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FACULTEIT INGENIEURSWETENSCHAPPEN

Practical steps in techno-economic evaluation of network deployment planning part 1: methodology overview

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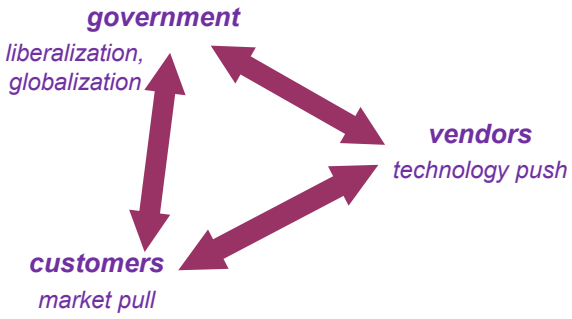
The telecom market is very competitive

- Technical superiority is not a guarantee for market success
- Additional requirements are
  - Understanding the market
  - estimating expected costs and revenues



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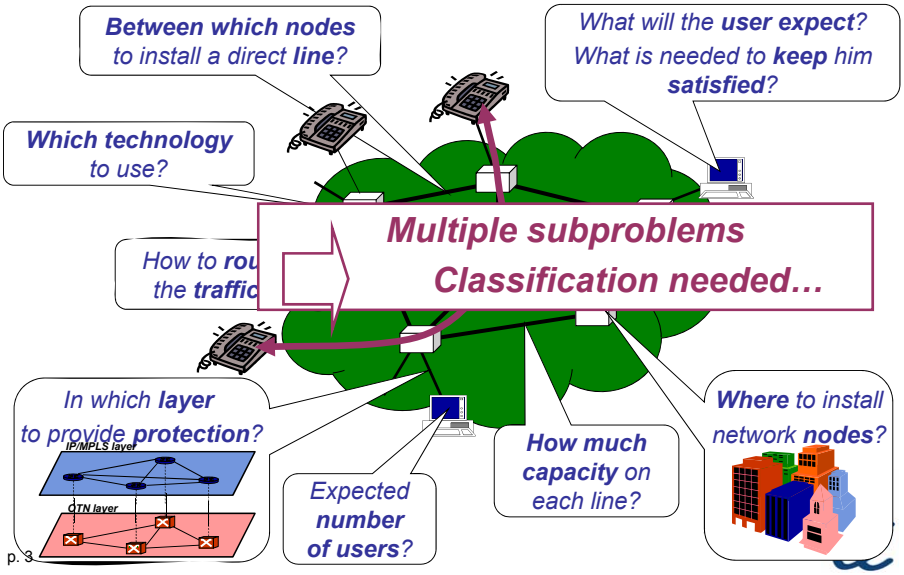
Network planning problem contains many subproblems



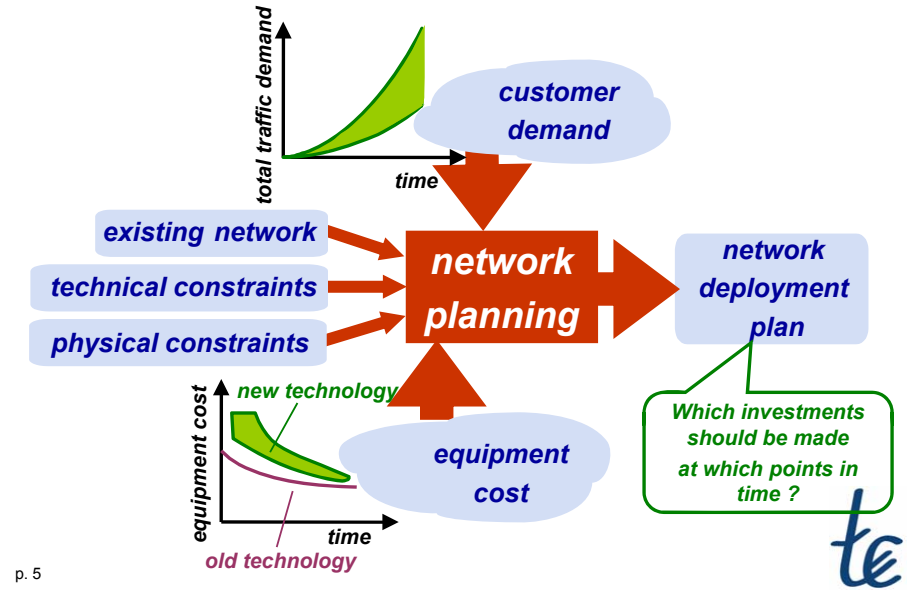
p. 3

Time scale dictates classification

	STP	MTP	LTP
	operational	tactical	strategic
Planning horizon	weeks	months … 1 year	up to 5 years
Uncertainty of planning environment	low	intermediate	high
Geographical scope of planning decisions	local	subnetwork	network-wide
Relative influence of individual decisions on cash flows	minor	medium	major
	e.g. configuration monitoring	e.g. dimensioning routing	e.g. network topology technology choice

