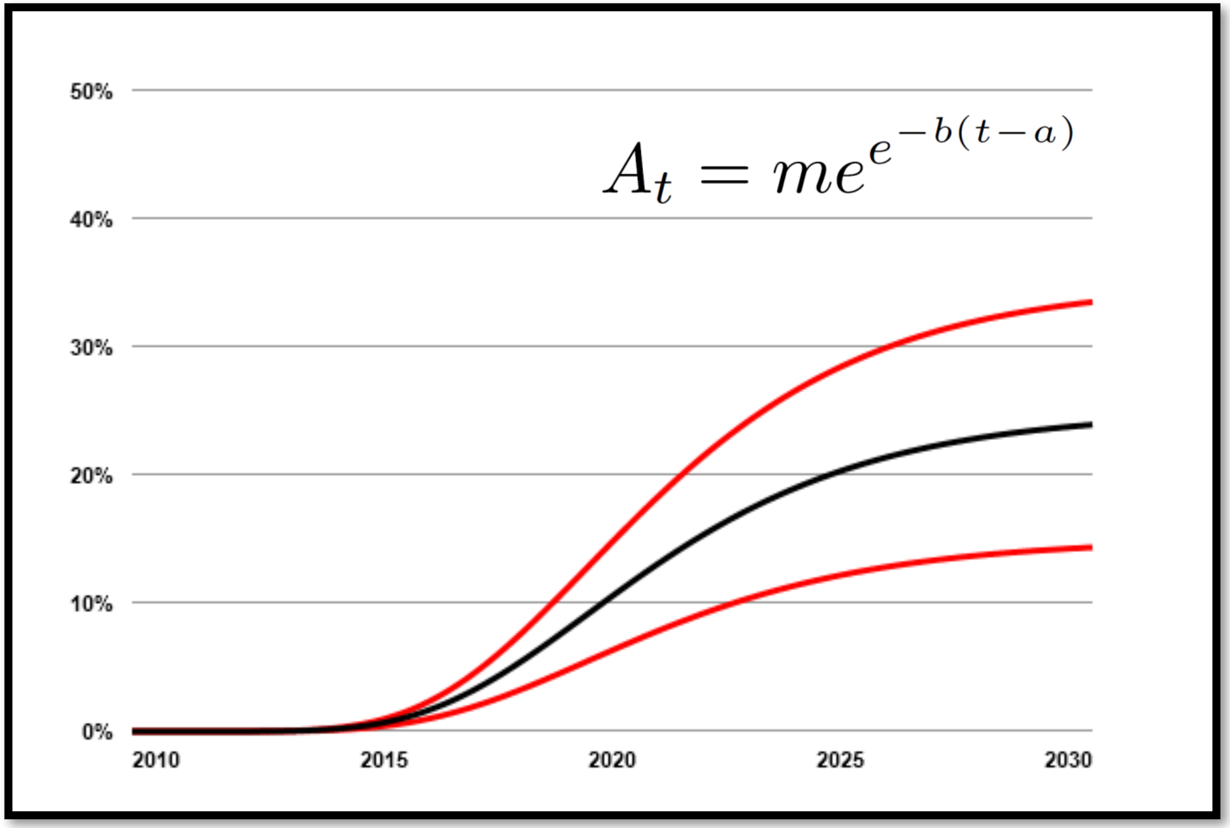
when the input is uncertain, the output is uncertain as well



Different ways to model
input uncertainty

Sources of uncertainty, in the case

estimated adoption between high and low extreme



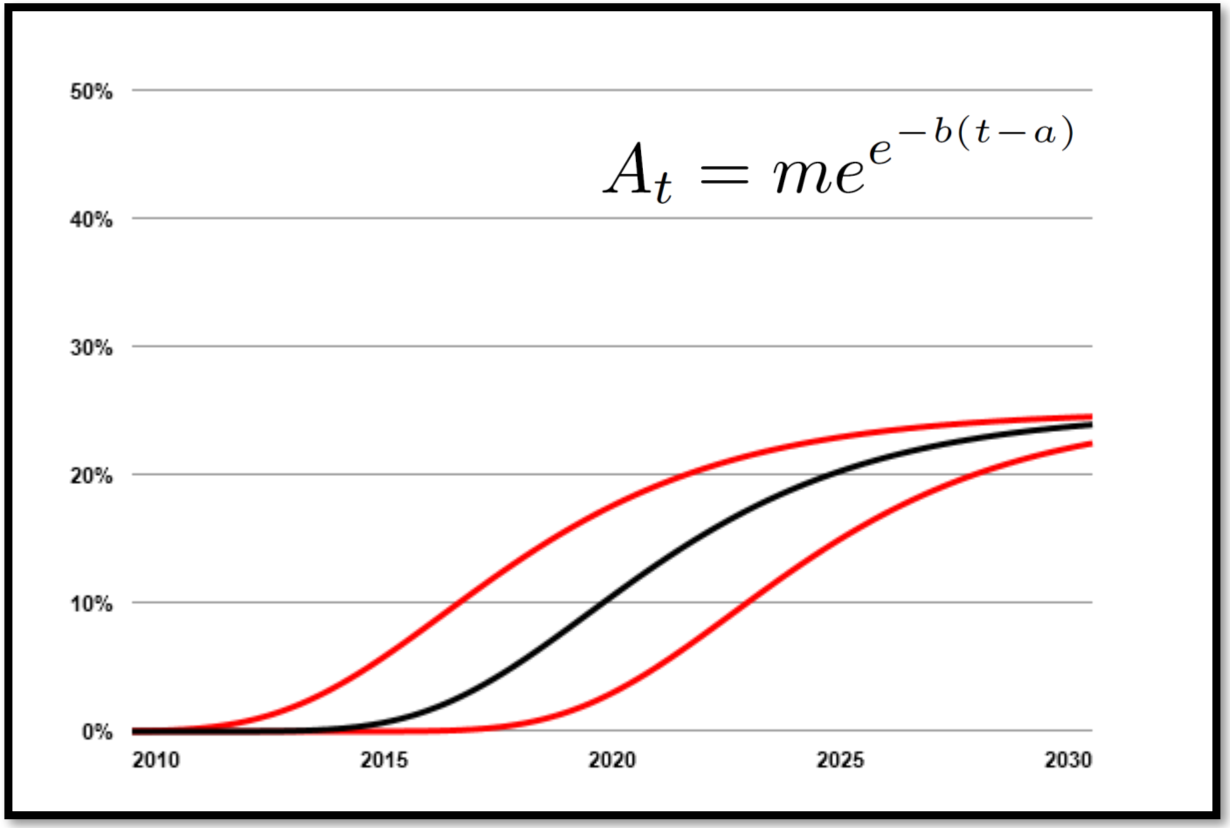
ADOPTION POTENTIAL

Gompertz Curve [1]:	
m:	0.15-0.35
a:	2019,5
b:	0.3

[1] Stragier et al. “A Priori Forecasting of FTTH uptake”, 11th Conference of Telecommunication, Media and Internet Techno-Economics (CTTE), 2012

Sources of uncertainty, other possibilities

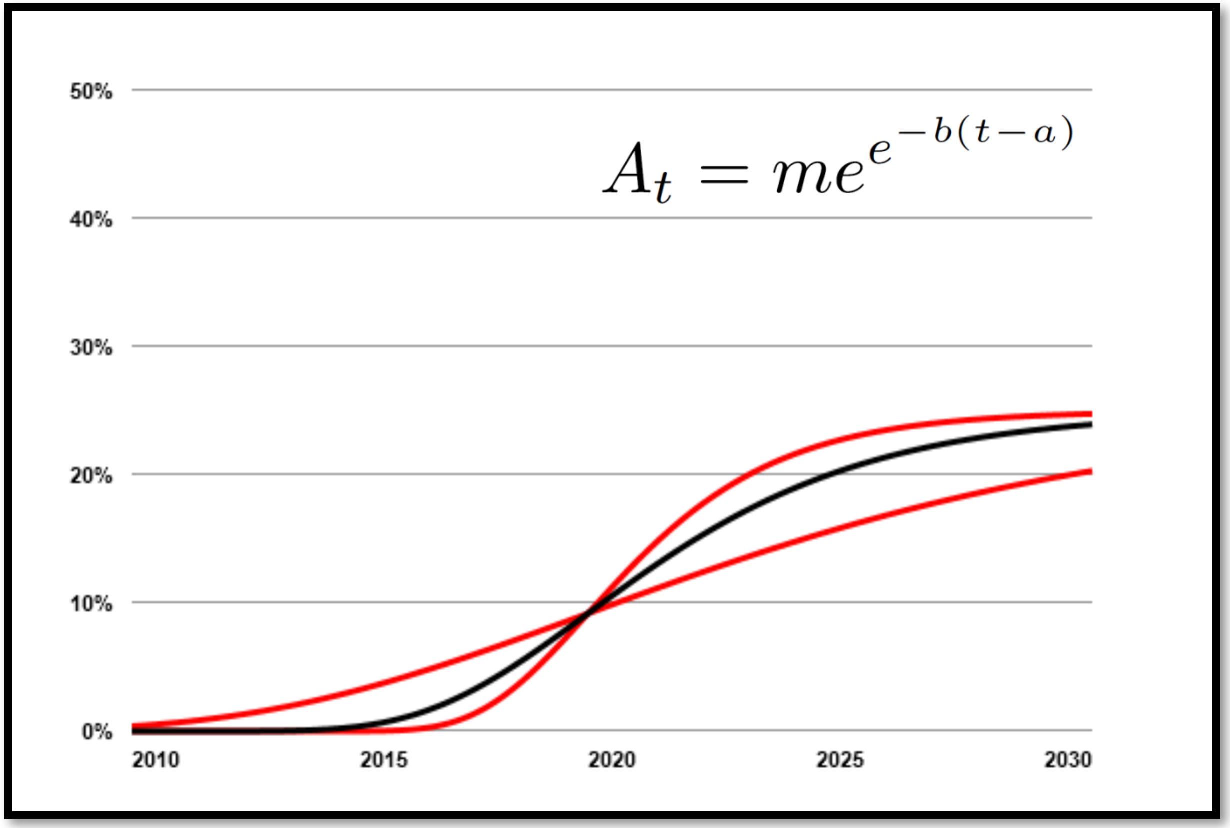
timing of the adoption (position of inflection point)



m:	**0.25**
a:	**2017,5 – 2021,5**
b:	**0.3**

ADOPTION TIMING

Sources of uncertainty, other possibilities
adoption rate (steepness of the curve)

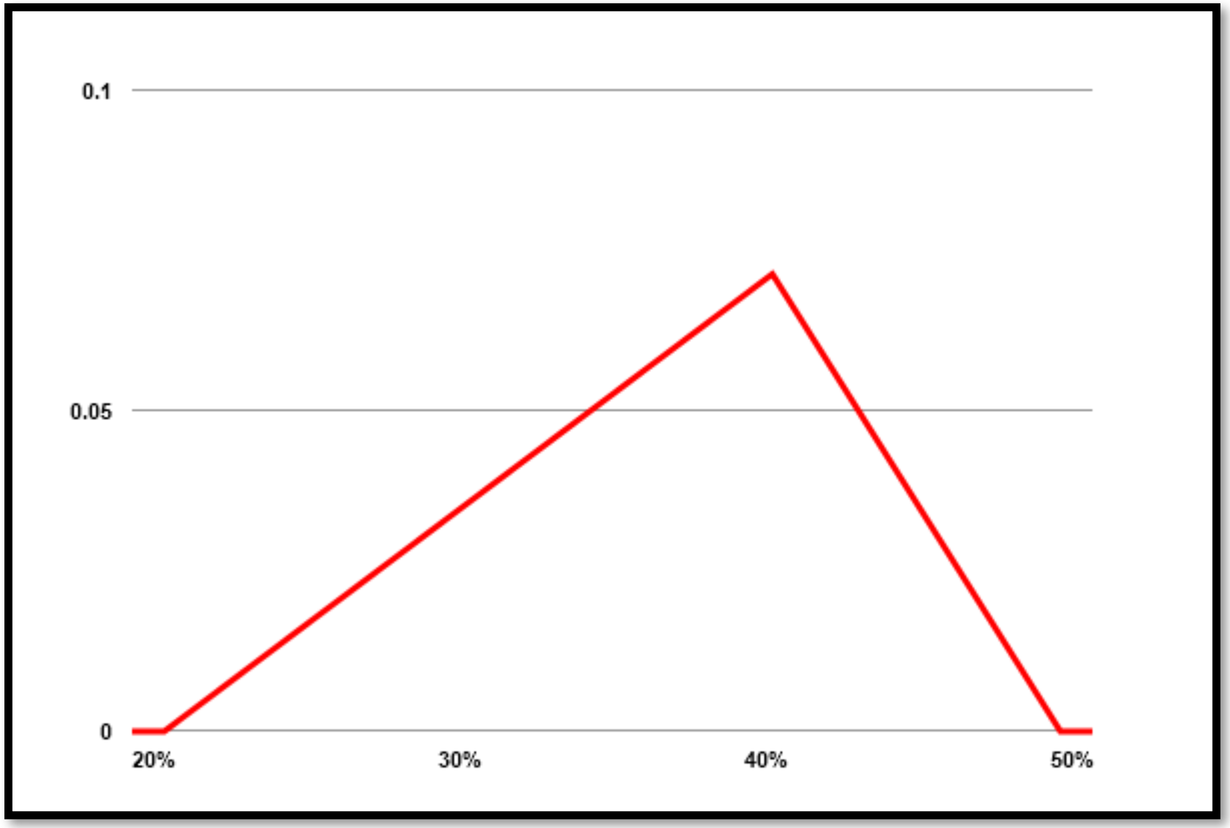


m:	0.25
a:	2019,5
b:	0.15 – 0.45

ADOPTION RATE

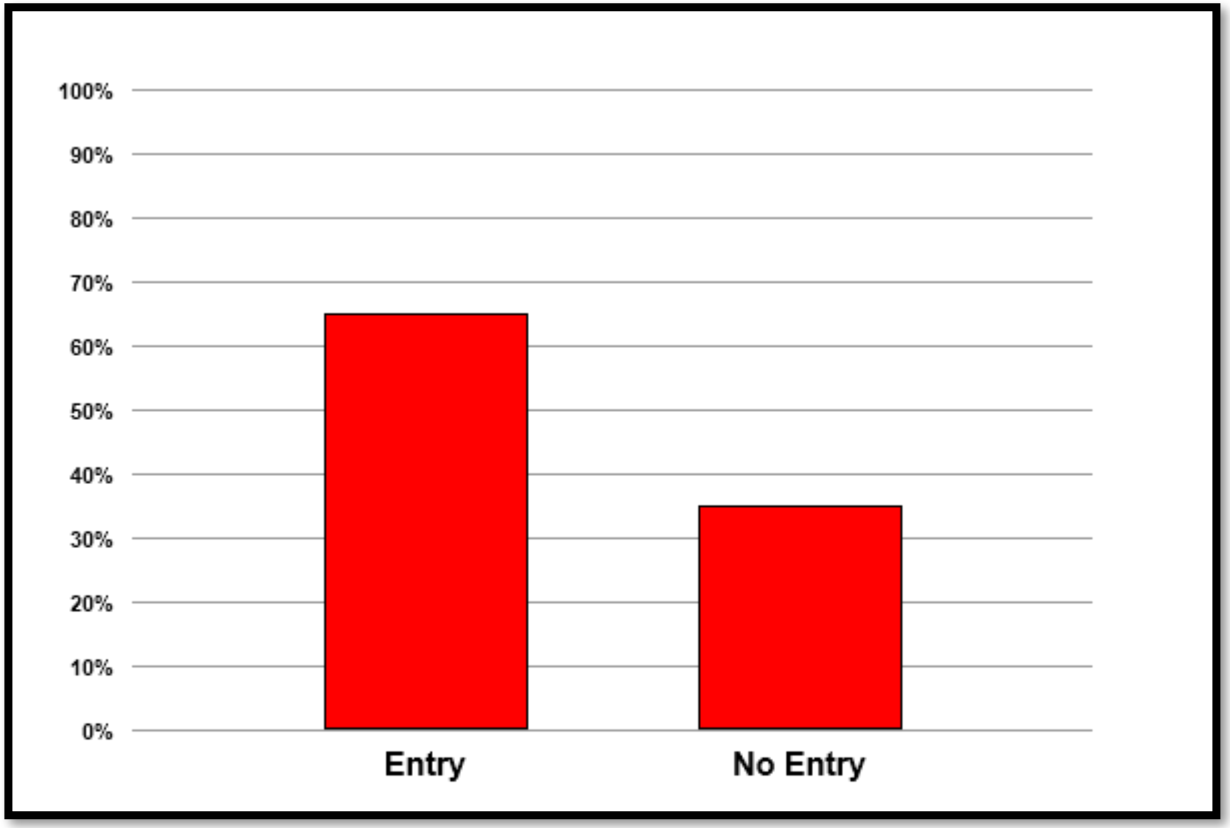
Sources of uncertainty, in the case

triangular between high and low extreme



TRAFFIC GROWTH

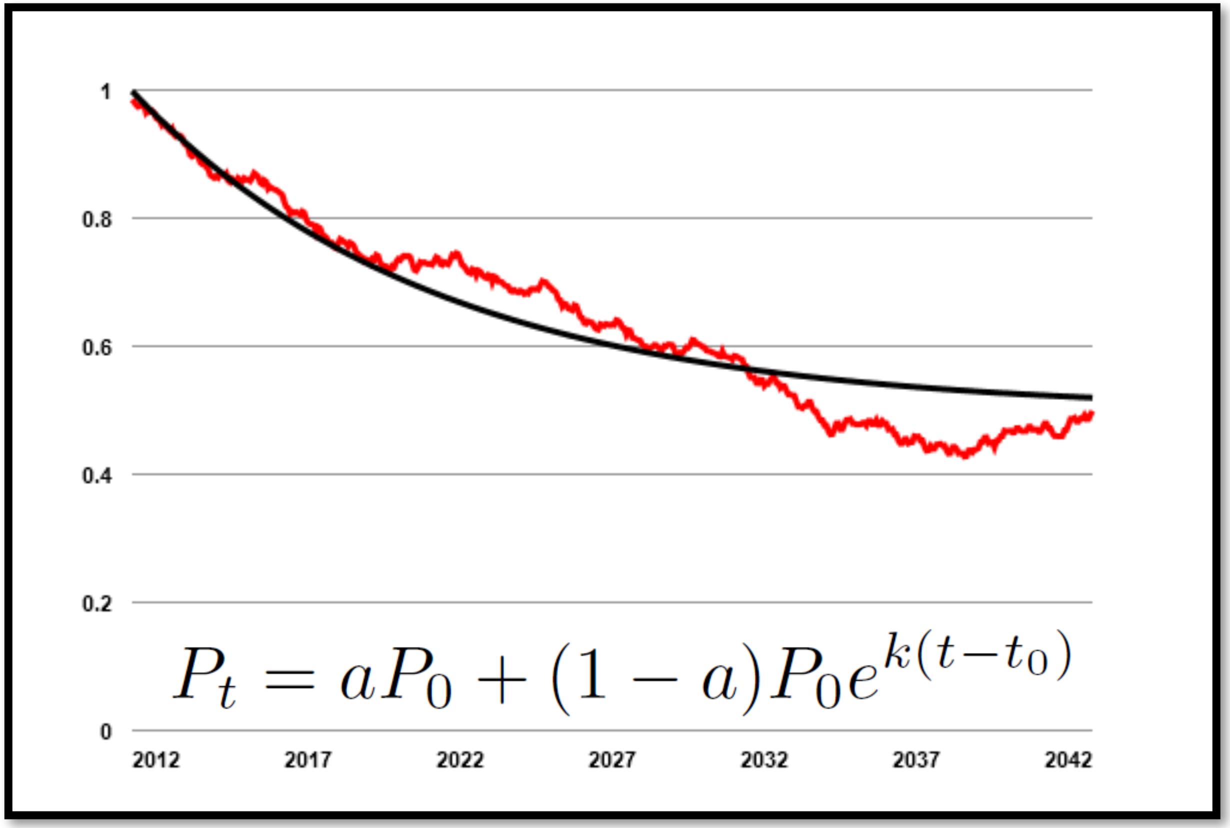
Sources of uncertainty, other possibilities
changes in competitive setting



COMPETITOR ENTRY

Sources of uncertainty, other possibilities

cost erosion over time



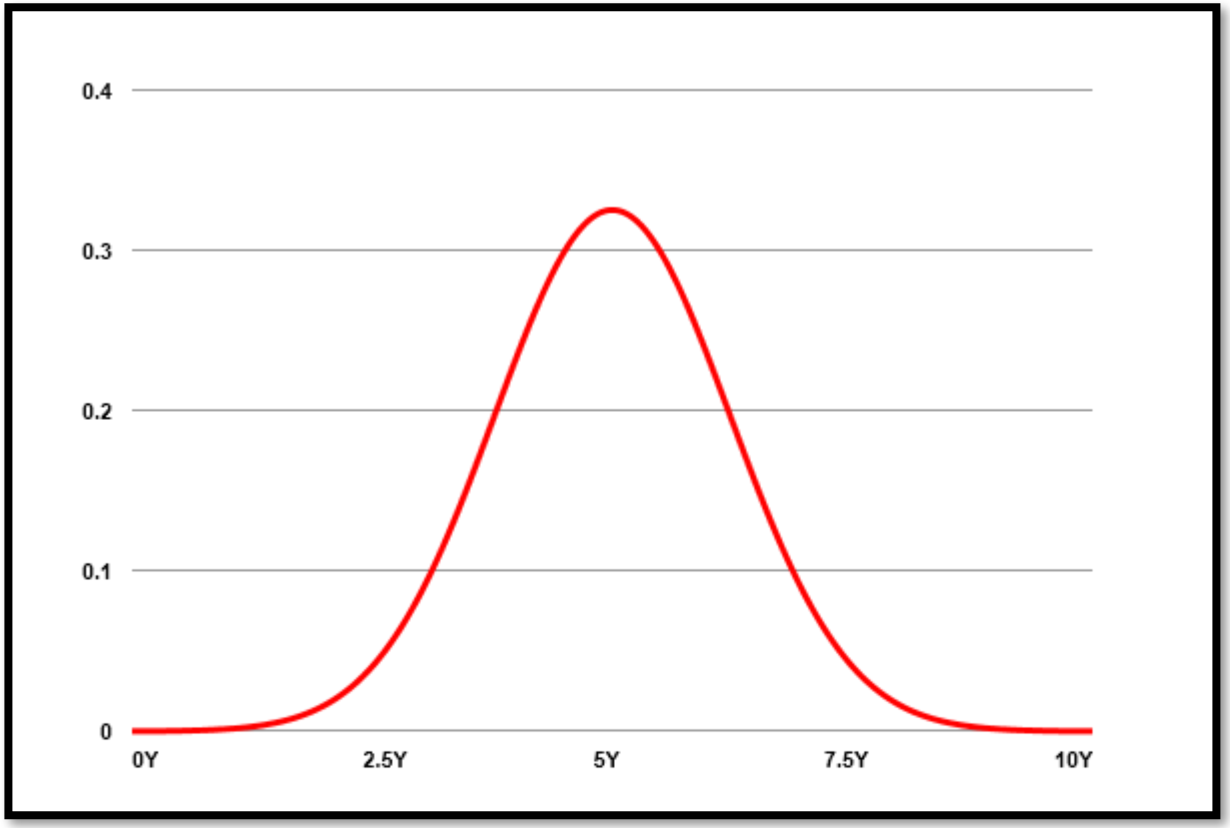
BASE STATION PRICE EVOLUTION

Simplified version of learning curve [1] with exponential decay:

P_0:	**1**
T_0:	**2012**
a:	**0.5**
k:	**-0.1**

[1] Borgart T. Olsen and Kjell Stordahl, Models for forecasting cost evolution of components and technologies", Telektronnikk 4, 2012