p. 4

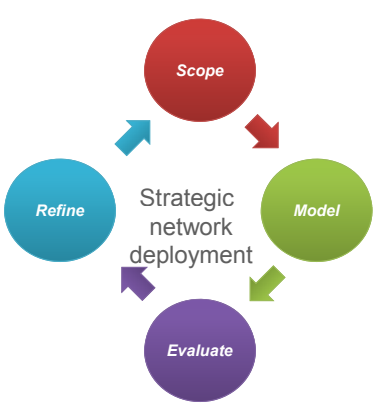
Strategic network planning process

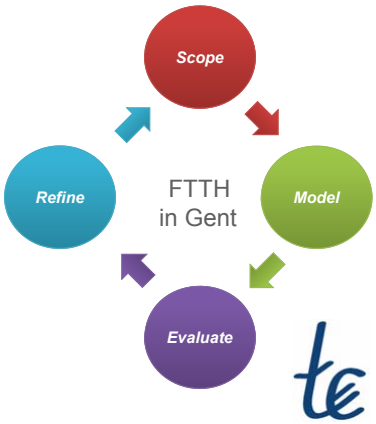


p. 5

Goal of this tutorial

- Before the break
  - Overview different steps
  - Models to be used
- After the break
  - Reference case
  - Tools demo



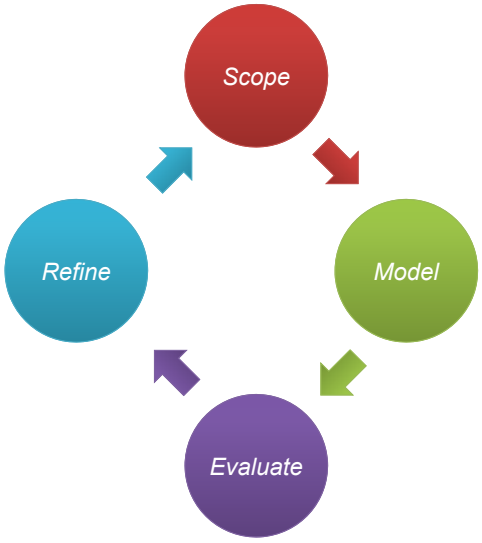


p. 6

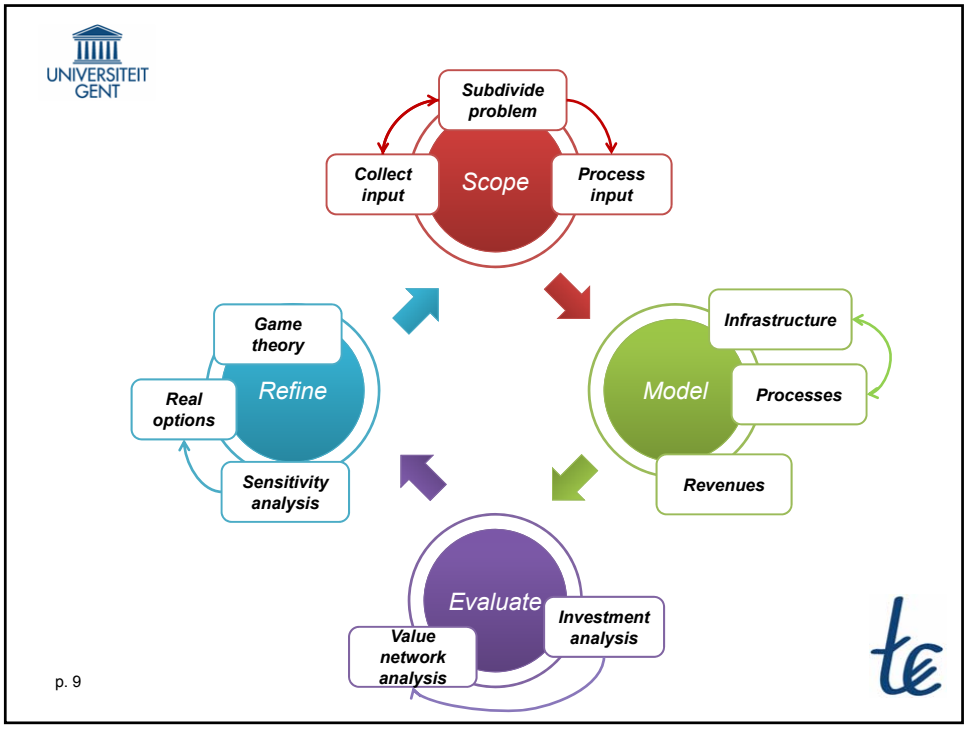
Practical steps in techno-economic evaluation of network deployment planning

GENERAL METHODOLOGY OVERVIEW

Methodology



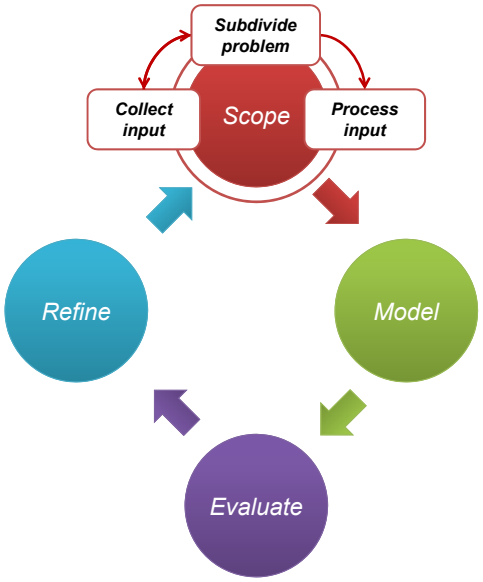
p. 8



Practical steps in techno-economic evaluation of network deployment planning

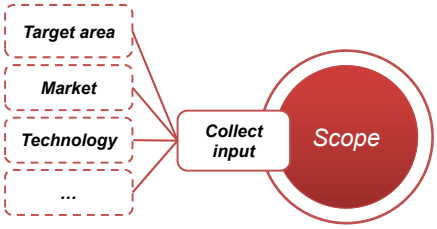
SCOPE

Step 1: Scope the problem



p. 11

Collect input
all available data relevant for the project



p. 12

Target area input

- Geographic / demographic / economic
  - **Area type**
  - **Population density**
  - **Level of education**
  - **Income**
- Legal
  - **Right of Way**
  - **Licenses**
  - **Competition regulation**
- Infrastructure
  - **Existing networks / equipment**
  - **Reuse of locations (poles, buildings)**

Market input

- Roles
  - **What?**
  - **E.g. Building network, maintenance, etc.**
- Actors
  - **Who?**
  - **E.g. Customers, network operators, content providers**

⇒ *Input for business modeling analysis*

- Users
  - **E.g. Residential, commercial, industrial**
- Services
  - **E.g. Triple play, bandwidths, mobility, etc.**

Technology input

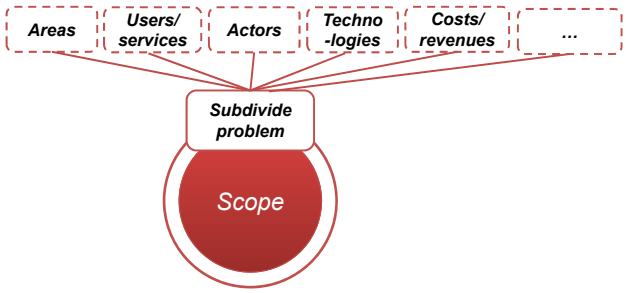
Scope

Collect input

Technology

- State-of-the-art
  - Available technology standards with their pros and contras
  - Commercial products ready for deployment
  - Technical specifications
- Costs
  - Cost figures for the different technologies
  - E.g. equipment costs, installation costs, operational costs, etc.

Subdivide the problem
in order to define the scope more clearly



Subdivide the problem to reduce complexity

Scope

Subdivide problem

Goal: split a complex problem logically into several smaller (manageable) subproblems

But, it can be hard to ...