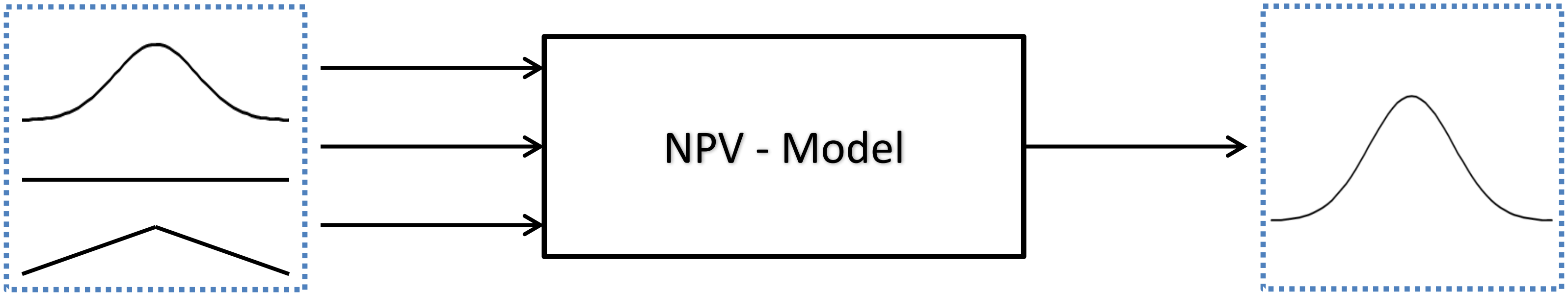
Sources of uncertainty, other possibilities
Gaussian distribution around mean expected lifetime



BASE STATION LIFETIME

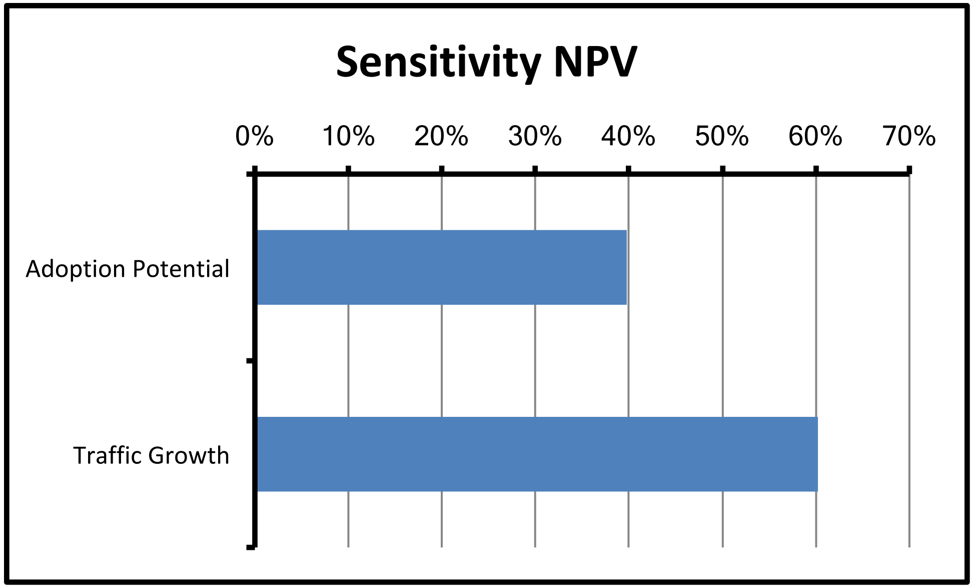
Impact of uncertainty on decision making

when the input is uncertain, the output is uncertain as well



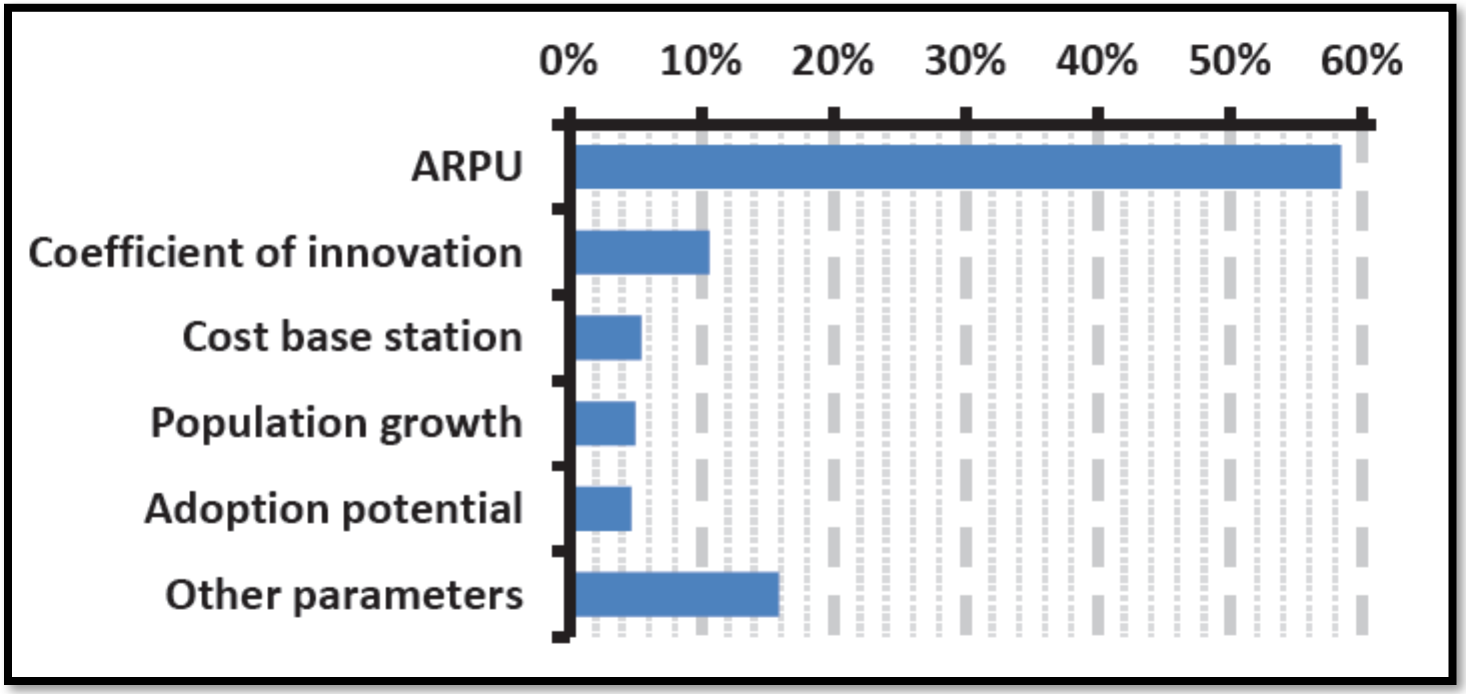
Ways to represent
impact of input
uncertainty in output

Impact of uncertainty
of input parameters on output values



Sample case

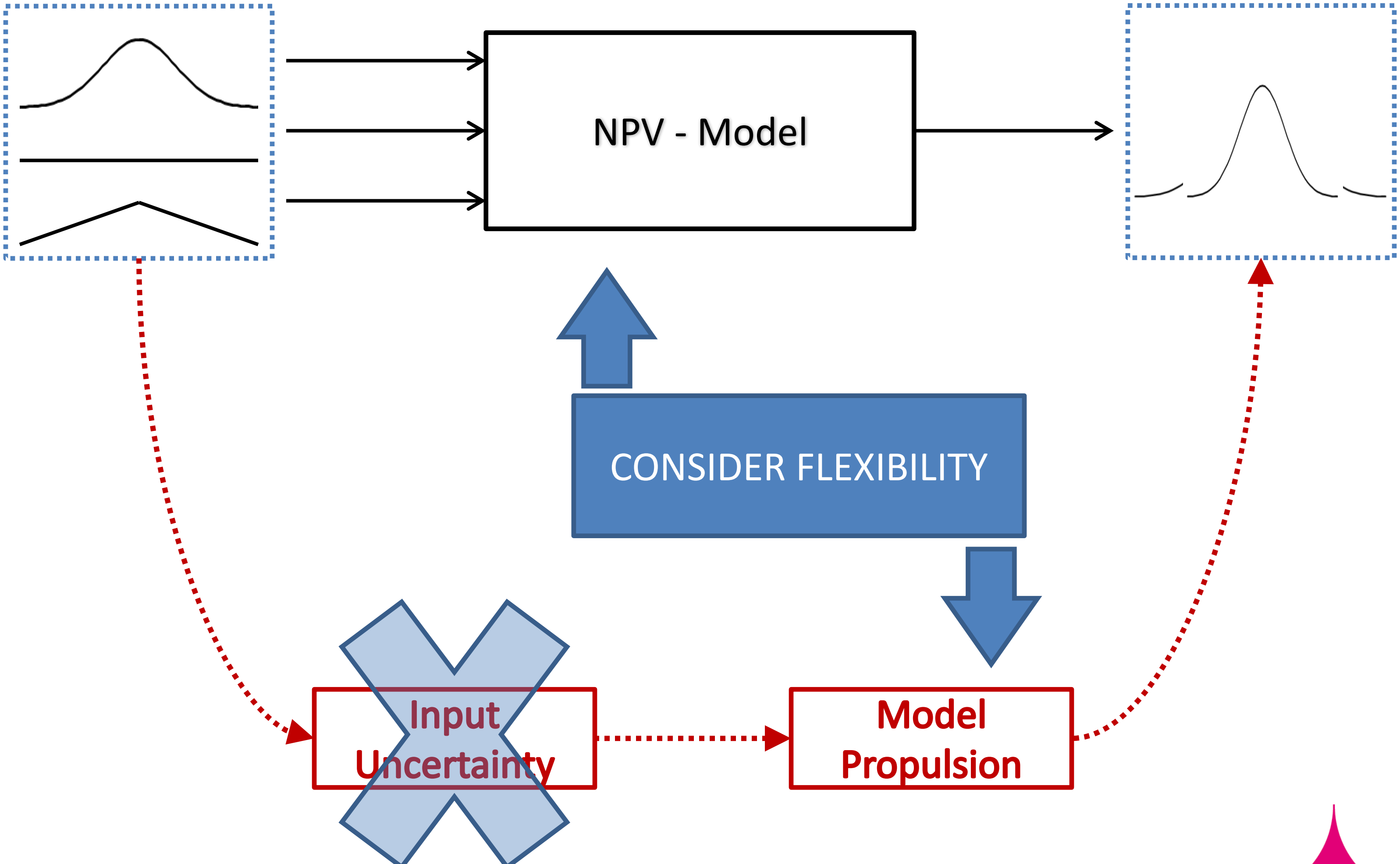
Impact of uncertainty
of input parameters on output values



Crowdsourced Wi-Fi project Ghent

Flexibility during the project course

can help to reduce the effect of the uncertainty



Types of flexibility

ACT

INVEST

- Expand geographic coverage
- Upgrade production capacity
- Improve product portfolio

DISINVEST

- Decrease geographic coverage
- Disinvest in production capacity
- Withdraw from market

LEARN

- Postpone decision
- Trial project
- Market research

Real Options

Indicate flexible options in real investment projects

Origin of Real Options
is in financial options

An option gives the buyer
the right
to buy or sell an asset
for a predetermined exercise price
over a limited time period.

A real option gives the manager
the possibility
to change the course of the project
at a certain cost
during the project's lifetime.

What are Real Options?

Real options

- Investment project over longer period
- Uncertain future
- Capture the value of managerial flexibility

Real options as an extension of NPV

Example

- 2 projects having the same NPV
- Intuitively choose the project which gives the most possibilities later on

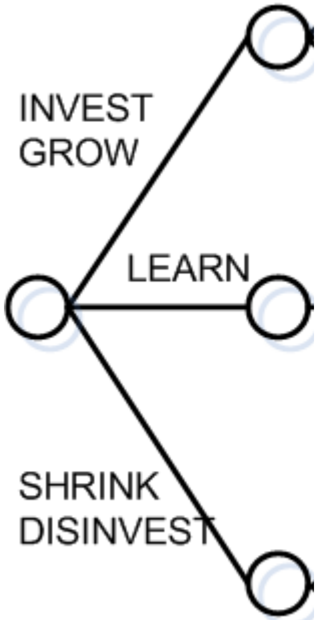
Weak aspect of NPV evaluation

- Assumes strict planning, with no flexibility

Real projects

- Anticipate on changing market circumstances

Categories of real options
based on the 7S framework



LTE deployment case study

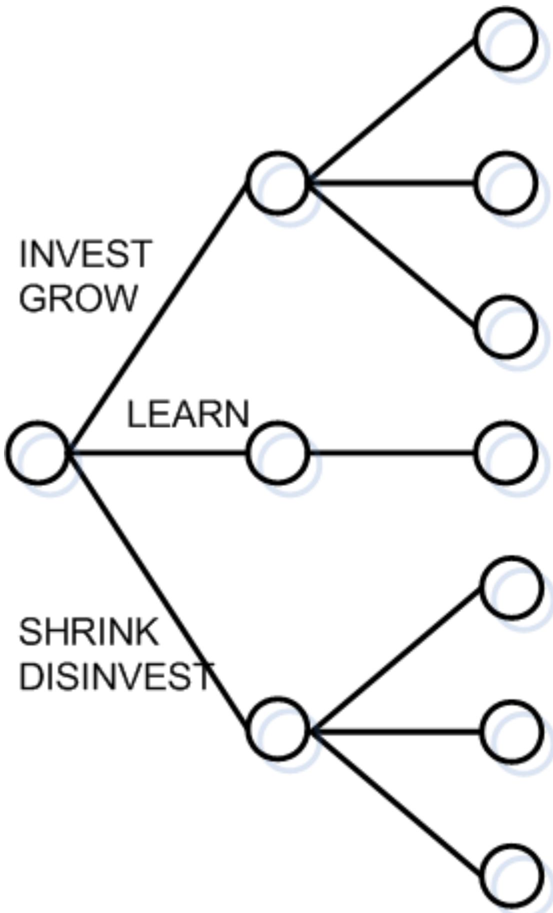
Roll-out in additional city

Deploy own backbone infrastructure

Differentiate between customers

Stop and sell off license

Real Options in Telecom

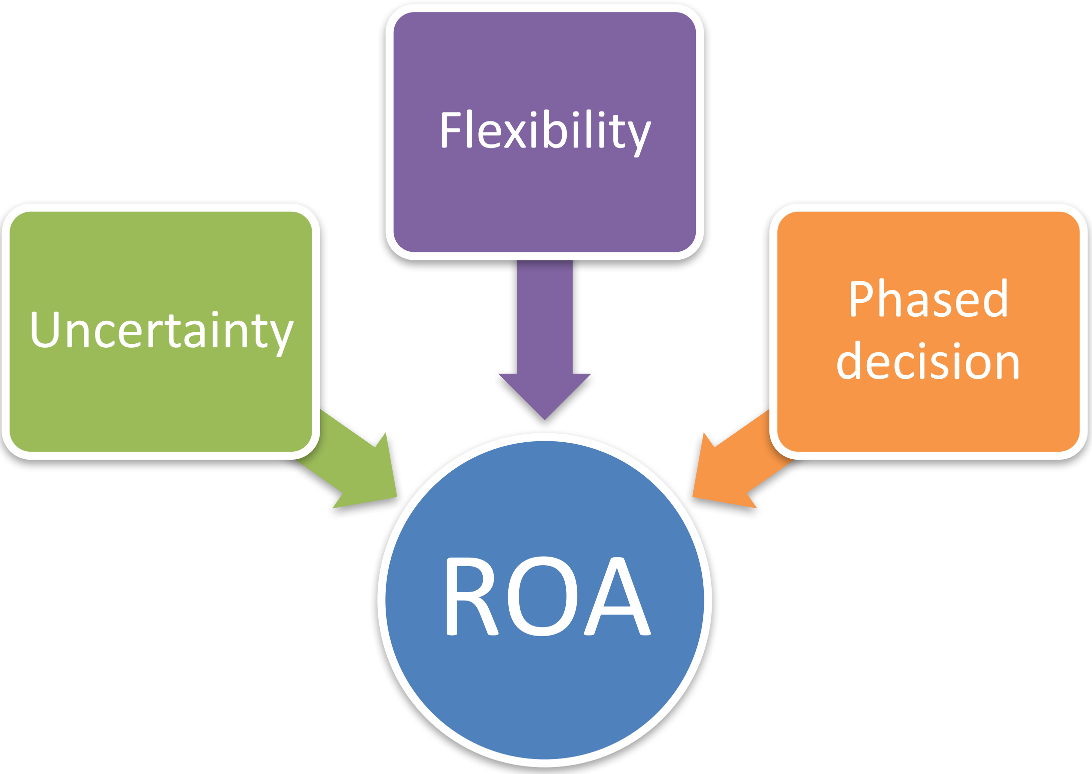


	Telecom examples
SCALE UP	Phased network rollout Acquiring licenses
SWITCH UP	Technology upgrade, e.g. ADSL to VDSL2 or 2G to 3G
SCOPE UP	Triple play Bitstream access
STUDY/ START	Trial project Testing of LTE Market studies
SCALE DOWN	Adapting network rollout scenario Abandoning project
SWITCH DOWN	Lease wavelengths instead of dark fiber in case of lower demand
SCOPE DOWN	Withdrawal from ISDN market

(Source: Copeland and Keenan, 1998)

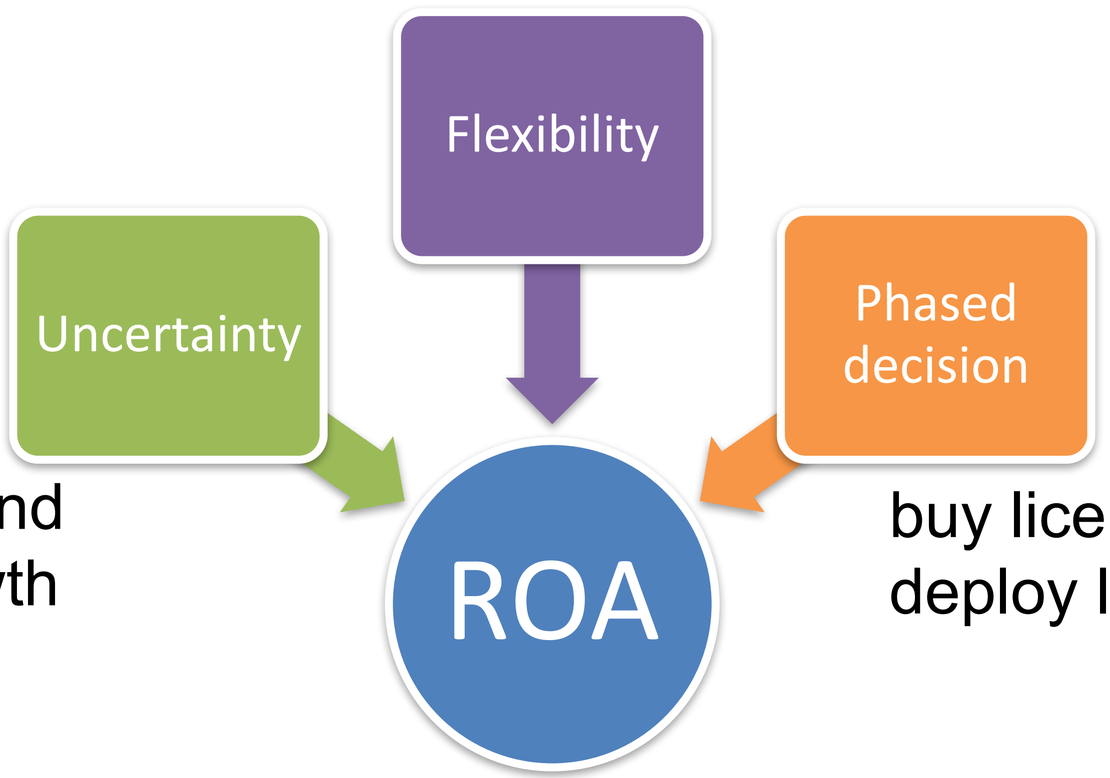
Real Option Category	Real Option Type	Description	Telco examples
Invest/ grow	Scale up	Cost-effective sequential investments as market grows	Expand area of wireless coverage from cities to semi-urban areas
	Switch up	Switch products given a shift in underlying price/demand	Start offering dedicated wavelengths using DWDM in case of equipment price drops
	Scope up	Enter another industry cost-effectively	Start offering IPTV next to Internet connectivity
Defer/ learn	Study/start	Delay investment until more info/skill is acquired	Wait till competitor strategy is more clear
Disinvest/ shrink	Scale down	Shrink or shut down project as new info changes expected payoffs	Abandon one region if competitor drops prices there
	Switch down	Switch to more cost-effective and flexible assets as new info is obtained	Lease wavelengths instead of dark fiber in some regions of lower demand
	Scope down	Abandon operations in related industry if there is no further potential	Stop offering hot spot services if market does not take off

Three conditions for a ROA



Three conditions for a ROA
as illustrated for the case of LTE deployment in Gent

move to bigger city



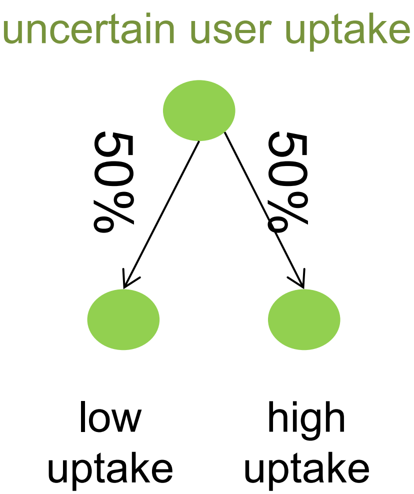
adoption and traffic growth

buy license now, deploy later

Condition 1: uncertainty

Uncertainty concerning initial assumptions

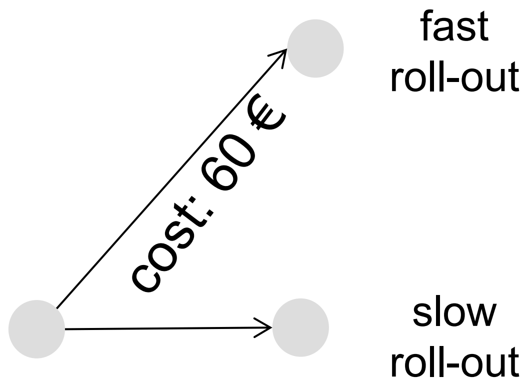
- Customer uptake
- Price evolutions
- …



Condition 2: Flexibility

Flexibility in decision

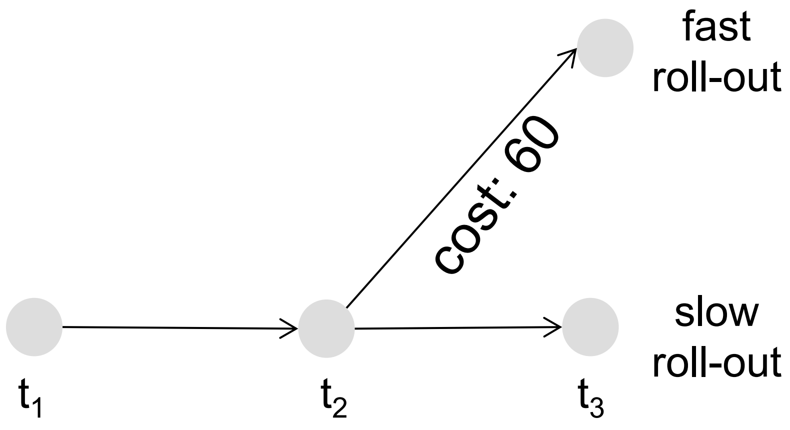
- According to the 7S framework
- Different paths available
- Example: fast or slow rollout



Condition 3: Timing

Phased investment

- Decisions to be made in future stages

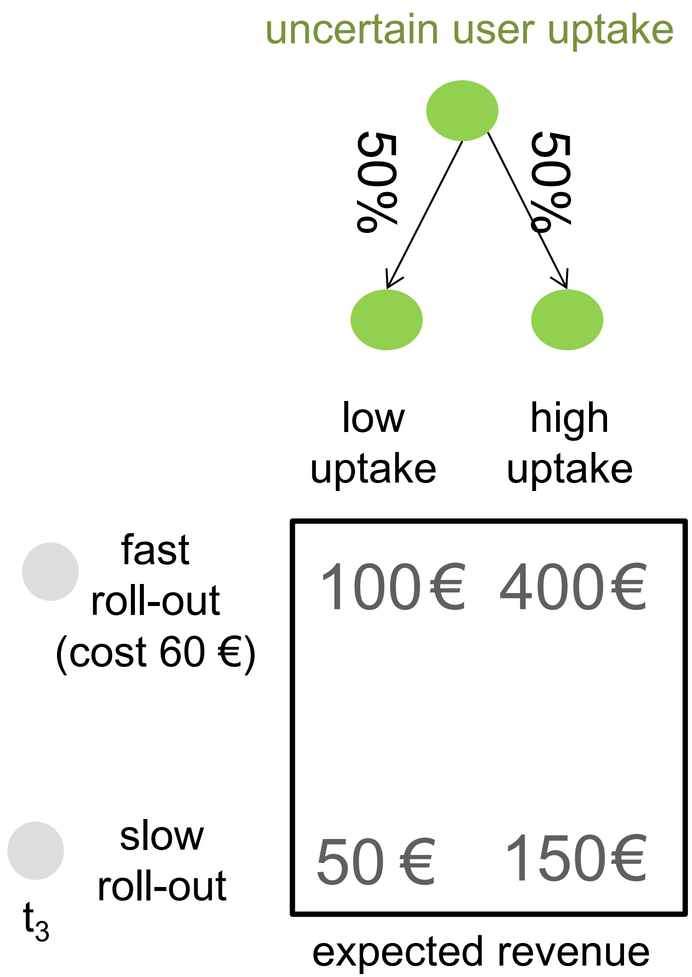


Methodology for calculating option value

is starting from traditional static analysis

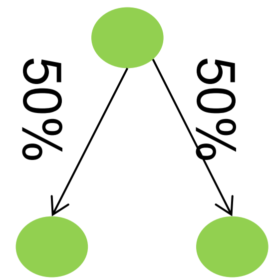
1. - Execute a standard NPV analysis
2. - Identify the uncertainties
3. - Identify the flexibility
4. - Calculate the option value

1. Execute standard NPV analysis



1. Execute standard NPV analysis

uncertain user uptake

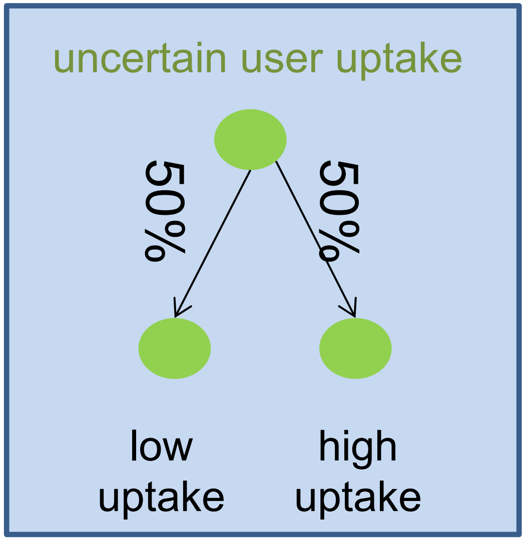


	low uptake	high uptake	NPV
fast roll-out	40 €	340€	190 €
slow roll-out	50 €	150€	100 €

t_3

NPV per scenario

2. Identify the uncertainties



NPV

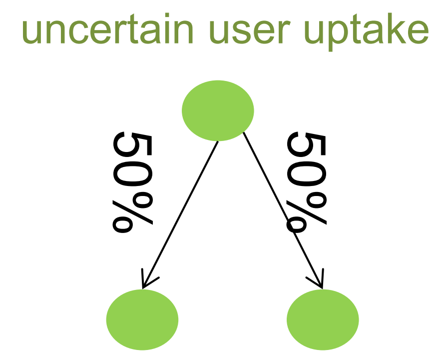
	low uptake	high uptake	NPV
fast roll-out	40 €	340€	190 €
slow roll-out	50 €	150€	100 €

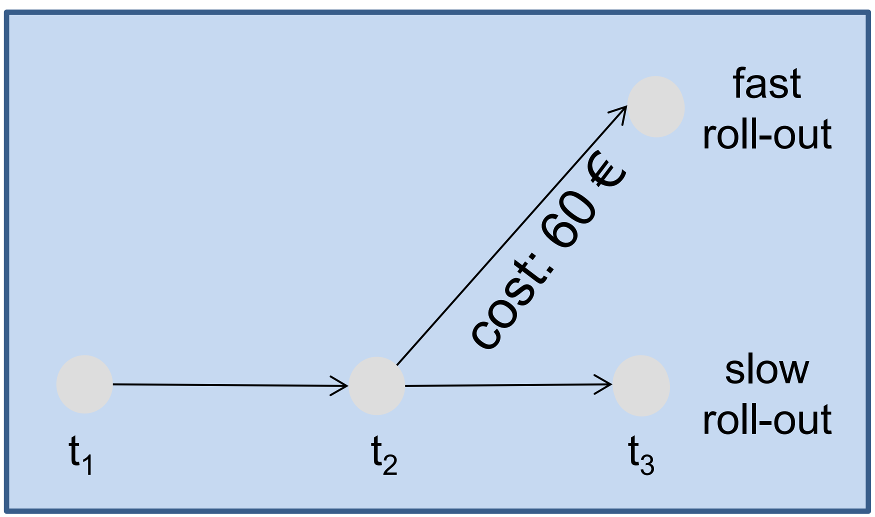
t_3

NPV per scenario

ibbt connect.innovate.create
UNIVERSITEIT GENT

3. Identify the flexibility





low uptake	high uptake
40 €	340€
50 €	150€

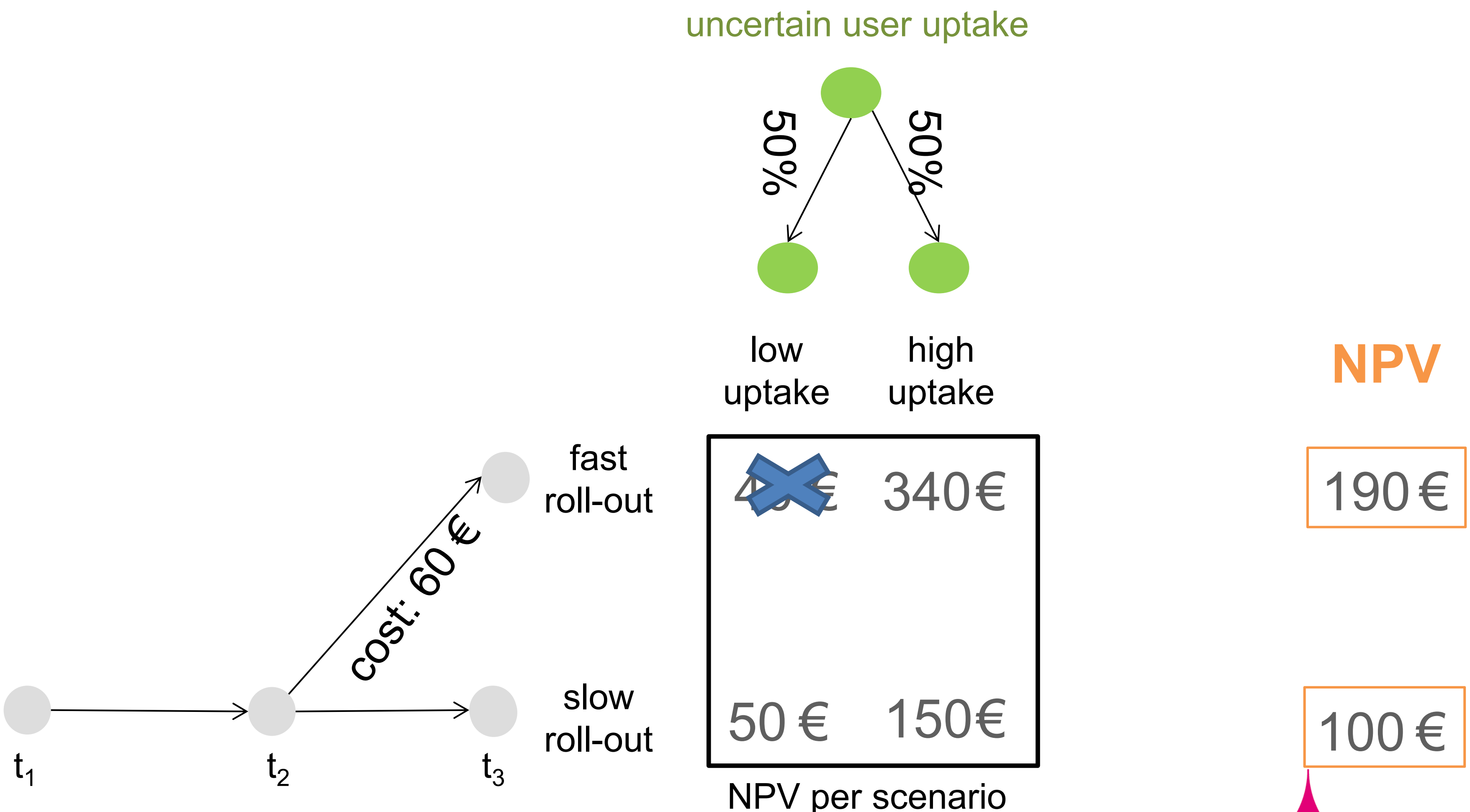
NPV per scenario

NPV

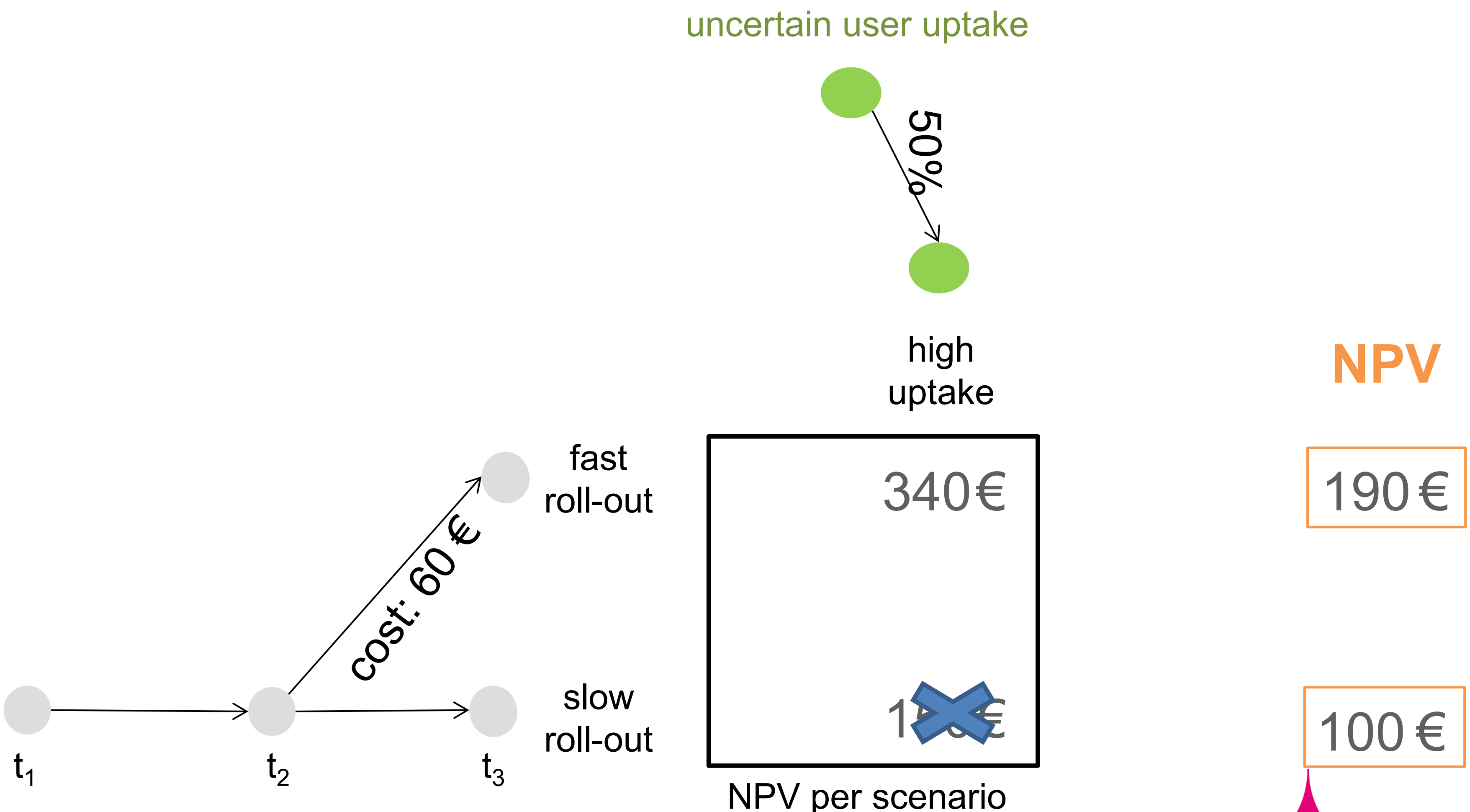
190 €

100 €

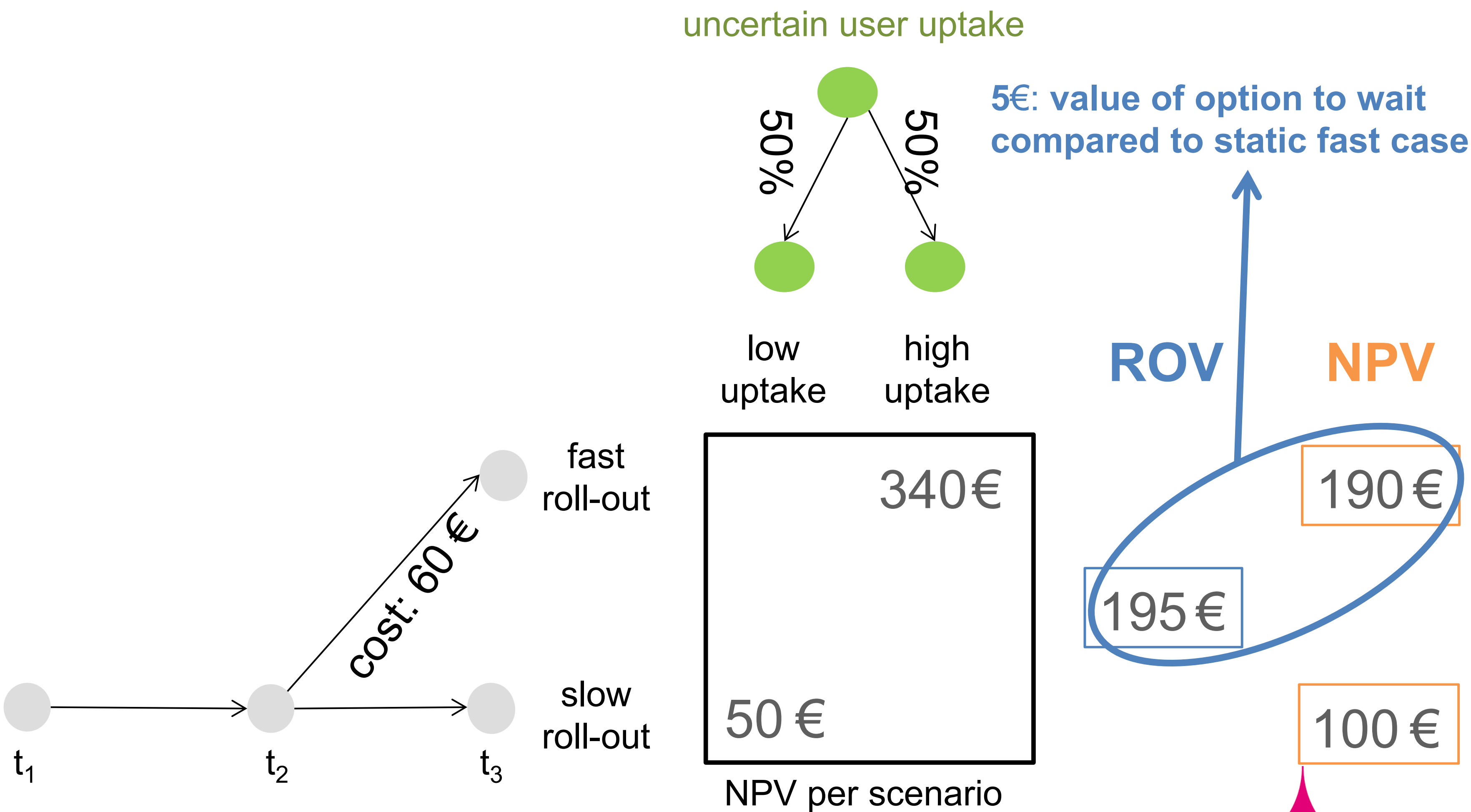
4. Calculate the option value



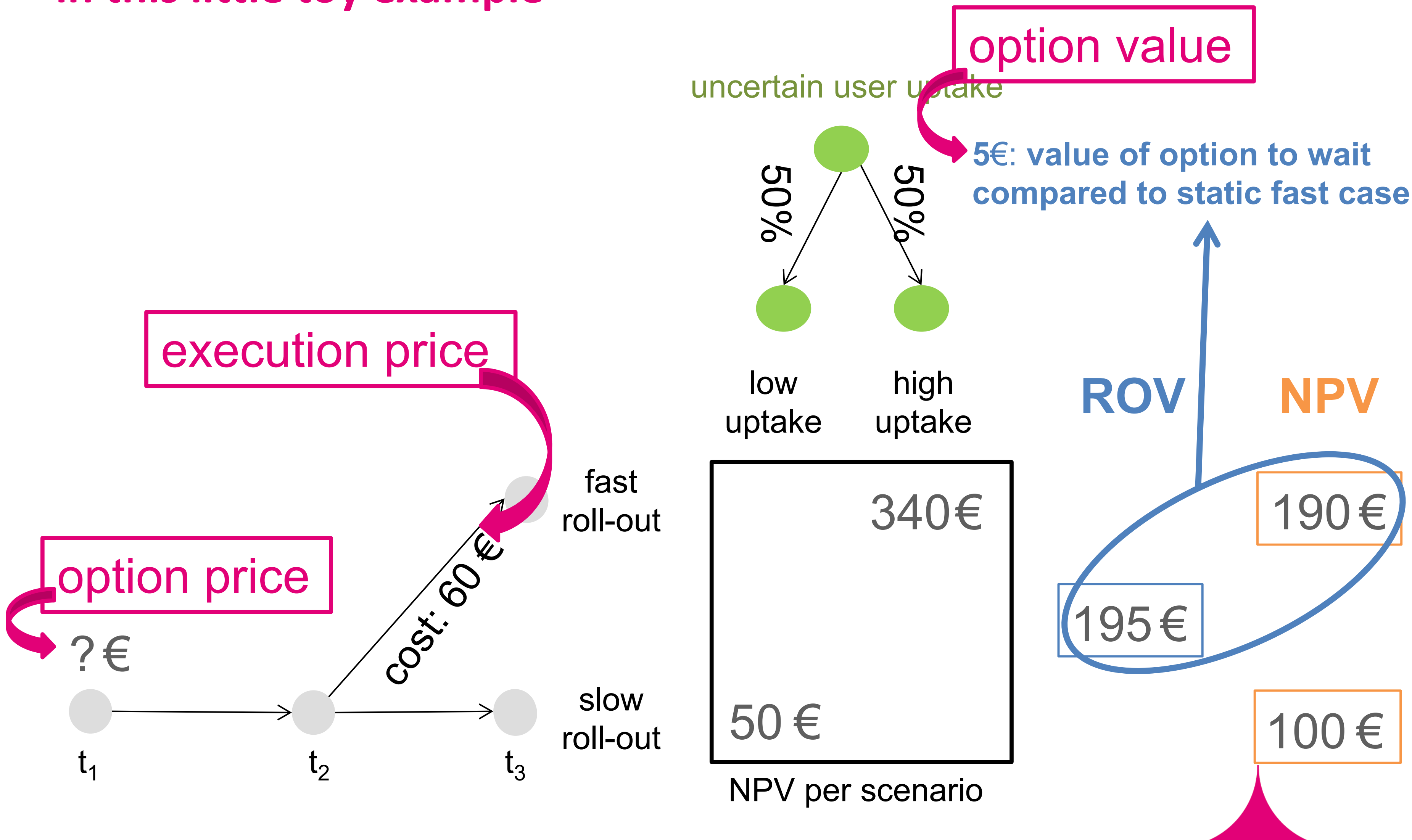
4. Calculate the option value



4. Calculate the option value



Some options terminology
in this little toy example



Some options terminology

applied to the use case of LTE in Gent

option value

= what do you get by executing the option?

e.g. revenues for Antwerp

execution price

= what does it cost to execute the option once you have it?

e.g. deployment cost for Antwerp

option price

= what does it cost to obtain the option?

e.g. bigger license for Antwerp

Evaluation a project with flexibility boils down to comparing option value to option price

option value

= what do you get by executing the option?

e.g. revenues for Antwerp

option price

= what does it cost to obtain the option?

e.g. bigger license for Antwerp

Determining the value of an option

by comparing execution price with real project value

Max(0, Project value - execution price)

=

option value

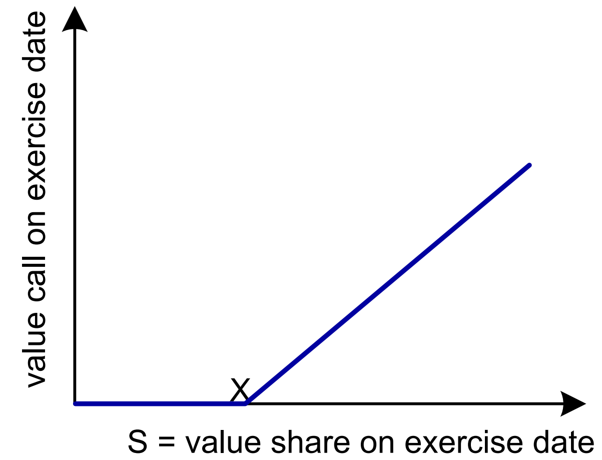
= what do you get by executing the option?

e.g. revenues for Antwerp

Determining the value of a call option

by comparing option price to stock value

- Call option = right to buy (a stock)
    - Predetermined exercise price: X
    - Market value of the stock on exercise date: S



- Value on exercise date
    - MAX (0,S-X)
    - always positive value
- Value of option = end value + time value
    - End value = value if today was exercise date
    - Time value
        - Grows with a growing time to maturity
        - Grows with volatility of share value
        - Small when difference between S and X is big

Some more terminology
originating from financial options

European option
can only be exercised on the exercise date

American option
can be exercised *till* the exercise data

Call option
option holder has right to *buy* the asset

Put option
option holder has right to *sell* the asset

Option price = option premium
Price to acquire the option, price to acquire to right

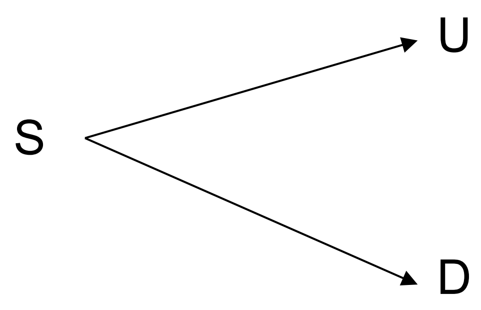
Exercise price = strike price
Price for which option holder can exercise the option (fixed)