- integrate calculations

  Combination of optima ≠ Overall optimum

- see influences from one part on the others (e.g. CapEx and OpEx interaction, etc.)

p. 17

Subdivide areas

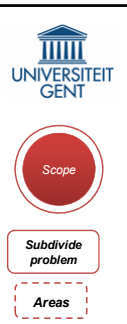
Scope

Subdivide problem

Areas

- Impossible to rollout the target area at once
  - **Due to practical limitations**
    - Time constraints
    - Resources (mostly manpower)
  - **Legal permissions**
- Careful selection of rollout sequence
  - **Type of network**
  - **Potential rollout speed**
- Cherry picking!

p. 18

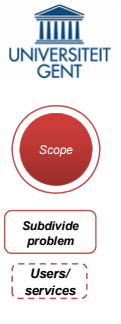


Cherry picking

Finding those areas with the highest return on investment

- Clustering of information based on:
  - **Distance**
  - **Market potential**
    - Type of building (high vs. low buildings)
    - User density (urban vs. rural)
    - Social status
    - Employment degree
    - Residential and commercial density
  - **Optimal utilization of equipment**
    - E.g. FTTH: central office, street cabinet, fibers per cable
    - E.g. wireless: central office, base station
- Different algorithms exist for this problem

p. 19



Subdivide users / services

- Define some typical user and service types
  - **Users**
    - Residential vs. industrial
    - Frequent vs. occasional
  - **Services**
    - Data vs. triple play
    - Fixed vs. nomadic vs. mobile