Several calculation methods
for option values can be found in literature

- Binomial tree model
  - Only discrete values for input
  - See toy example before
- Black and Scholes model
  - From financial options
  - Mathematical model
- Monte Carlo Analysis
  - Simulation based method
  - Spreadsheet approach
  - See demo in a minute

Binomial tree option valuation
is the most intuitive method

- For European call option
- Assumes 2 possible end values



- Can be expanded for more time periods
  - software needed

Black and Scholes option valuation

is not intuitive at all

Formula for European call option

$$C = SN(d1) - Xe^{-rt}N(d2)$$

$$d1 = \frac{\ln(S/X) + rt + \sigma^2 t/2}{\sigma\sqrt{t}}$$

$$d2 = \frac{\ln(S/X) + rt - \sigma^2 t/2}{\sigma\sqrt{t}}$$

N(d) = cumulative normal distribution
X = exercise price of the option
S = current value of the share
σ^2 = variance of the return of the share per time period
r = risk free interest rate

Assumptions

- arbitrage-free pricing: financial transactions that make immediate profit without any risk do not exist (there is a general economic equilibrium)
- stock prices *S* follow Brownian motion (random walk) $dS = \mu S dt + \sigma S dw$

Parameters used in Black and Scholes formula

for financial versus real options

	Stock option	Real option
X	exercise price of the option	investments required to carry out the project
S	value of the underlying stock	NPV of the cash flows generated by the investment project
σ	volatility of the stock	risk grade of the project
r	the risk-free interest rate	risk-free interest rate
t	life time of the option	time period where company has the opportunity to invest in the project

Monte Carlo analysis for option valuation

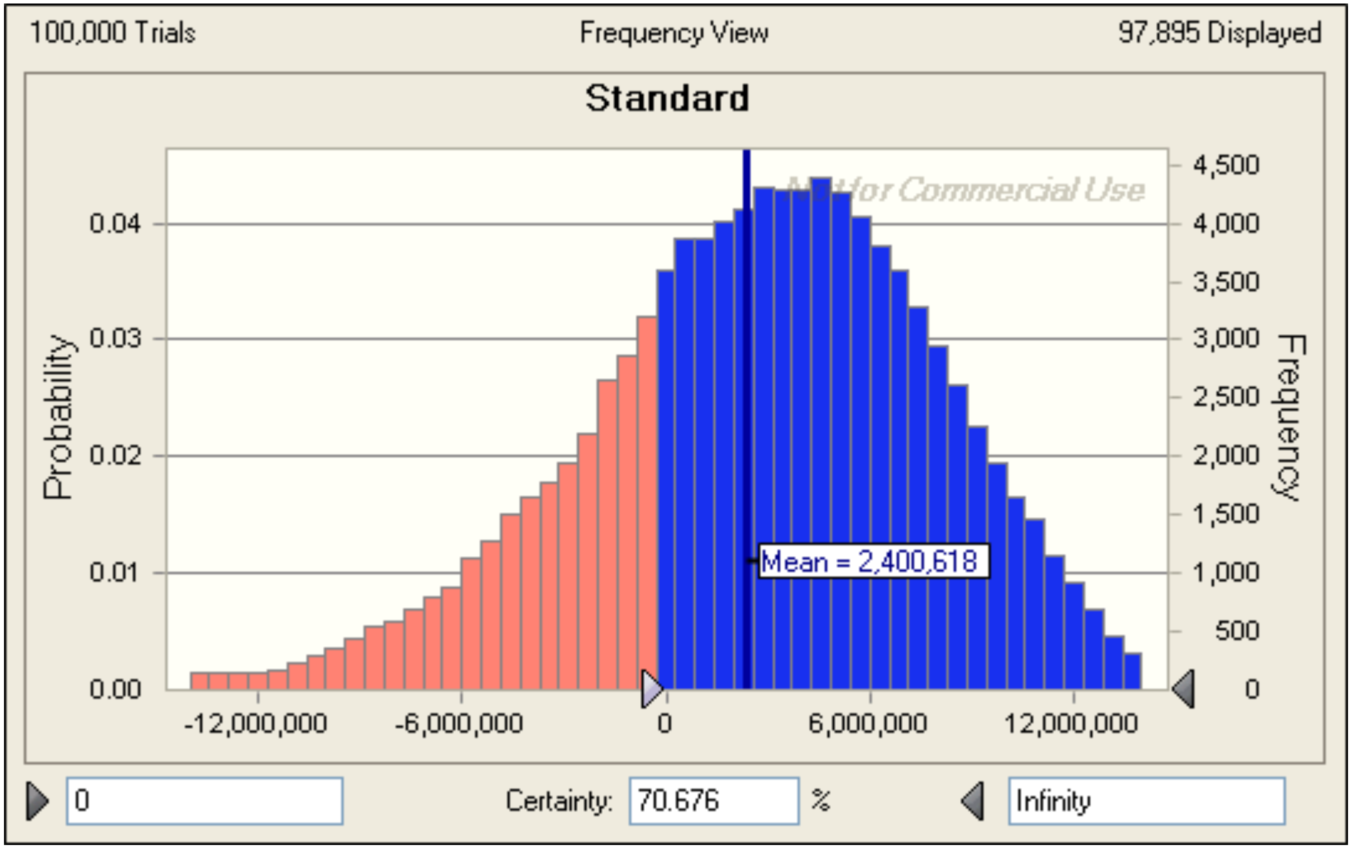
demonstrated in demo

Sensitivity and Uncertainty Analysis

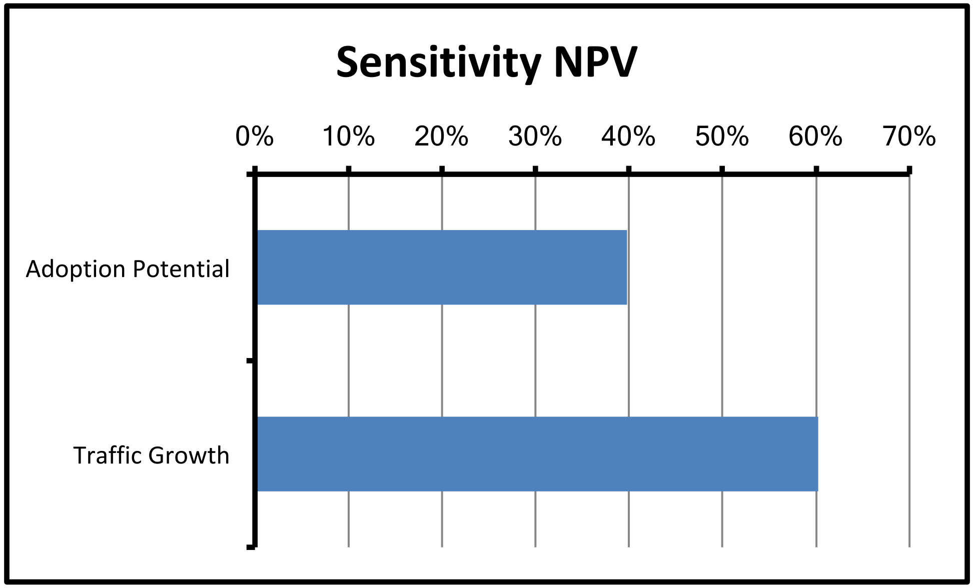
How do we measure the impact of uncertainty and flexibility?

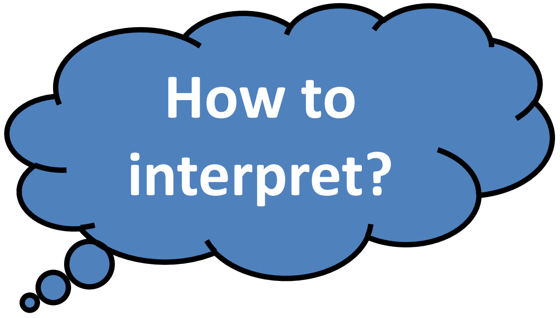
Histograms

How to interpret?



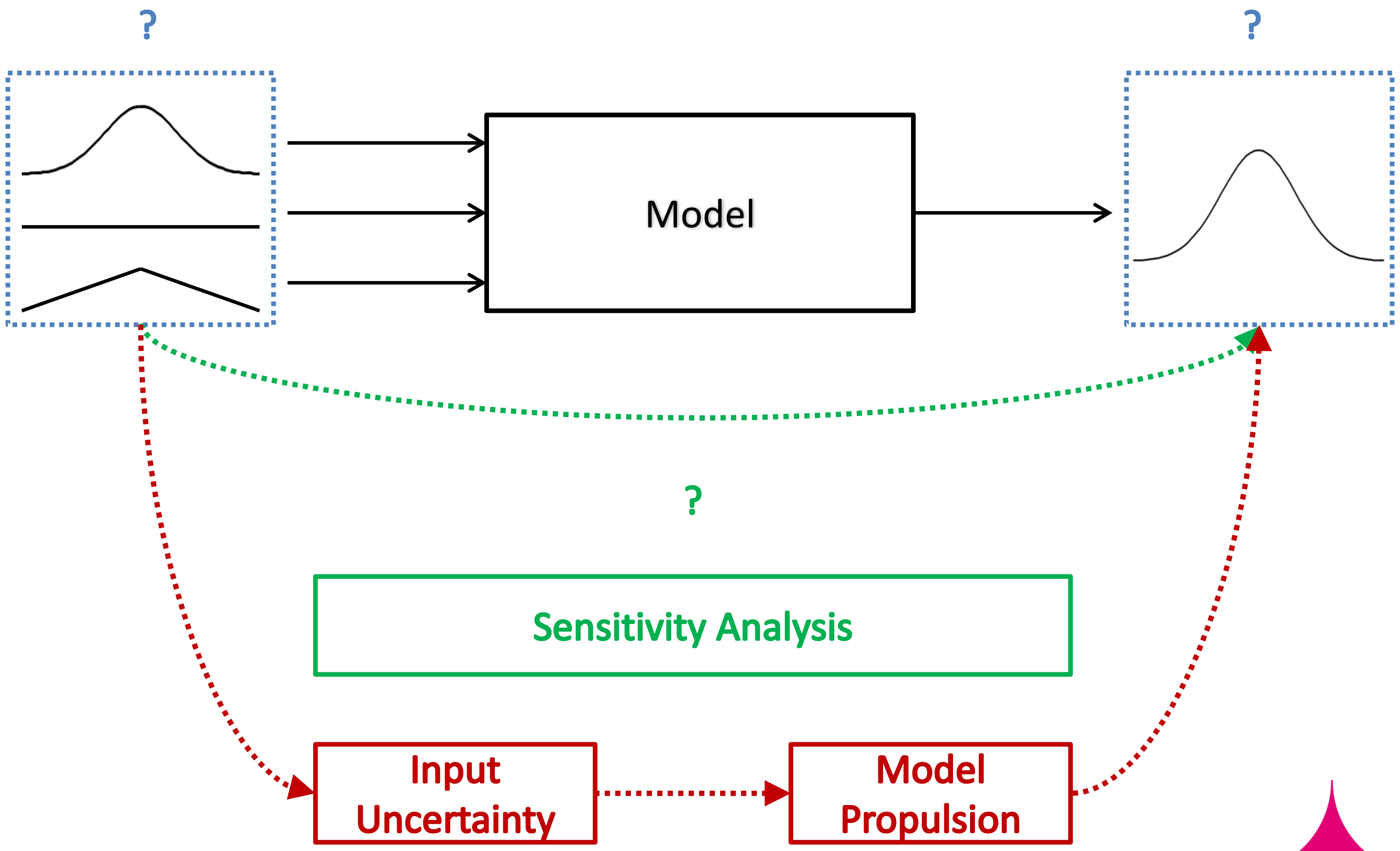
Tornado charts





Uncertainty analysis

and the meaning of sensitivity analysis in there



Comparison

UNCERTAINTY ANALYSIS	SENSITIVITY ANALYSIS
• OBJECTIVE: **Quantify** and describe uncertainty.	• OBJECTIVE: **Relate** input and output uncertainty • Research prioritization • Model simplification • Factor mapping
• USES: **Descriptive Statistics** from Monte Carlo analyses • Expected Value • Variance • Higher order moments • **→ Histograms**	• USES: **Sensitivity Indices** from Monte Carlo analyses • Based on Rank Cor. • Based on variance • Based on MC Filtering • Based on Lin.Regression • **→ Tornado charts**

Relevance to ROA? Measure flexibility impact

- Using: **Expected value of model’s output**
  - measures: **global profitability**
  - One would expect that adding ROA to the business model would increase the model’s expected NPV since it allows the manager to steer away from scenario’s depleting NPV
- Using: **Variance of model’s output**
  - measures: **global uncertainty**
  - We would expect that the total variance of the project would have dropped since the manager can steer away from extreme outcomes.

Relevance to ROA? Measure flexibility impact

- Using: **Conditional Variance and Mean Value**
  - measures: **Risk**
  - What is my expected loss in the worst case scenario?
  - What is the confidence interval around this estimate?

- Using: **First Order sensitivity Indices**
  - measures**: Relative importance inputs**
  - Rank correlation based (Crystal Ball)
  - We would expect that the relative importance of some uncertainty sources has switched. Against some you can react against others you can't.

Let’s return to our case: what did we expect?

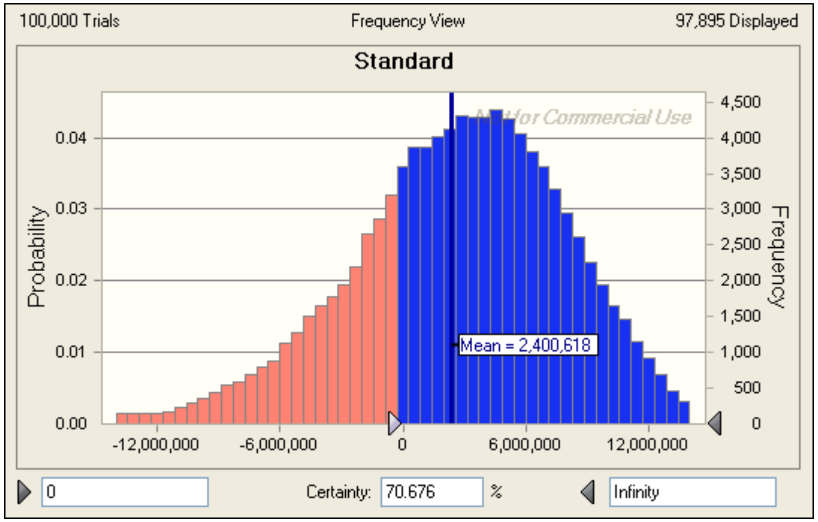
↓ Variance NPV
- Lower overall uncertainty

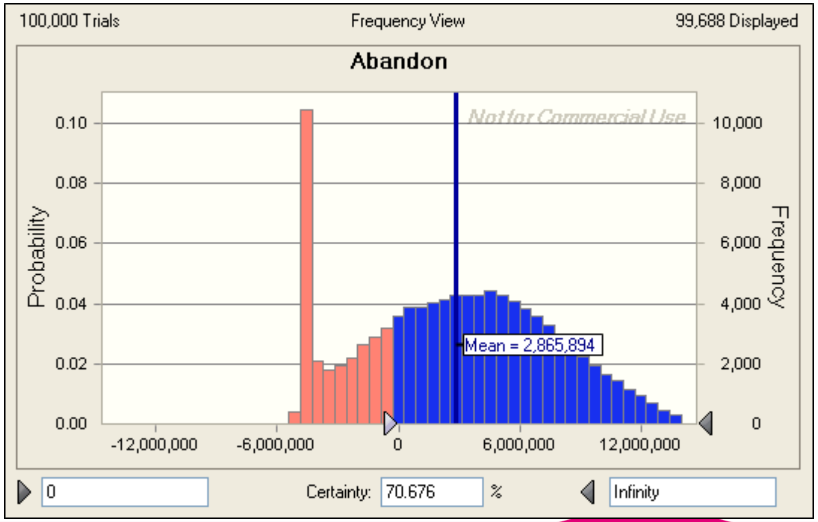
↑ Expected value NPV
- Global profitability increases
- Positive option value

↓ Conditional Var & EV in negative scenario
- Lower overall risk

→ Truncated distribution
- Exit option

Let’s return to our case: evaluation





No option:

- Expected NPV: 2.4m
- S.E. NPV: 5.8m

Abandon option:

- Expected NPV: 2.9m **(+19%)**
- S.E. NPV: 4.7m **(-19%)**
- Truncated distribution **(visual)**
- Expected negative NPV **(+20%)**

Let's return to our case: what did we expect?

🡻 Sensitivity Indexes

- Certain input uncertainty is made less important

➔ Switch in relative importance of uncertainty

- Flexibility has more effect on certain types of uncertainty

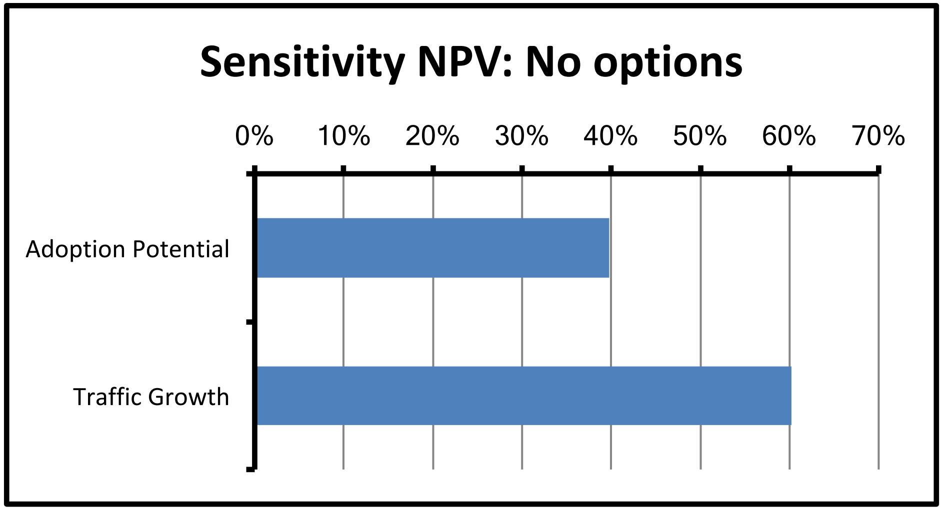
Let’s return to our case: evaluation

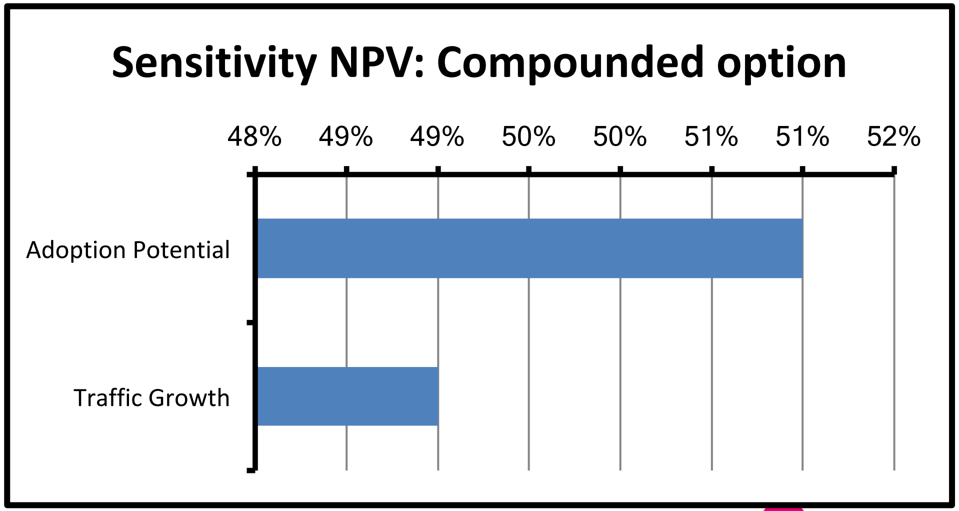
No option:

- Adoption potential: 39%
- Traffic Growth: 61%

Compounded option:

- Adoption potential: 51%
- Traffic Growth: 49%



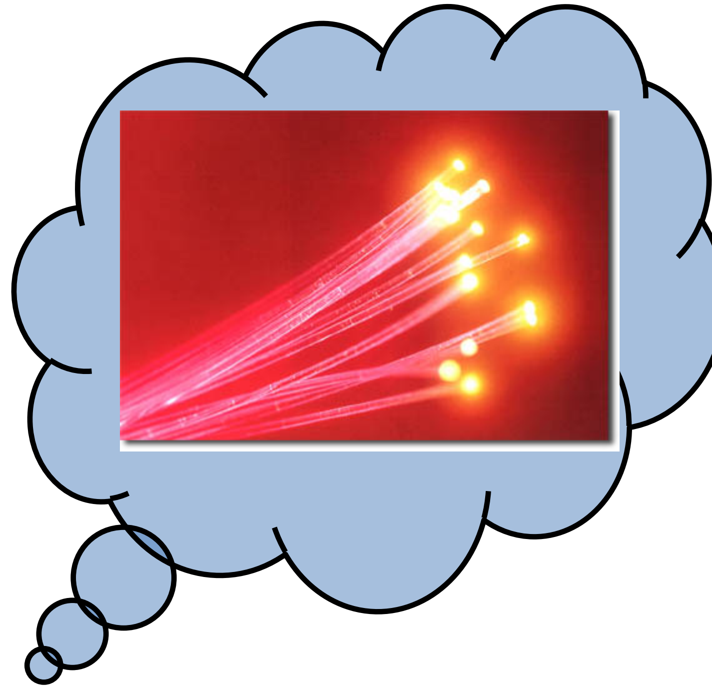


Different case studies

What cases can RO be applied to?

Case study overview
where we applied ROA before

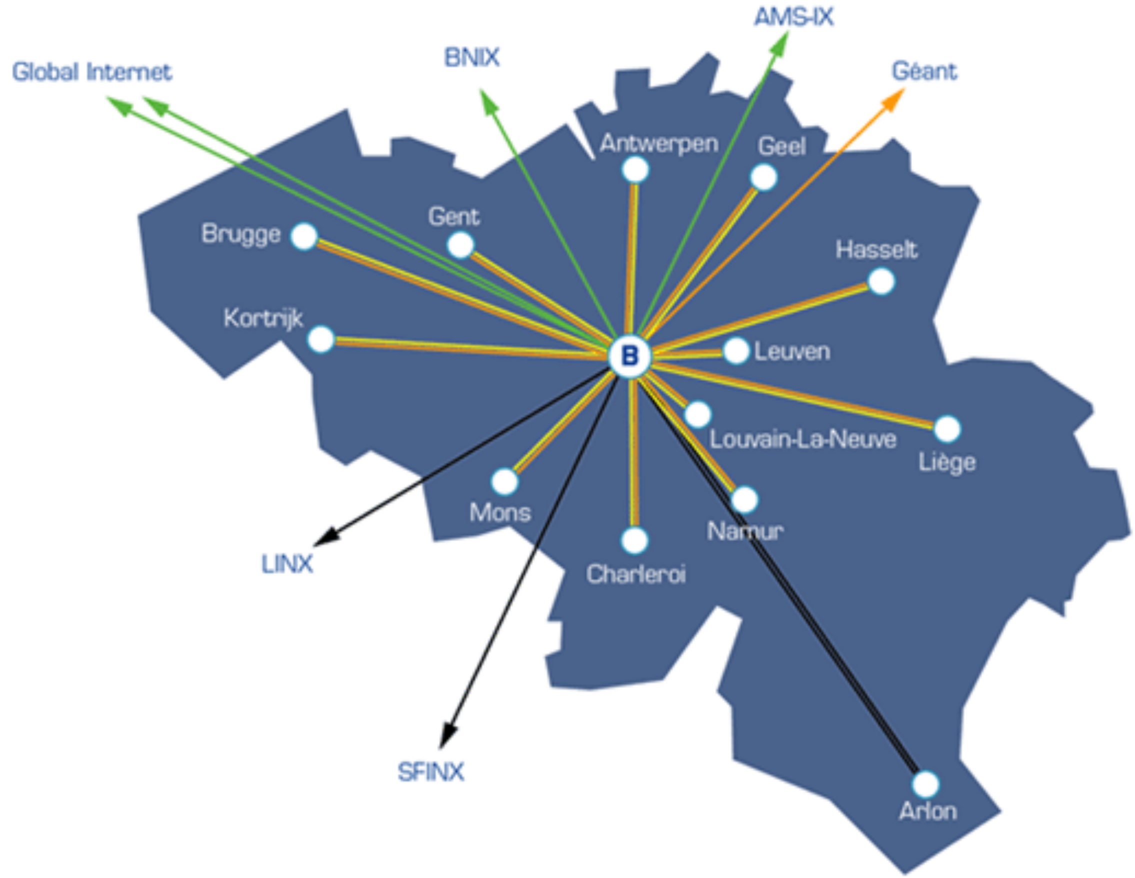
1. Make or lease fiber network?
2. Which areas to deploy wireless sensor network?
3. Optimal cabinet size for FTTcab roll-out?



Do I install my own backhaul or do I lease dark fiber?

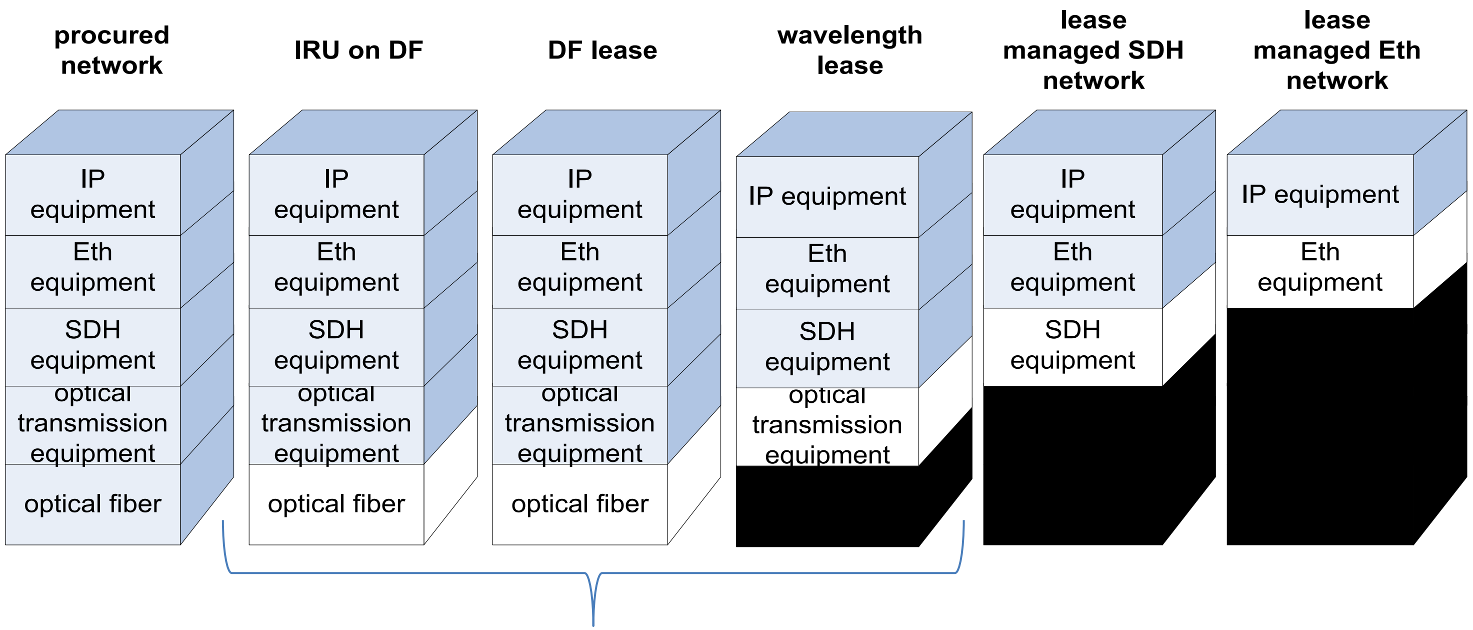
Belgian network

where a fiber topology is needed



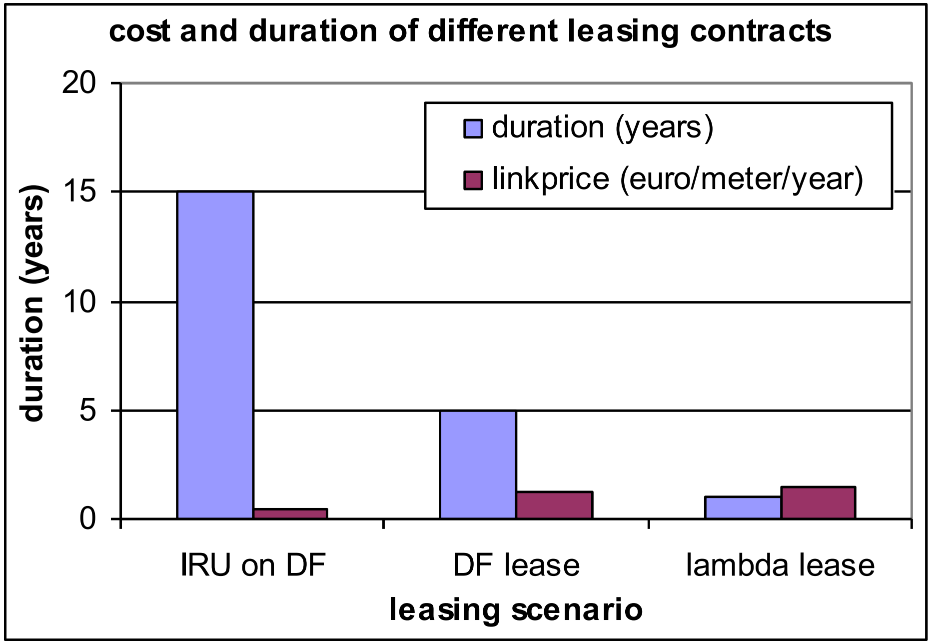
Several ownership models

for optical network deployment



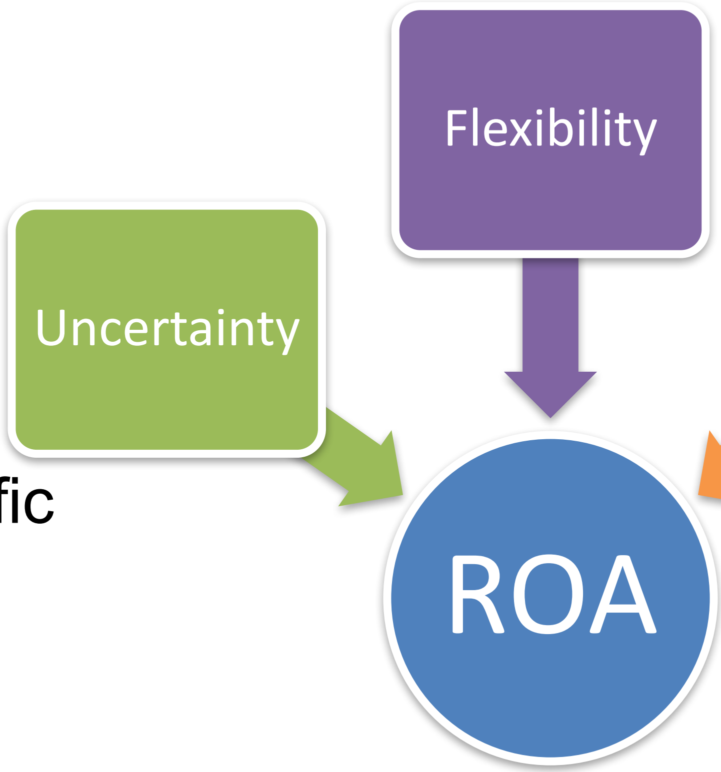
Different ownership models

have different input information on cost and duration



Three conditions for a ROA
for the case Make or lease dark fiber

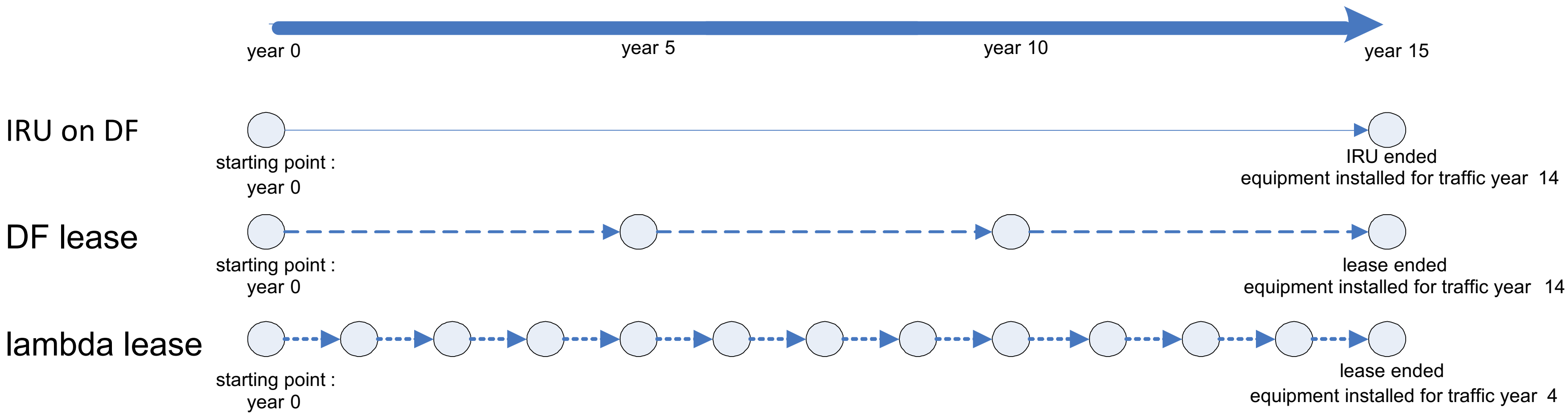
Flexibility within ownership model
Possibilities to change model at contract end



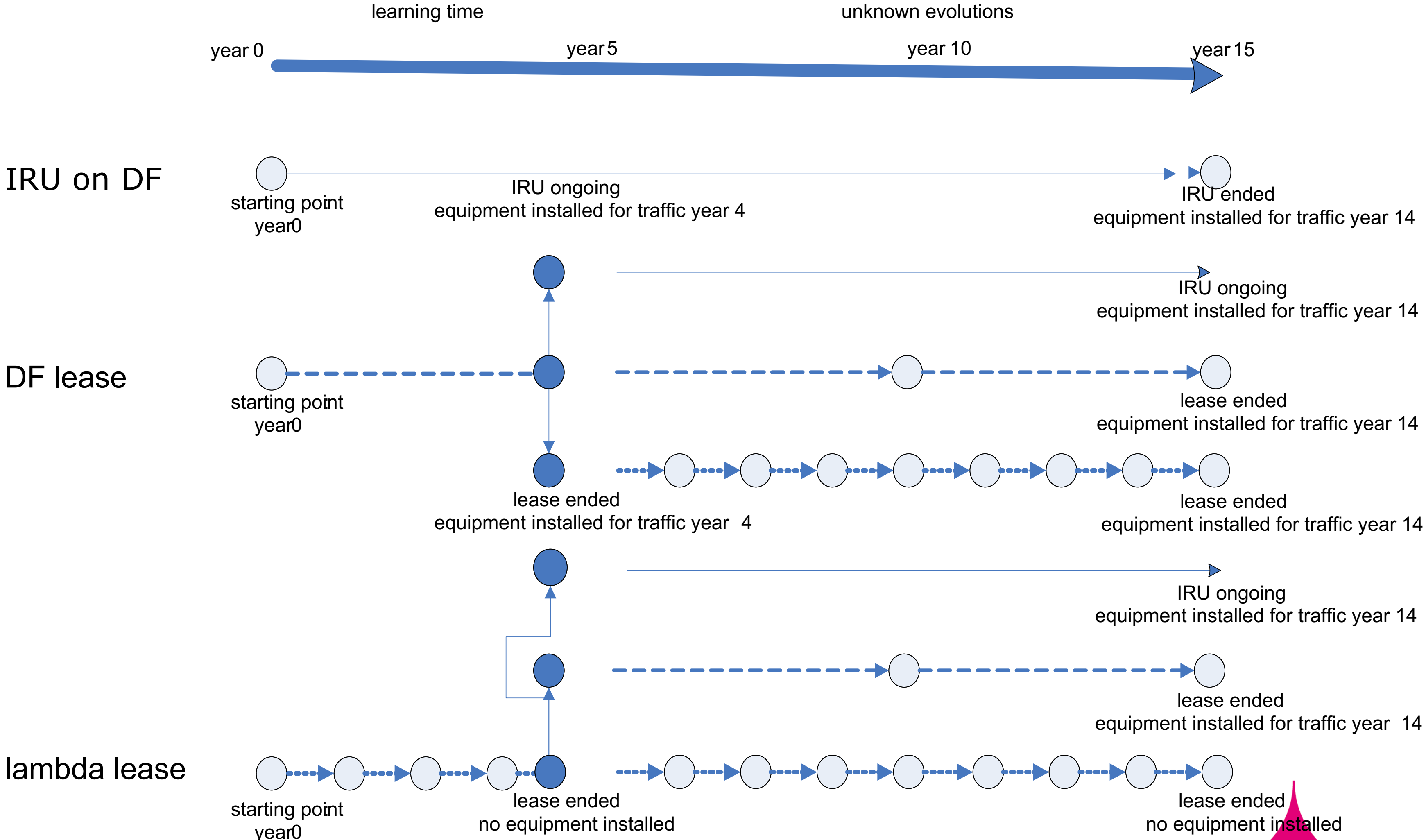
Abrupt traffic change

Initial choice for 5 years

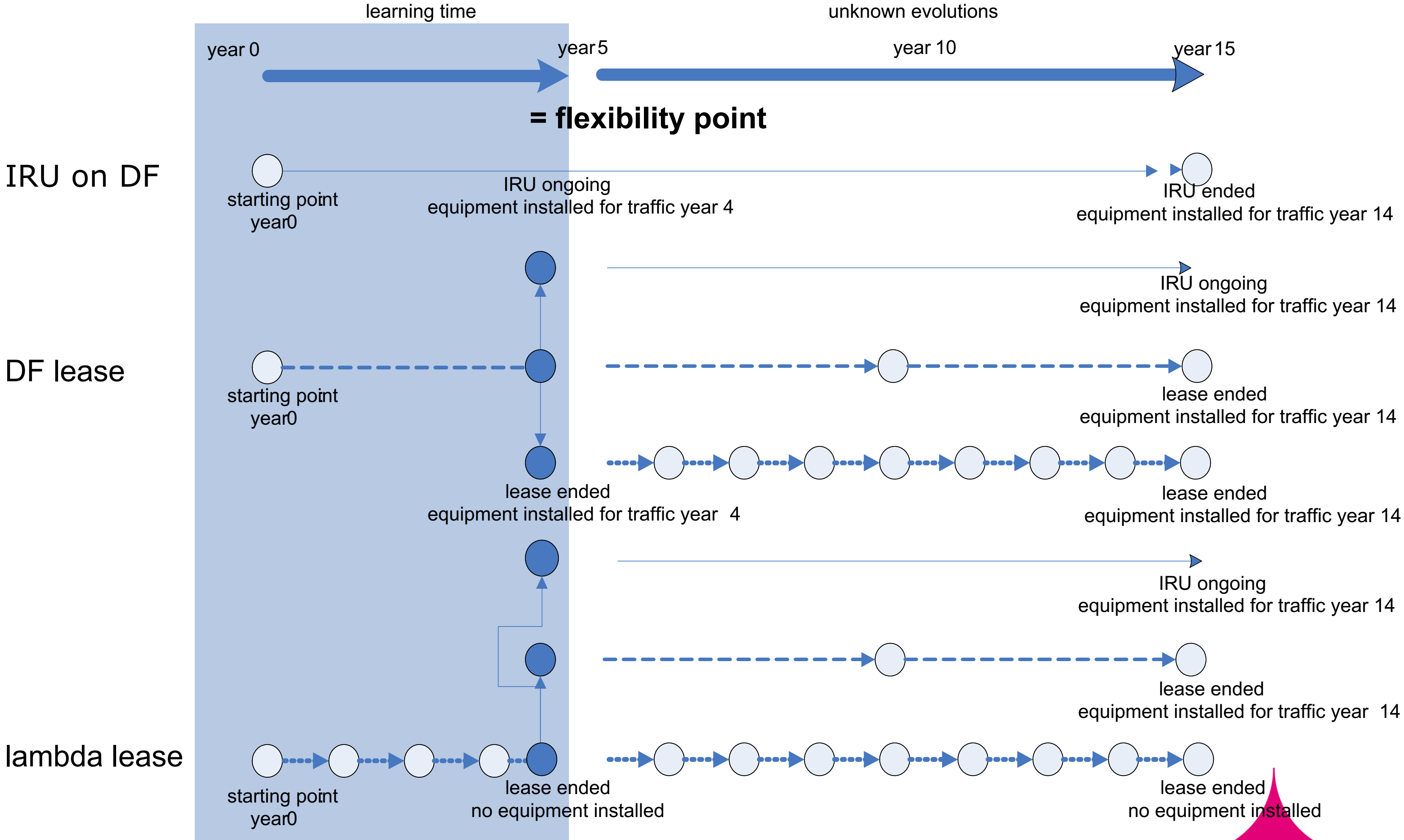
In-/decrease capacity within certain scenario
is a first form of flexibility



Switch between scenarios at contract end
is second form of flexibility



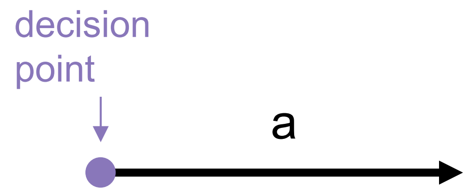
Phased decision
is included via flexible upfront decision

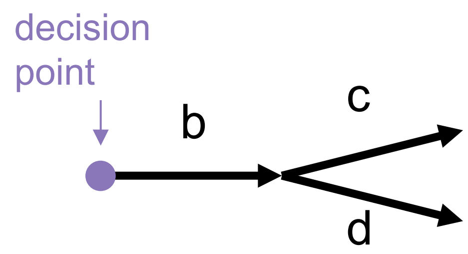


Methodology for calculation option value
based on binominal tree for this case

1. Execute a standard NPV analysis
2. Identify the uncertainties
3. Identify the flexibility
4. Calculate the option value

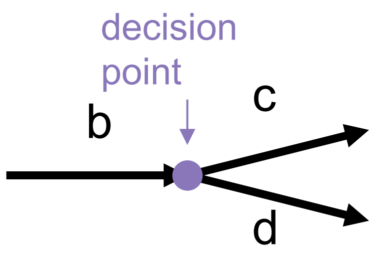
Formulae behind the evaluation
show the difference with and without option





NO REAL OPTION Plan which is cheapest on average over all scenarios

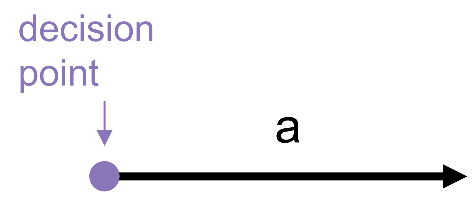
WITH REAL OPTION Plan which is cheapest on average taking into account flexibility during course of deployment



Formulae behind the evaluation

show the difference with and without option

- Single deployment path:
  no flexibility (average over all uncertain scenarios)

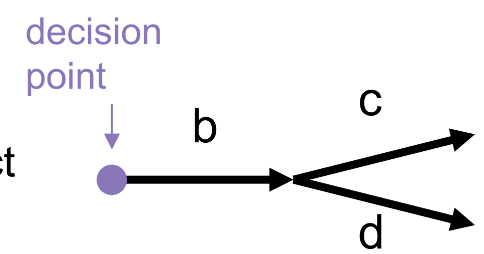


$$E_{uncertain\,traffic\,evolutions}\left[cost(a)\right]$$

- Path with the alternative subpaths

NO REAL OPTION

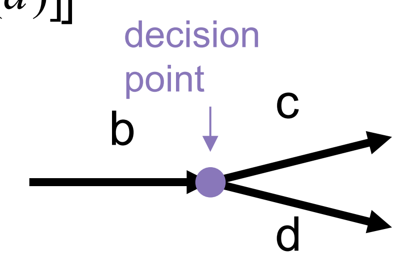
- Choice between alternatives is to be made at the beginning of the deployment path: no flexibility to react to changes happening during first subpath



$$E_{uncertaintrafficevolutions}\left[cost(b)\right]+\min\left[E_{uncertaintrafficevolutions}\left[cost(c),cost(d)\right]\right]$$

WITH REAL OPTION

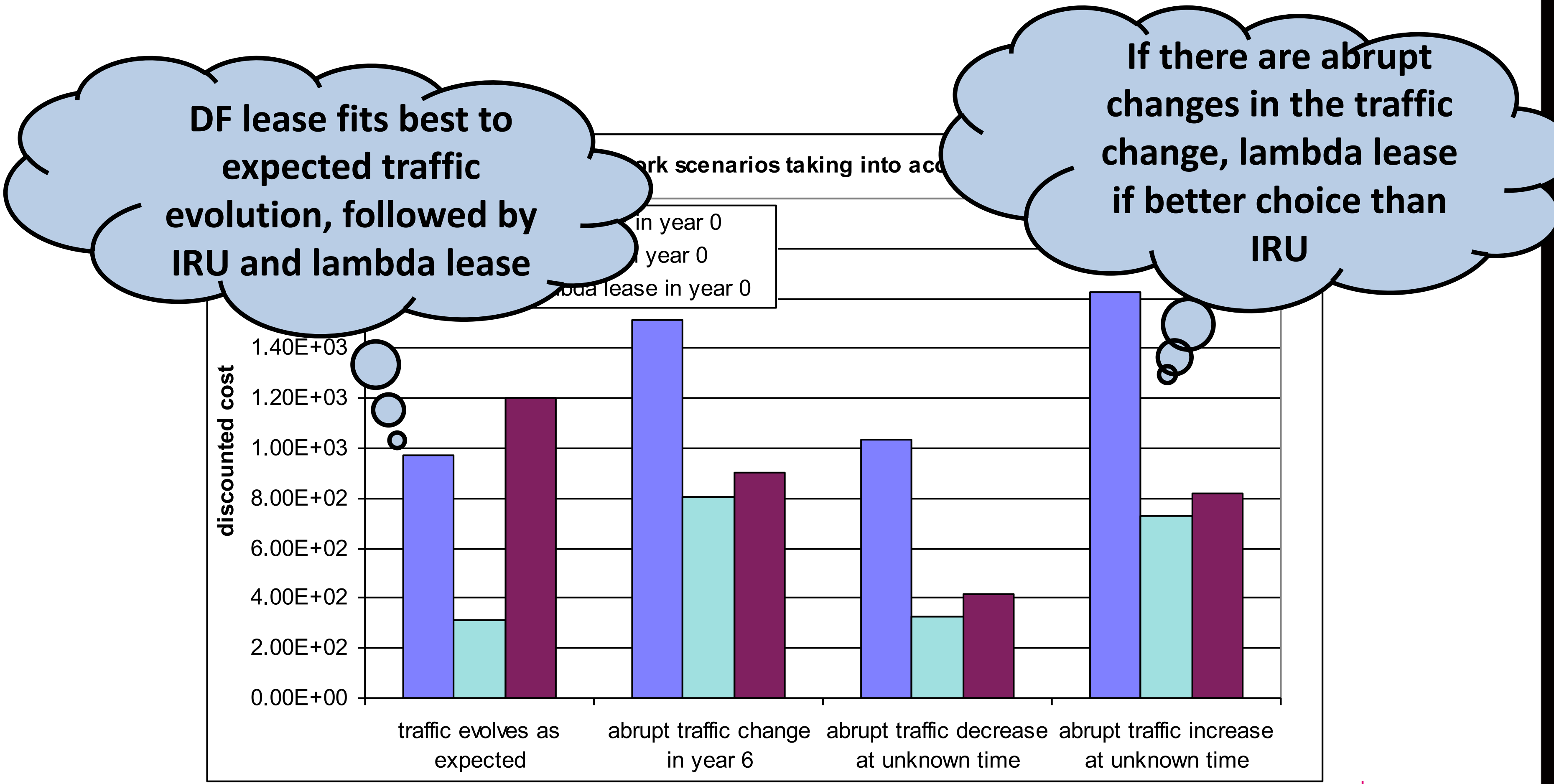
- Choice between alternatives is only made at the end of first subpath: true flexibility



$$E_{uncertaintrafficevolutions}\left[b+\min\left[cost(c),cost(d)\right]\right]$$

Impact of flexibility

shows that lambda lease adopts better to change than IRU



Case study summary

Make or lease fiber network?

- Type of uncertainty (4 types of threats)
  - Operational Threats: Traffic Intensity uncertainty
- Option type (7S)
  - Switch option
- Calculation method
  - Binomial tree
  - Monte Carlo simulation
- Case results
  - Dark fiber lease outperform IRU on case study
  - Situation gets worse in case of abrupt changes

Case study overview
where we applied ROA before

1. Make or lease fiber network?
2. Which areas to deploy wireless sensor network?
3. Optimal cabinet size for FTTcab roll-out?

Trial phase in a small area

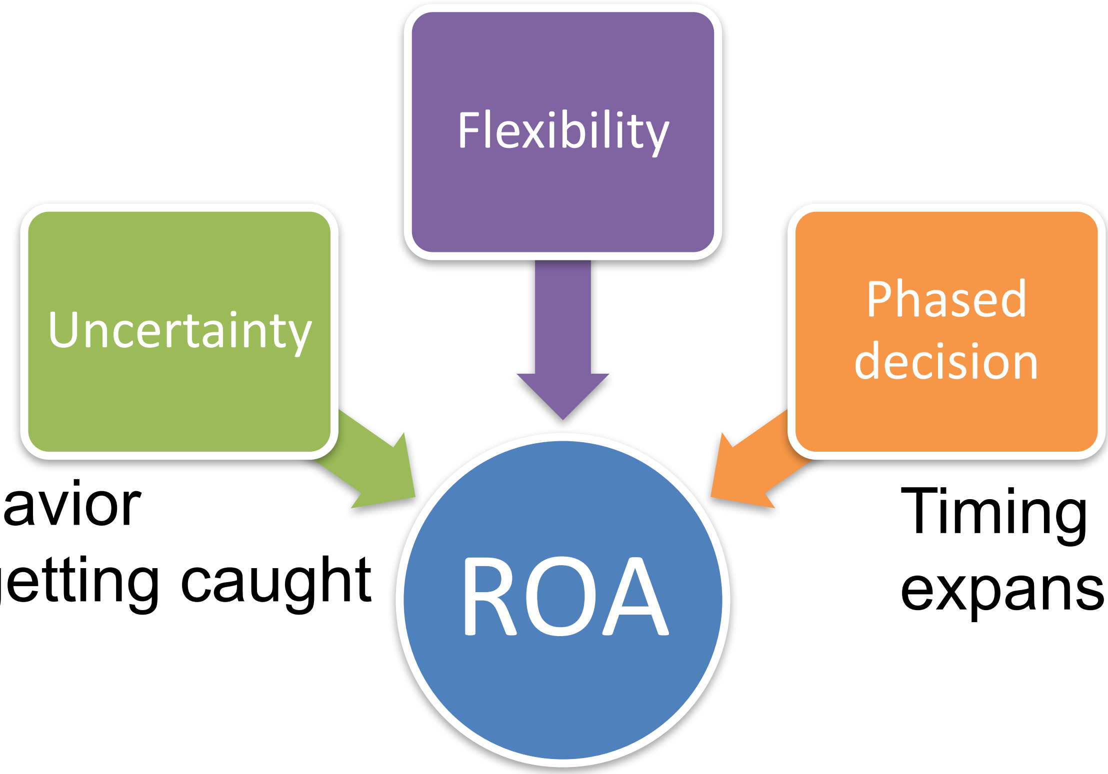
Do I install the sensors in the entire city?

What is the optimal area to deploy the network?

Three conditions for a ROA

for the case Which areas to deploy wireless sensor network

Area to deploy network in



Parking behavior
Chance of getting caught

Timing of area expansion

Uncertainty

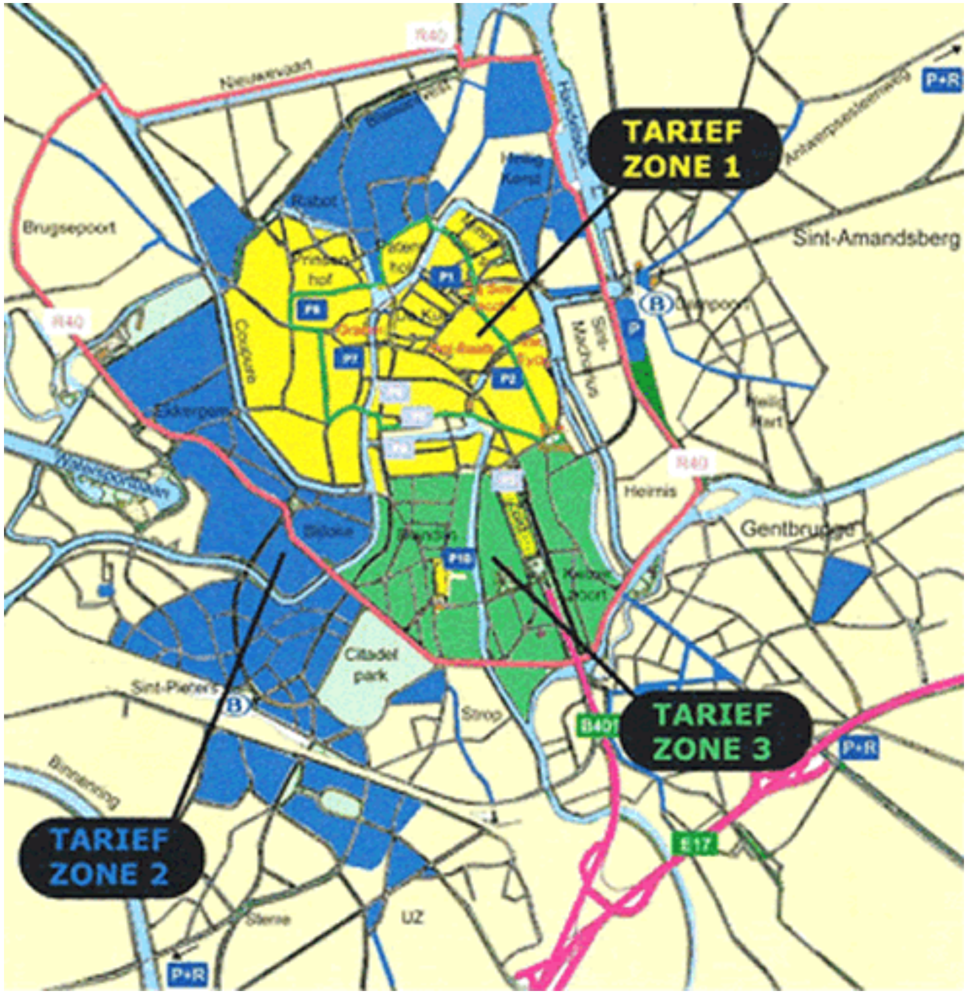
Both technical and behavioral uncertainties

Chance of getting fined

Sensor lifetime

Flexibility

Choose the zone to install the PSN in

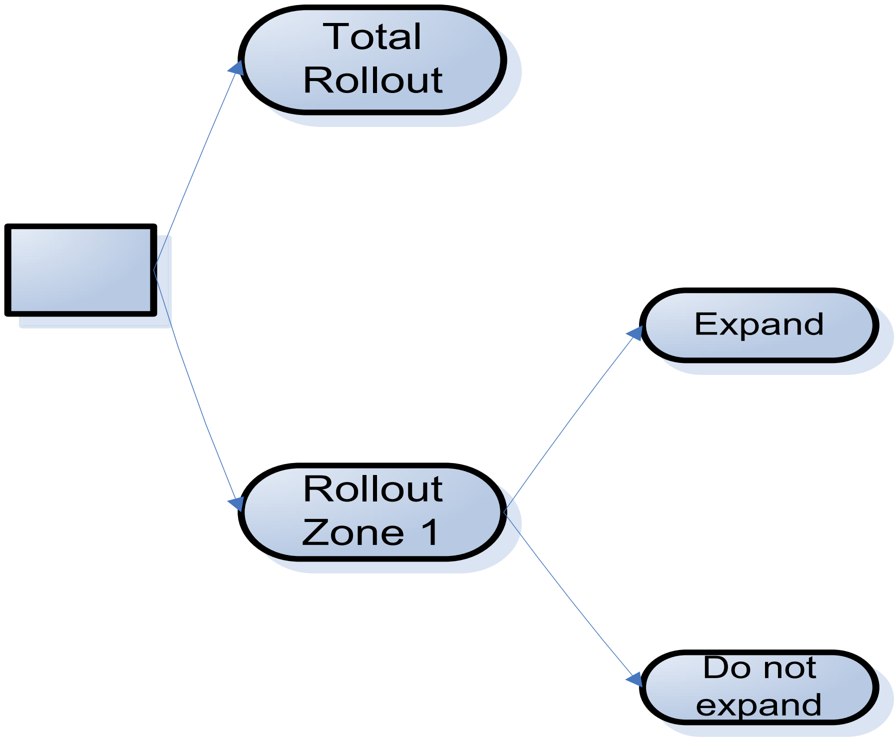


ibbt
connect.innovate.create

UNIVERSITEIT GENT

Timing

Start small, decide later to scale



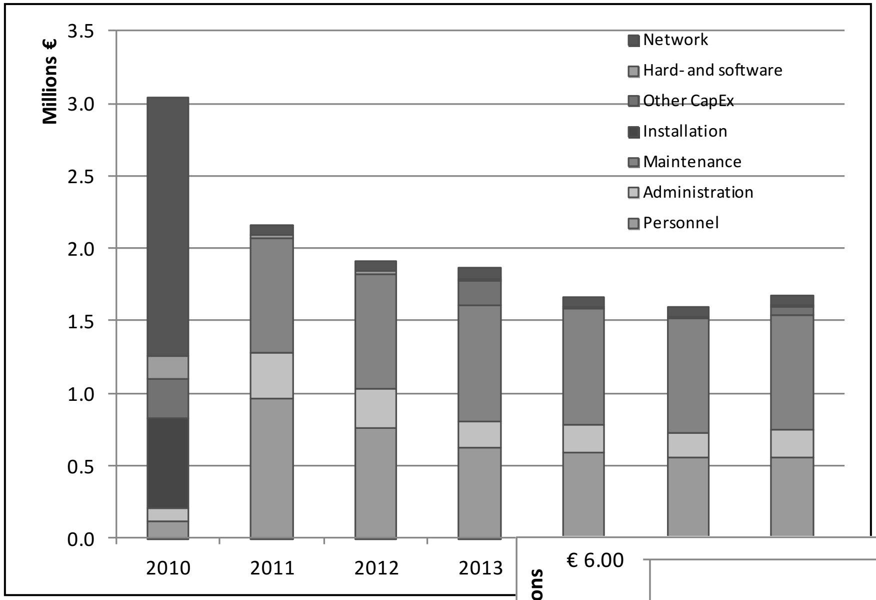
Methodology for calculation option value

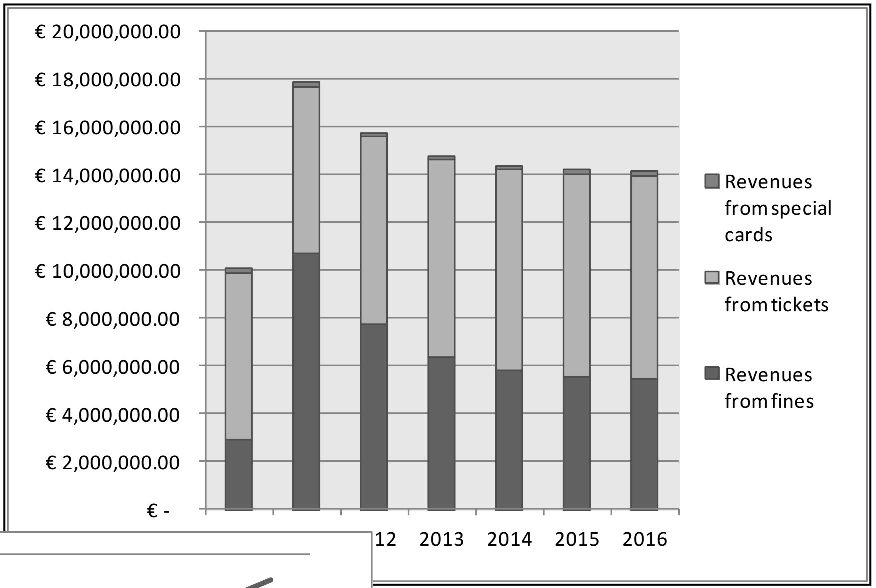
based on simulations for this case

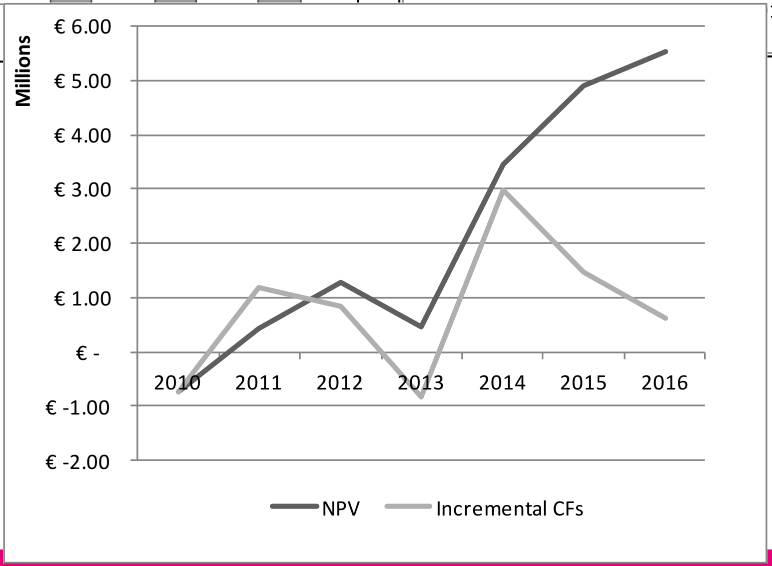
1. Execute a standard NPV analysis
2. Identify the uncertainties
3. Identify the flexibility
4. Calculate the option value

1. Execute a standard NPV analysis

Modeling costs and revenues

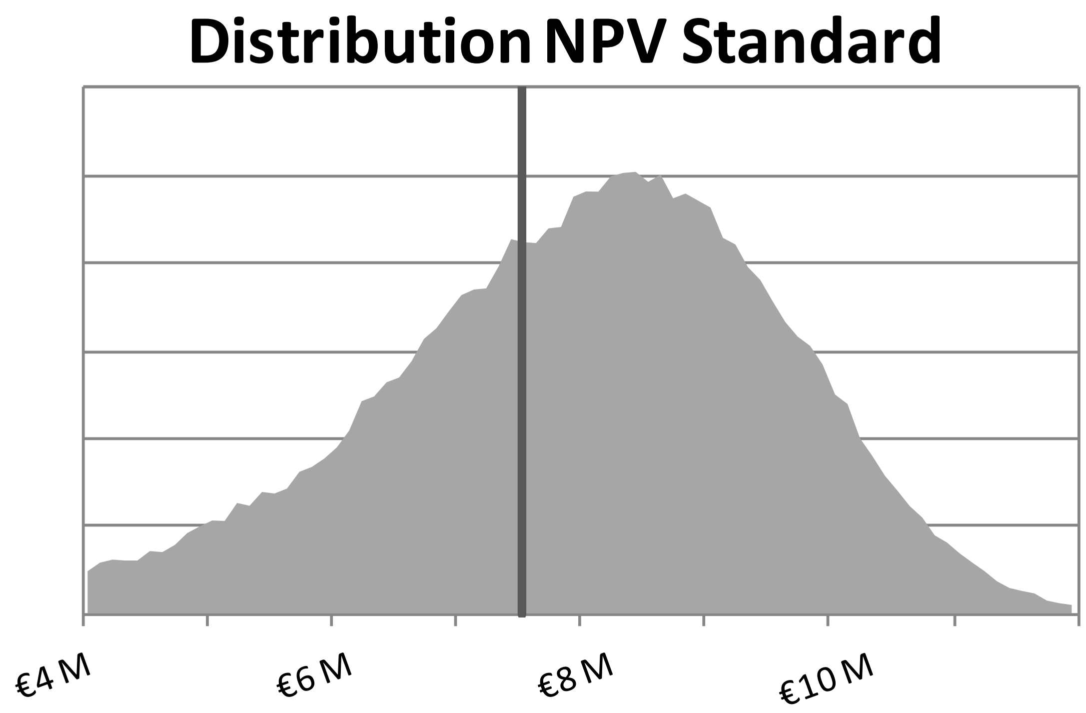






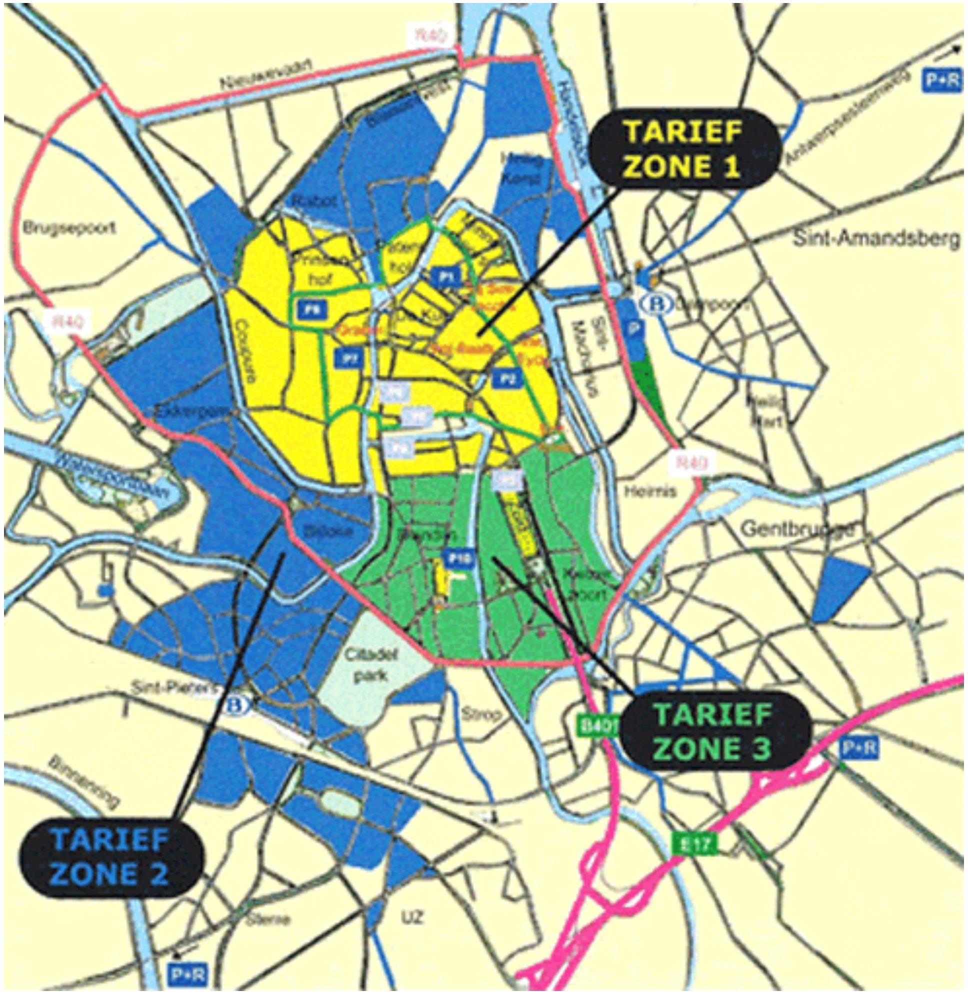
2. Identify the uncertainties

Input uncertainty impacts output



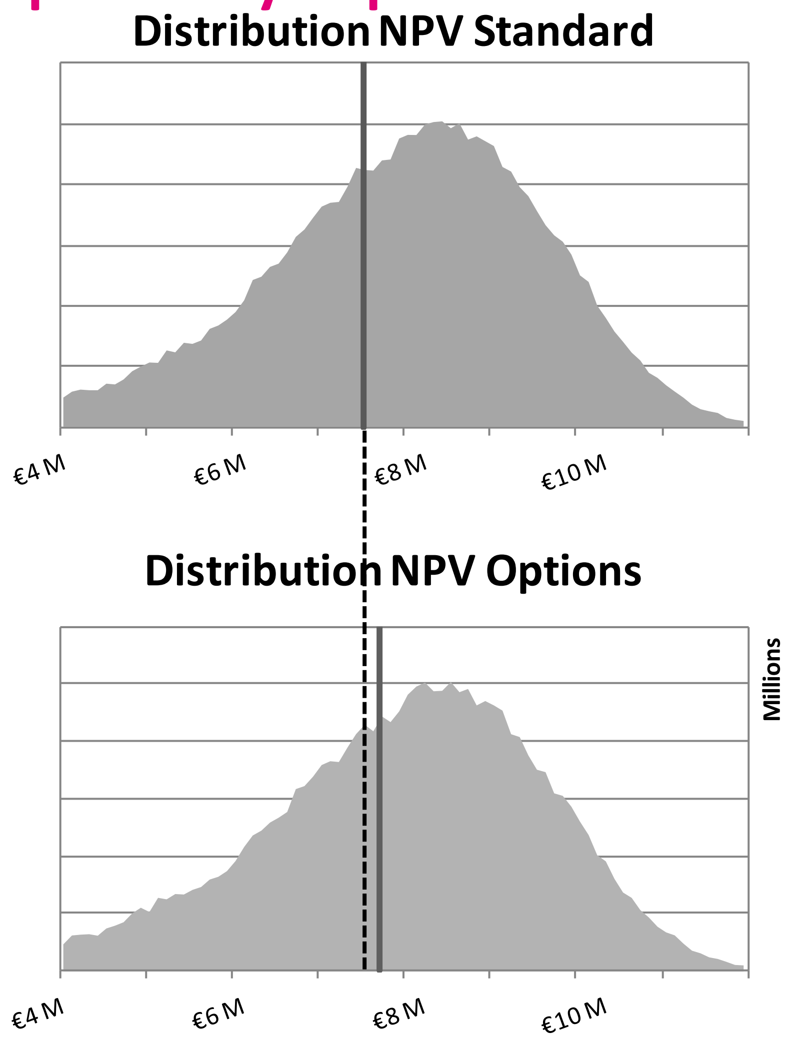
3. Identify the flexibility

Different areas with different characteristics



4. Calculate the option value

Option to expand positively impacts result



Case study summary

Which areas to deploy wireless sensor network?

- Type of uncertainty (4 types of threats)
  - Operational – sensor lifetime
  - Strategic – impact on consumer behavior
- Option type (7S)
  - Scale up
- Calculation method: Monte Carlo simulation
- Case results
  - Scale option positively impacts case result

Case study overview

where we applied ROA before

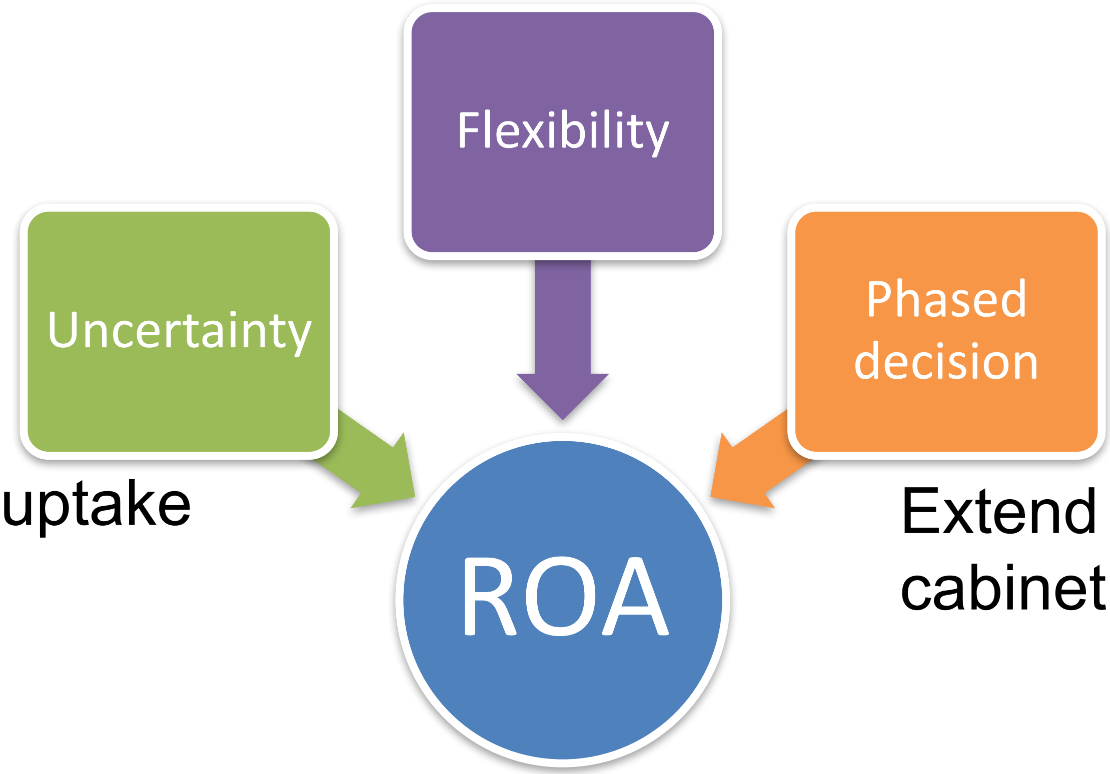
1. Make or lease fiber network?
2. Which areas to deploy wireless sensor network?
3. Optimal cabinet size for FTTcab roll-out?

What is the optimal capacity to install in an FTTC rollout?

Three conditions for a ROA

for the case Optimal cabinet size for FTTcab roll-out

Install large cabinet or small one with flexible extensions

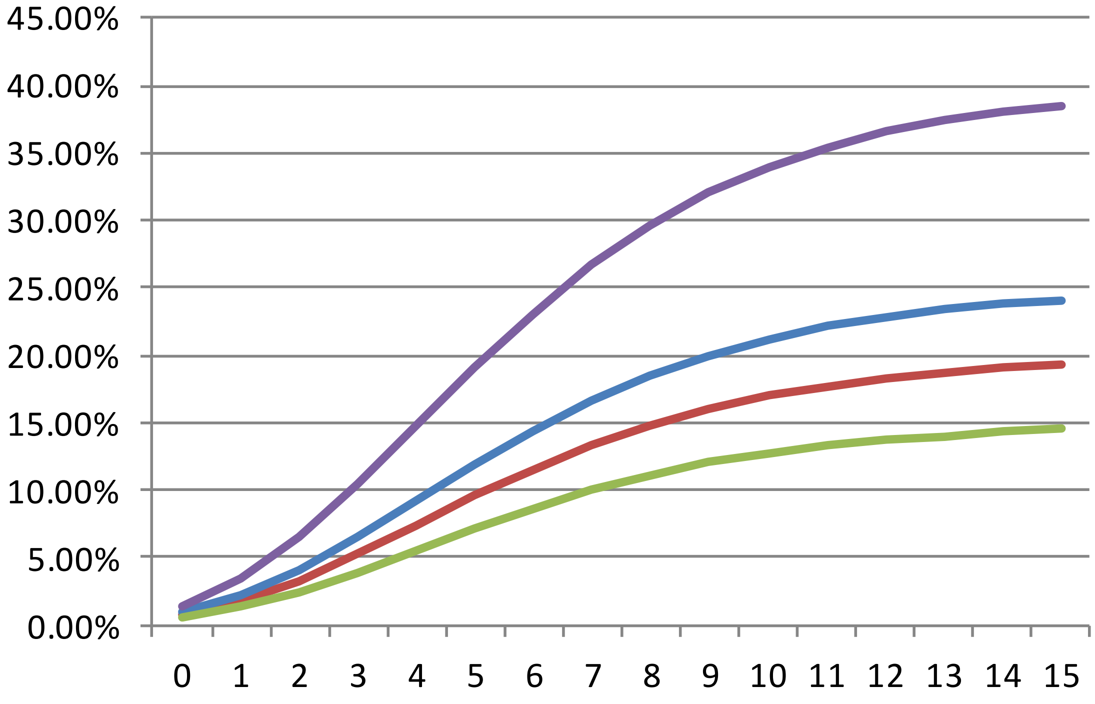


Customer uptake

Extend small cabinet later

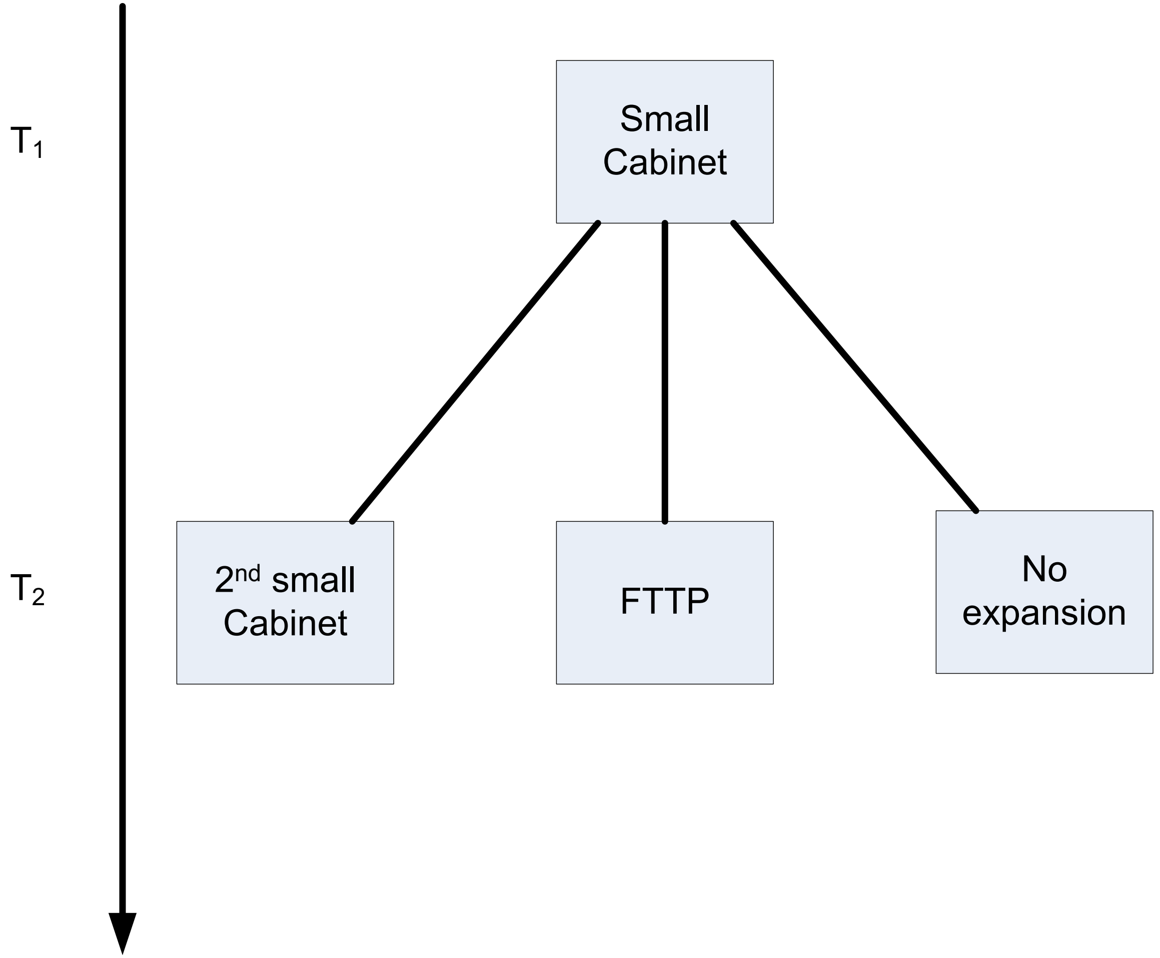
Uncertainty

What is the expected customer uptake?



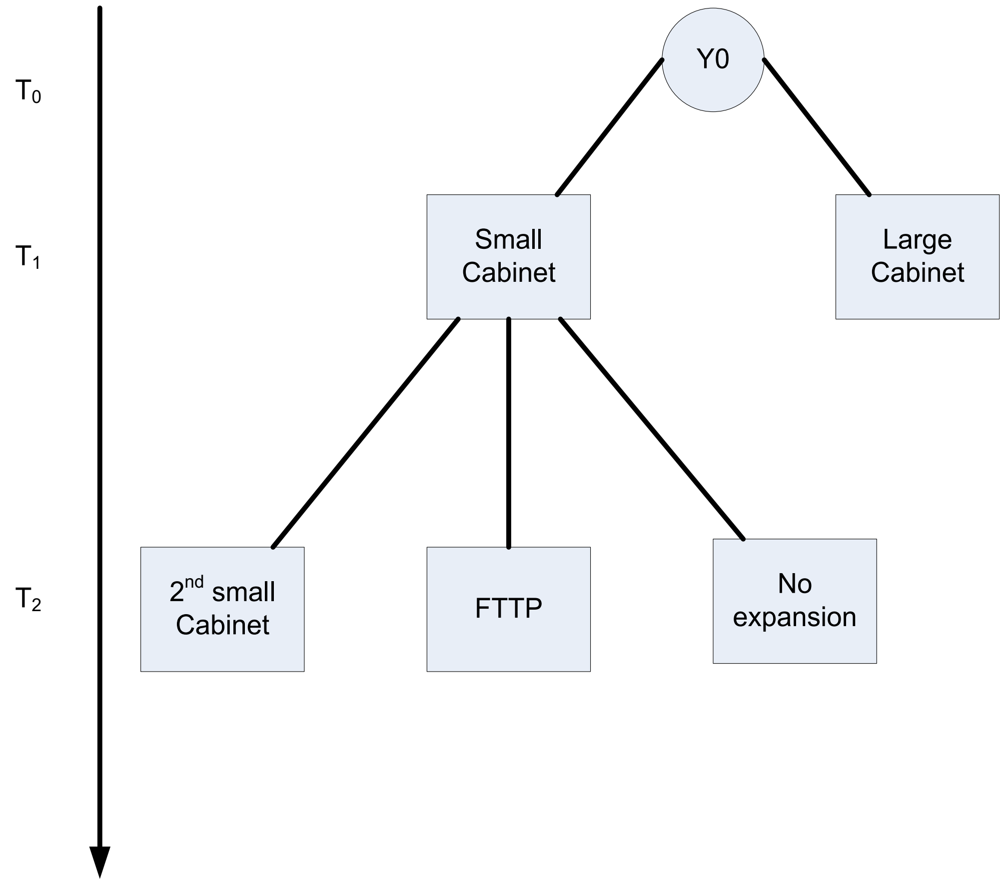
Flexibility

Different possible future migrations



Timing

The migration choice can be postponed



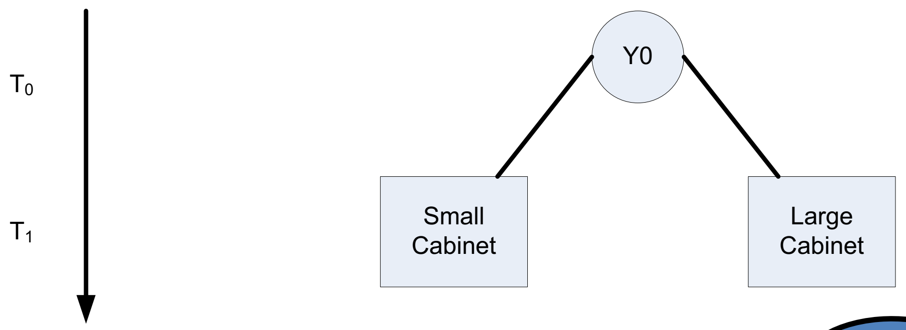
Methodology for calculation option value

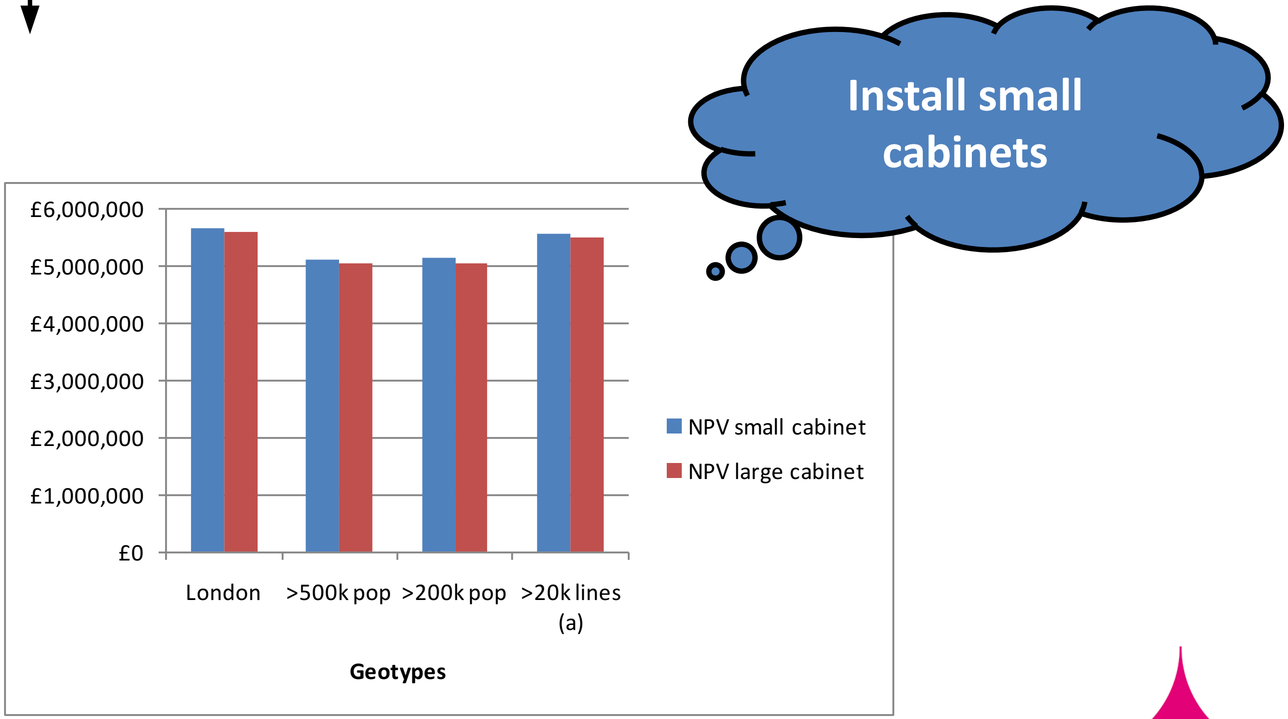
based on simulations for this case

1. Execute a standard NPV analysis
2. Identify the uncertainties
3. Identify the flexibility
4. Calculate the option value

1. Execute a standard NPV analysis

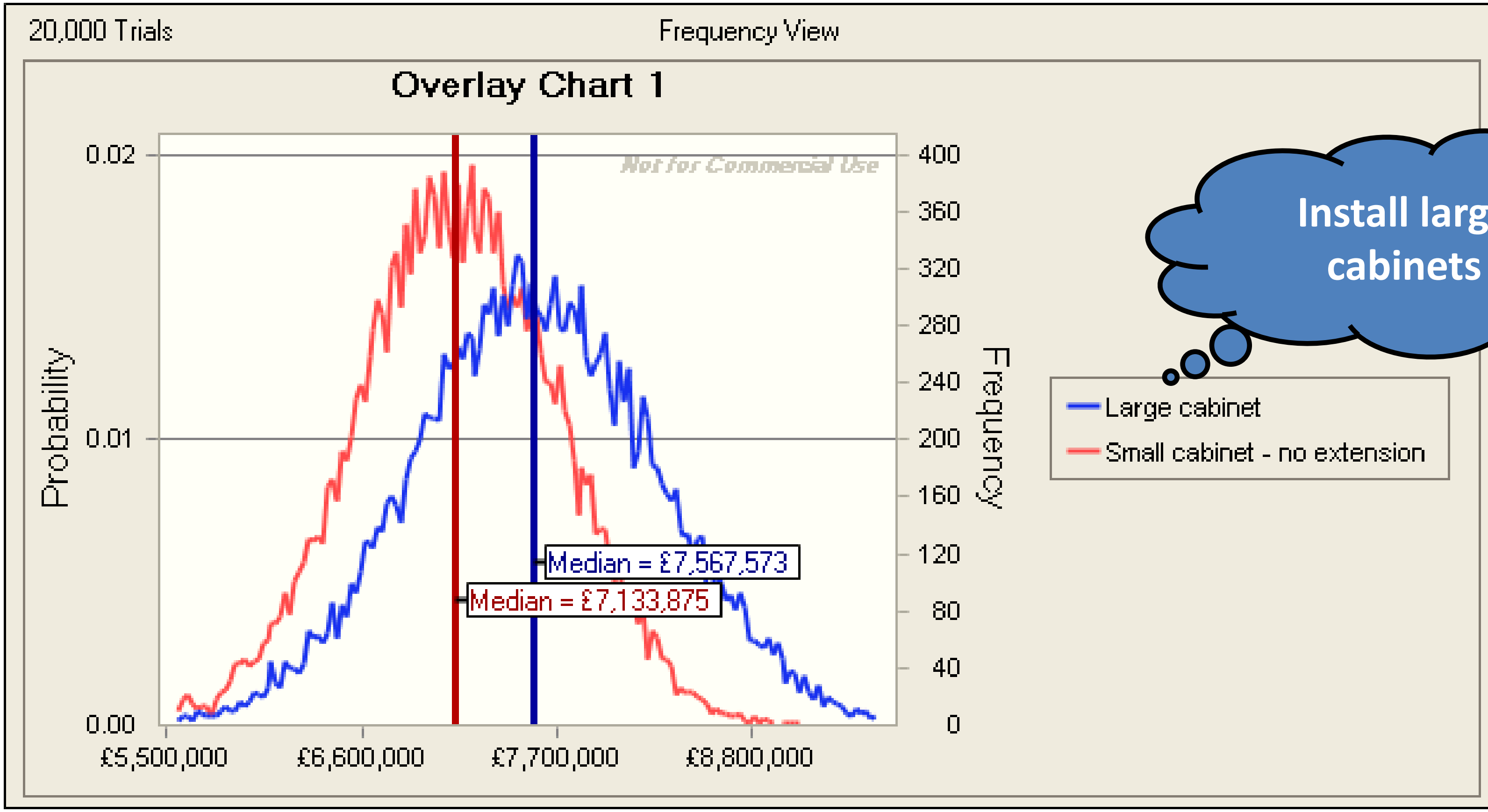
with expected adoption small cabinet is best





2. Identify the uncertainties

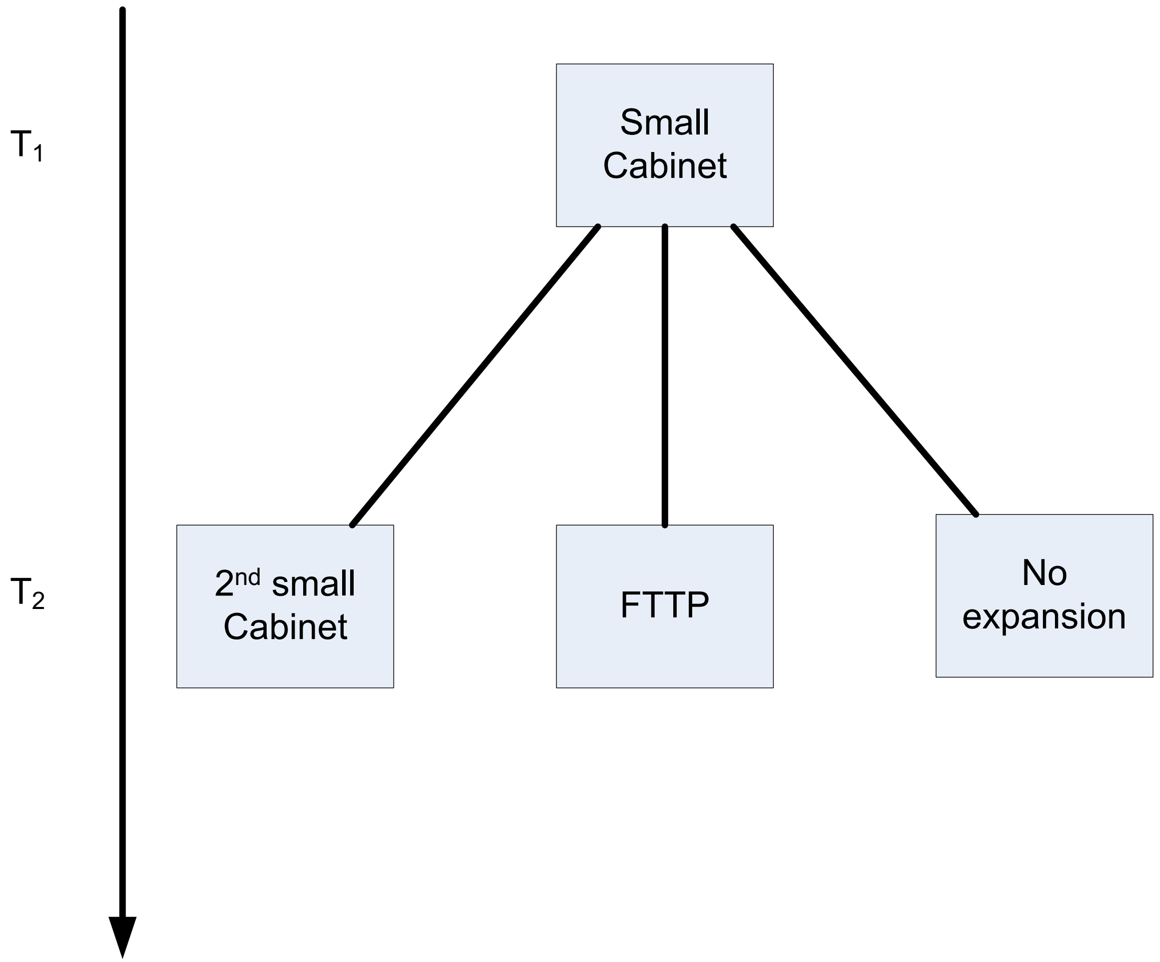
with range of adoptions, large cabinet is better on average



Install large cabinets

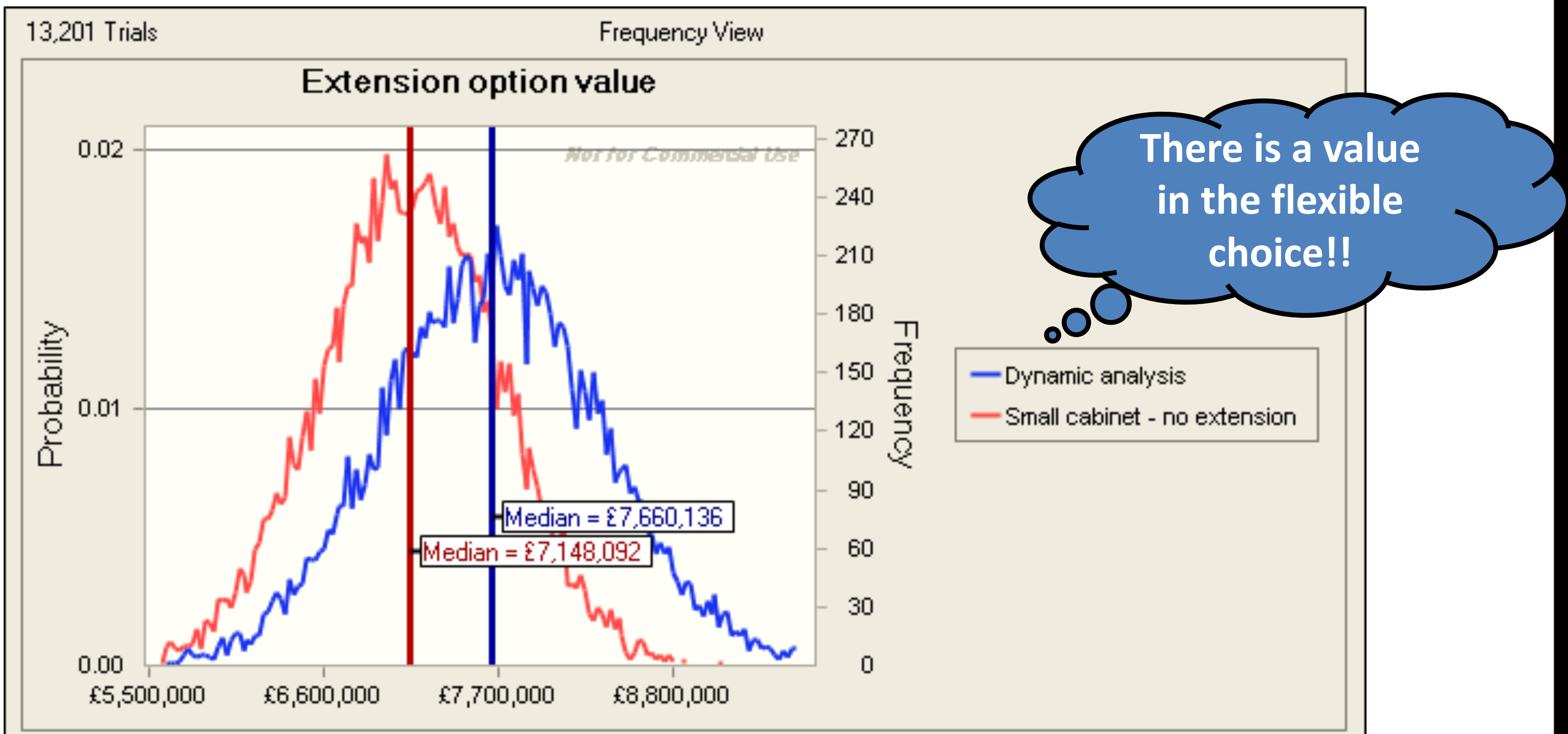
3. Identify the flexibility

Different possible future migrations



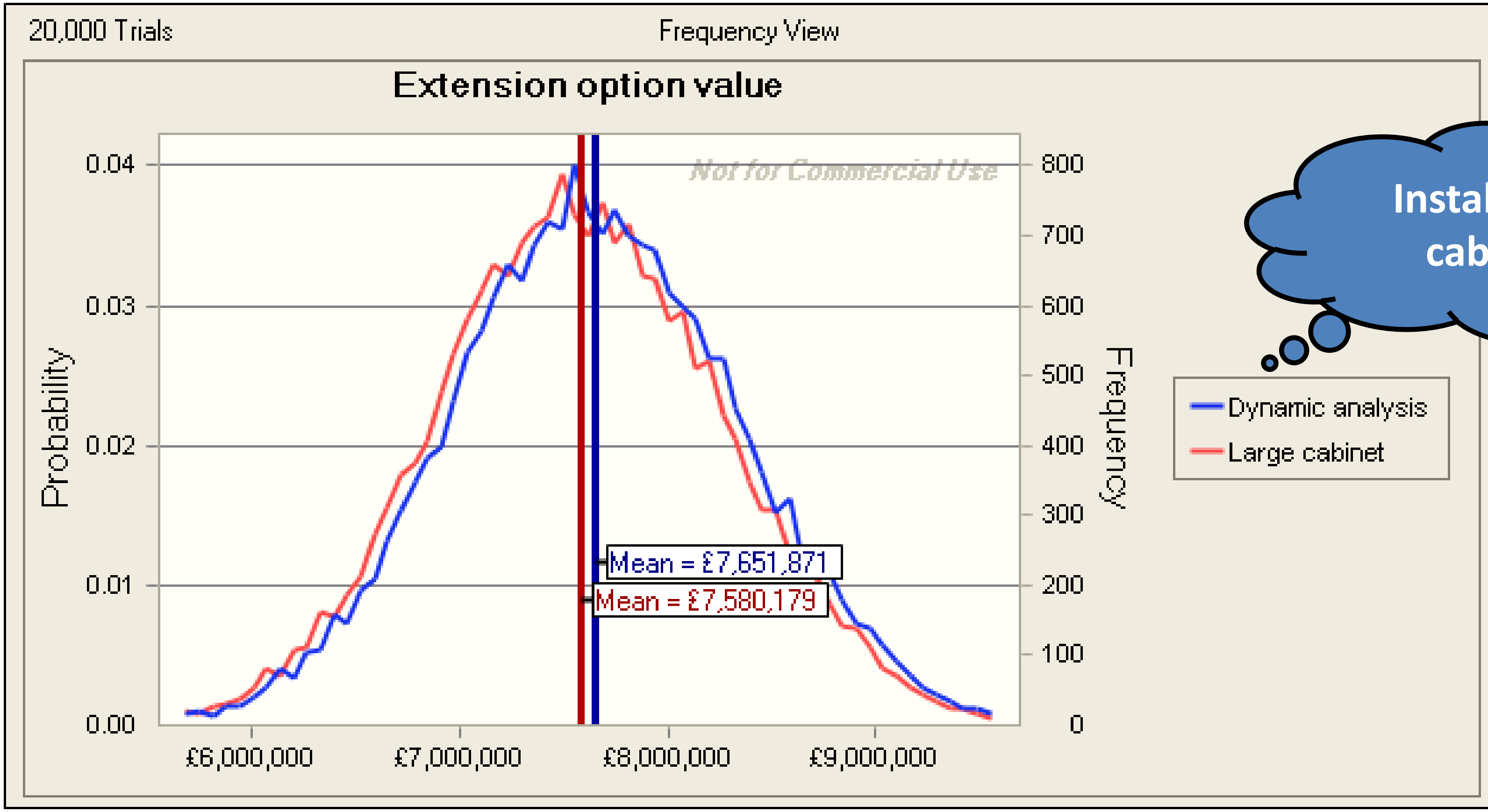
4. Calculate the option value

by comparing flexible path with static small cabinets



4. Calculate the option value

flexibility has more value than large cabinet installation

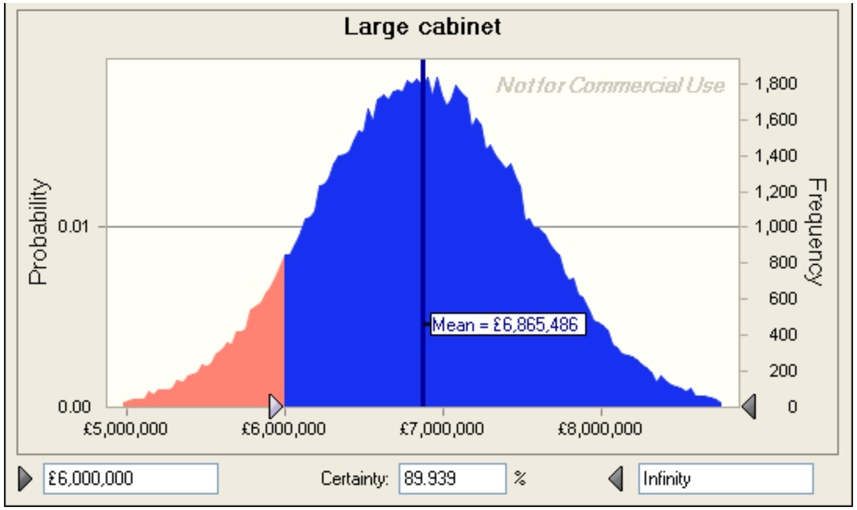


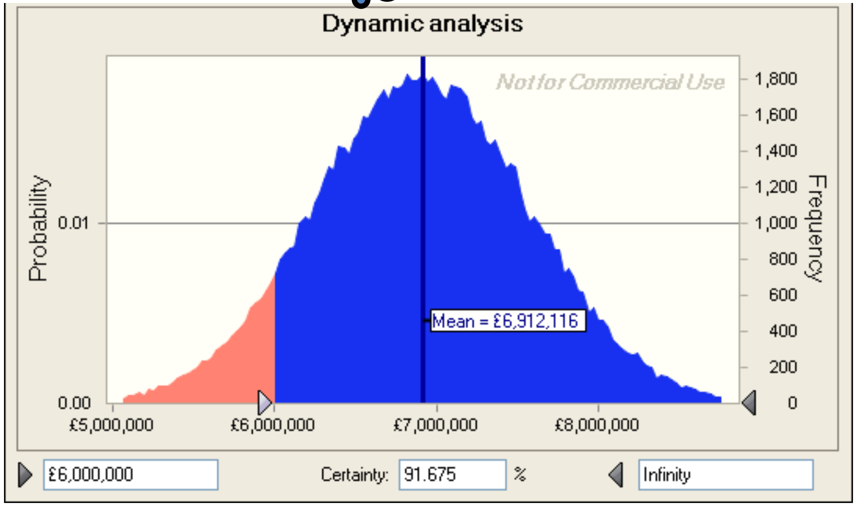
Install small cabinets

ROA

shows that we can reduce the risk of negative outcome

Install small cabinets





10% risk: NPV < £6,000,000

8.3% risk: NPV < £6,000,000

Case study summary

Optimal cabinet size for FTTcab roll-out

- Type of uncertainty (4 types of threats)
  - Strategic – service uptake
  - Operational – re-usable ducts
- Option type (7S)
  - Scale up – install extra small cabinets
  - Switch up – migrate to FTTP
  - Scope up – offer enhanced services
- Calculation method: Monte Carlo simulation
- Case results
  - Small cabinets offer different options
  - These add significant value to change decision

Extensions

Modeling competitive behavior

Sources of uncertainty in telecom planning

allow to classify typical uncertain parameters

Compliance Threats

- Regulatory change
- Corporate governance standards
- Radiation emission standards

Operational Threats

- Technological change
- Traffic Intensity uncertainty
- Equipment Lifetime uncertainty

Telecom Uncertainty

Strategic Threats

- Competition uncertainty
- Adoption uncertainty
- Willingness to pay evolution

Financial Threats

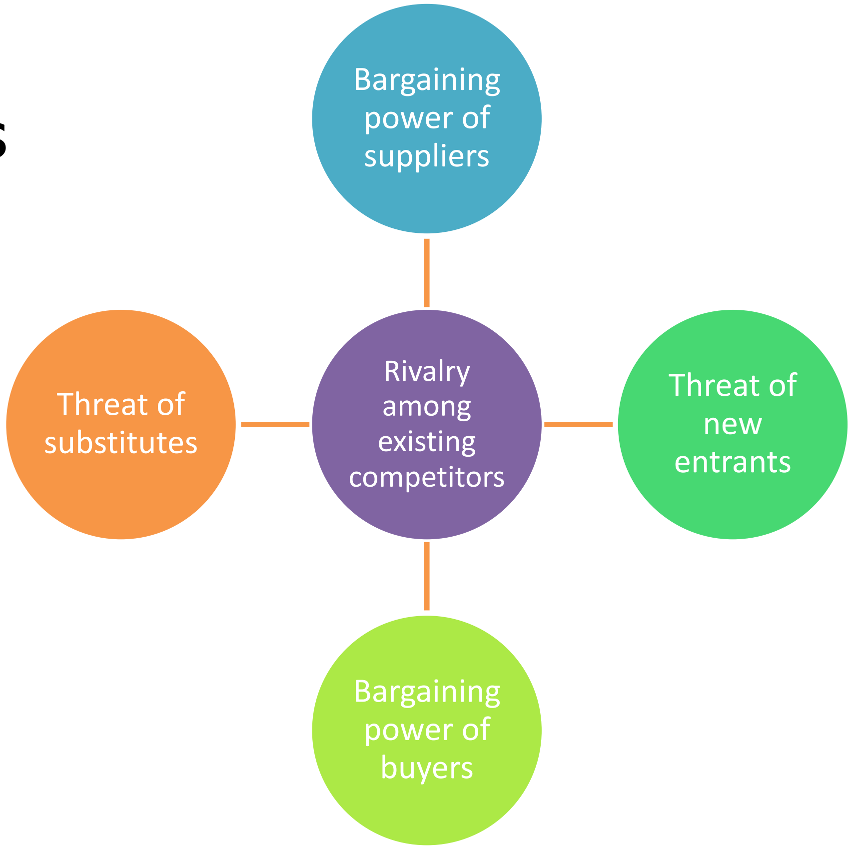
- Component price evolution
- Evolution of borrowing capacity

Competition uncertainty

How will competitors react to my strategy?

Real options and strategies
- Scope: offering new services
- Scale: entering a new geographic market
- Switch: upgrading technology

Impacts the competitive equilibrium



Game Theory

Modeling competitive interaction

Game theory *is "aimed at modeling situations in which decision makers have to make specific actions that have mutual, possibly conflicting, consequences" (Felegyhazi & Hubaux, 2006, p. 1).*

Solving the game
Identifying the equilibria

- Nash
  - No player can gain a higher payoff by unilaterally changing his strategy
  - Competition equilibrium
- Pareto
  - No player can gain a higher payoff without reducing the payoff of another player
  - Social optimum

Techno-economic Game Theory

		2. Municipality														
		enabler			independent			independent			independent			independent		
1. Commercial Wifi	3. 3G				18			19			20			21		
18	Scenario 1	0.33	1.81	0.52	-1.75	0.23	-0.17	-1.73	0.12	-0.10	-1.67	-0.04	0.07	-1.61	-0.26	0.23
	Scenario 2	0.18	1.68	0.87	-2.19	-0.15	0.40	-2.14	-0.26	0.43	-2.06	-0.44	0.55	-2.00	-0.70	0.69
	Scenario 3	**0.05**	**1.56**	**1.10**	-2.57	-0.51	0.80	-2.52	-0.62	0.85	-2.43	-0.82	0.96	-2.35	-1.10	1.05
	Scenario 4	0.21	1.70	0.74	-2.16	-0.10	0.26	-2.10	-0.21	0.30	-2.02	-0.40	0.41	-1.95	-0.64	0.52
19	Scenario 1	0.26	1.71	0.57	-1.77	0.36	-0.10	-1.74	0.26	-0.04	-1.67	0.08	0.13	-1.60	-0.13	0.29
	Scenario 2	0.12	1.59	0.91	-2.19	0.00	0.43	-2.14	-0.12	0.48	-2.06	-0.29	0.60	-1.98	-0.55	0.73
	Scenario 3	0.00	1.48	1.13	-2.61	-0.35	0.84	-2.54	-0.44	0.89	-2.44	-0.67	1.00	-2.36	-0.92	1.07
	Scenario 4	0.16	1.62	0.78	-2.13	0.03	0.30	-2.07	-0.07	0.34	-2.00	-0.25	0.46	-1.92	-0.49	0.57
20	Scenario 1	0.20	1.64	0.76	-1.83	0.58	0.07	-1.78	0.47	0.14	-1.69	0.30	0.30	-1.62	0.10	0.45
	Scenario 2	0.07	1.53	1.08	-2.28	0.22	0.57	-2.25	0.10	0.62	-2.15	-0.06	0.75	-2.06	-0.30	0.86
	Scenario 3	-0.05	1.42	1.27	-2.67	-0.12	0.98	-2.63	-0.22	1.02	-2.53	-0.44	1.08	-2.44	-0.68	1.17
	Scenario 4	0.11	1.57	0.93	-2.22	0.25	0.42	-2.18	0.15	0.47	-2.08	-0.02	0.58	-1.99	-0.26	0.71
21	Scenario 1	0.13	1.57	0.93	-1.94	0.79	0.25	-1.90	0.70	0.31	-1.80	0.53	0.47	-1.73	0.35	0.55
	Scenario 2	0.00	1.45	1.21	-2.40	0.44	0.72	-2.33	0.34	0.77	-2.22	0.16	0.88	-2.15	-0.07	1.01
	Scenario 3	-0.12	1.34	1.40	-2.82	0.13	1.07	-2.77	0.00	1.11	-2.65	-0.19	1.20	-2.53	-0.43	1.29
	Scenario 4	0.04	1.49	1.05	-2.32	0.48	0.55	-2.28	0.39	0.60	-2.18	0.22	0.73	-2.08	-0.01	0.84

- Modeling all strategic combinations
- Finding the equilibrium

Real Options vs. Game Theory

Is it a strategy or an option?

Real Options

- Managerial flexibility
- Counter uncertainty
- Competition as external factor

Game Theory

- Dynamic interaction between competitors
- Competition as internal factor

Option games

Combining Real Options and Game Theory

		Firm 2	
Firm 1		Invest	Wait
	Invest		
	Wait		

Demand evolution

Per year in thousands of tons

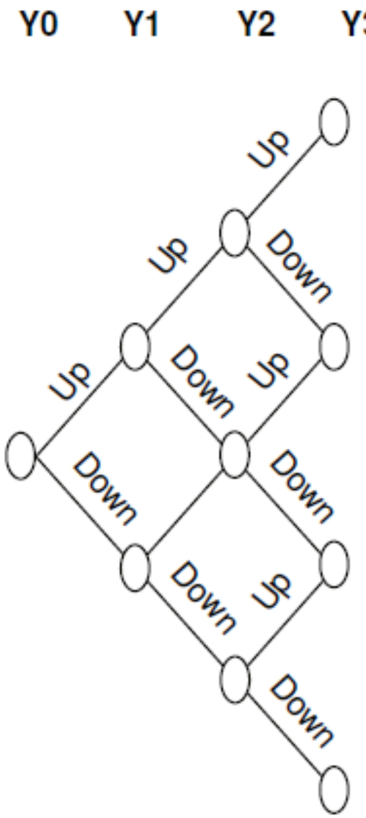
Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
						2970
					2825	
				2687		2687
			2556		2556	
		2431		2431		2431
	2313		2313		2313	
2200		2200		2200		2200
	2093		2093		2093	
		1991		1991		1991
			1894		1894	
				1801		1801
					1713	
						1630

McKinsey, “Option Games”: Filling the hole in the valuation toolkit for strategic investment, available online

Option Games

Combining Real Options and Games

Evolution of demand to Y3



MineCo \ CompCo	Invest	Abandon
Invest	**(143, 71)**	(410, 0)
Abandon	(0, 405)	(0, 0)

Probability of reaching node: 3%

Expected value of payoffs in year 3 (U.S. $ millions): Dominant strategy
- MineCo = 143
- CompCo = 71

MineCo \ CompCo	Invest	Abandon
Invest	(-2, -114)	**(87, 0)**
Abandon	**(0, 71)**	(0, 0)

Probability of reaching node: 19%

Expected value of payoffs in year 3 (U.S. $ millions): Mixed strategy (average)
- MineCo = 43.5
- CompCo = 35.5

MineCo \ CompCo	Invest	Abandon
Invest	(-45,-169)	(-11, 0)
Abandon	(0, -102)	**(0, 0)**

Probability of reaching node: 44%

Expected value of payoffs in year 3 (U.S. $ millions): Dominant strategy
- MineCo = ∅
- CompCo = ∅

MineCo \ CompCo	Invest	Abandon
Invest	(-57,-185)	(-55, 0)
Abandon	(0, -158)	**(0, 0)**

Probability of reaching node: 34%

Expected value of payoffs in year 3 (U.S. $ millions): Dominant strategy
- MineCo = ∅
- CompCo = ∅

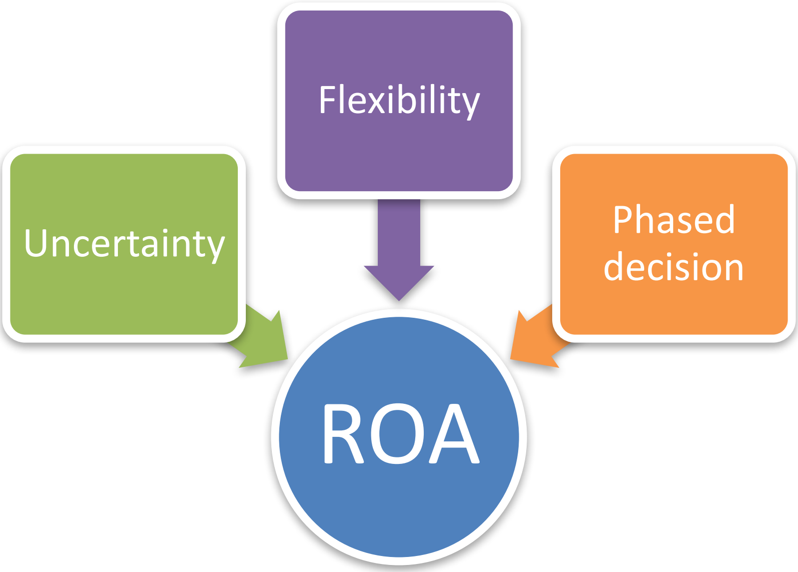
Conclusions

Summary

- ROA is a way to formalize a good practice
  - "I choose this solution because it is more flexible"

Summary

- ROA is a way to formalize a good practice
  - "I choose this solution because it is more flexible"
- There are 3 essential conditions

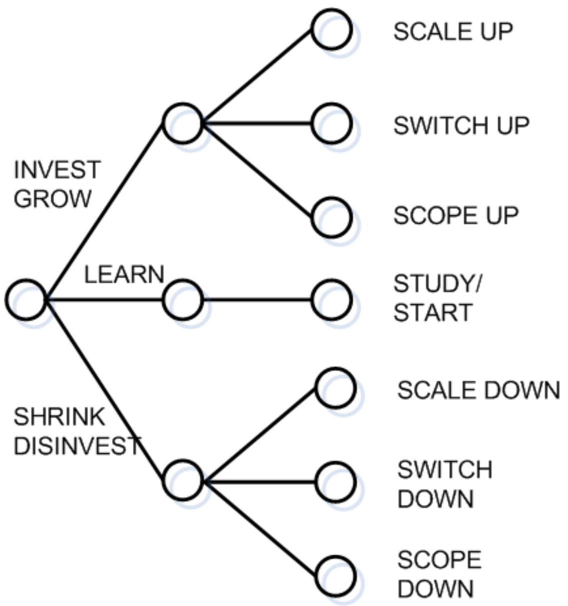


Summary

- ROA is a way to formalize a good practice
  - "I choose this solution because it is more flexible"
- There are 3 essential conditions
- Find all uncertain parameters and model them

Summary

- ROA is a way to formalize a good practice
  - "I choose this solution because it is more flexible"
- There are 3 essential conditions
- Find all uncertain parameters and model them
- Describe all flexibility in the project



Summary

- ROA is a way to formalize a good practice
  - "I choose this solution because it is more flexible"
- There are 3 essential conditions
- Find all uncertain parameters and model them
- Describe all flexibility in the project
- Quantify the value of these options

1. • Execute a standard NPV analysis
2. • Identify the uncertainties
3. • Identify the flexibility
4. • Calculate the option value

References

Real options & sensitivity analysis methodology

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Tools

- Crystal Ball

  http://www.oracle.com/us/products/applications/crystalball/index.html

- TESS – java implementation

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Questions?

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