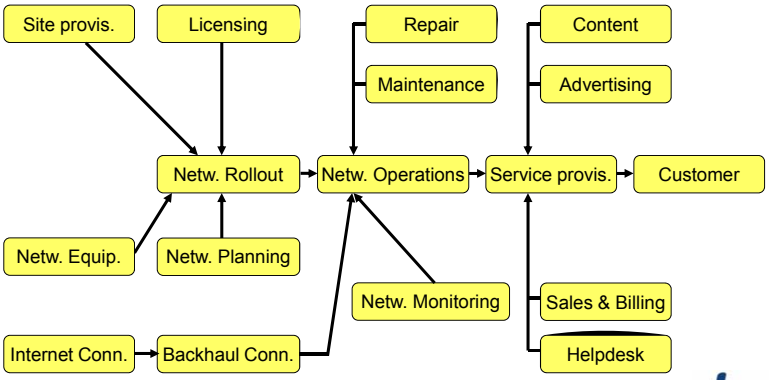
p. 20

Roles and actors
for a wireless network

Scope

Subdivide problem

Actors



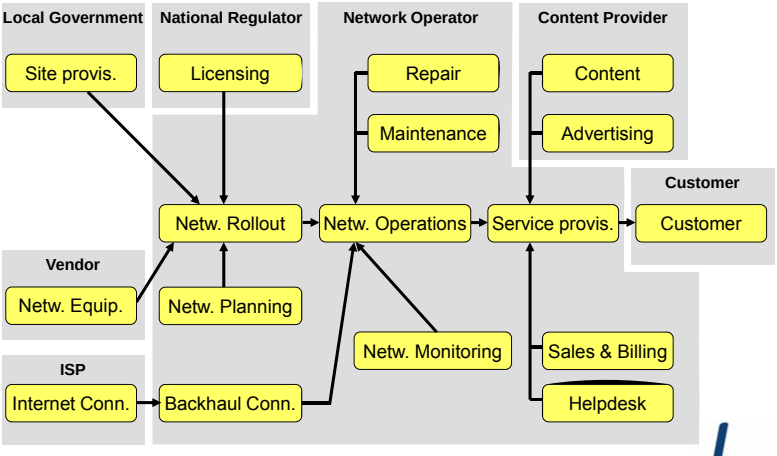
p. 21

Roles and actors
for a wireless network

Scope

Subdivide problem

Actors



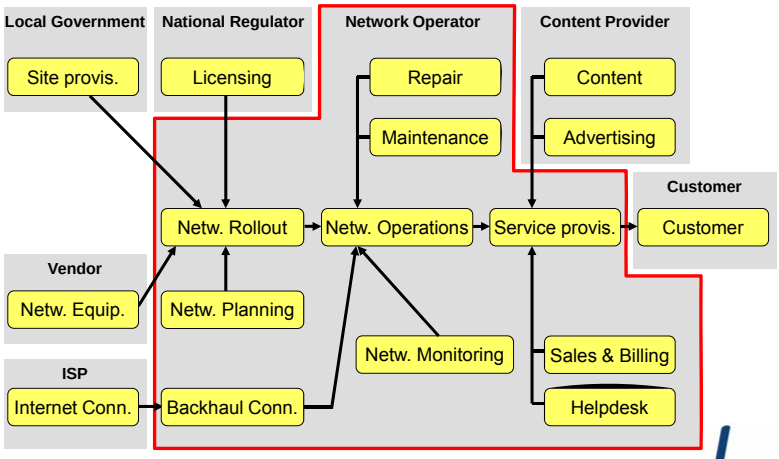
p. 22

Roles and actors
for a wireless network

Scope

Subdivide problem

Actors

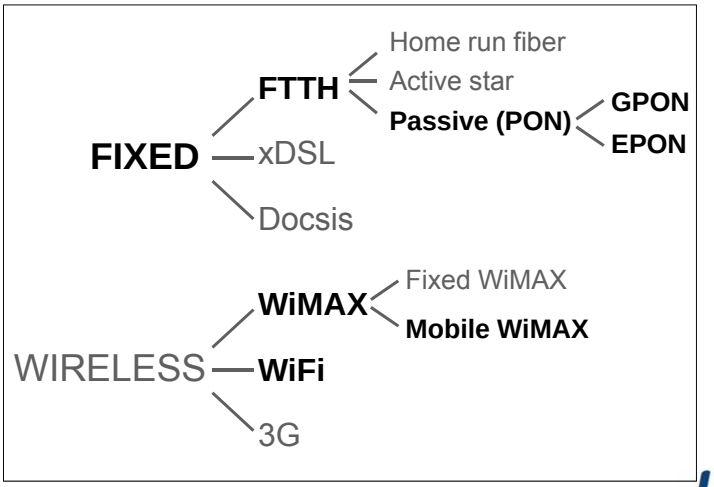


Subdividing technologies

Scope

Subdivide problem

Techno -logies



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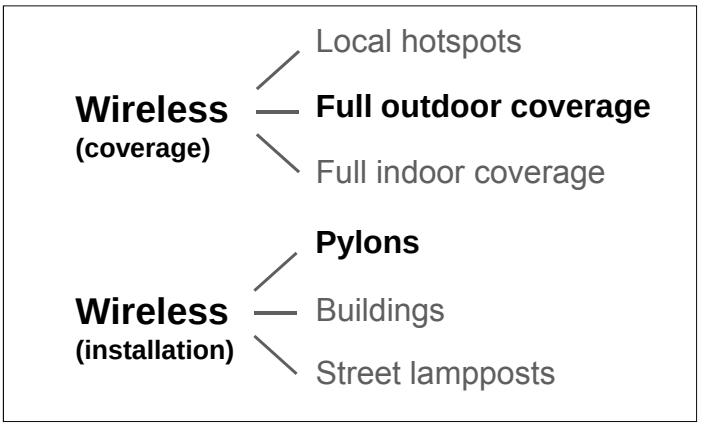
Scope

Subdivide problem

Techno -logies

Subdividing technologies



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Scope

Subdivide problem

Costs/ revenues

Subdivide costs / revenues

- A logical division of the total costs
  - **Lifecycle**
    - Installation
    - Running
    - Teardown
  - **CapEx vs. OpEx**
  - **Network vs. services**

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Costs

Scope

Subdivide problem

Costs/ revenues

- CapEx (depreciated)
  - Land, buildings
  - Passive infrastructure
  - Equipment
  - Network deployment
  - …
- OpEx
  - Power consumption
  - Floor space

equipment driven

- Maintenance
- Repair
- …

activity driven

Standard: eTOM

p. 27

Direct versus indirect costs

Scope

Subdivide problem

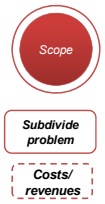
Costs/ revenues

- Direct costs
  - **Equipment**
  - **Powering**
  - **Activities**
  - …
- Indirect costs
  - **Environmental impact**
    - CO2 emissions
  - **Impact on employment**
  - …

Longer term impact

p. 28

Direct versus indirect revenues

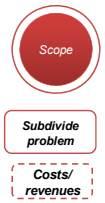


- Direct revenues
  - **From subscriptions**
  - **Business versus residential**
  - **…**
- Indirect revenues
  - **Benefit for community**
  - **Attracting more SMEs to the city/region/…**
  - **Positive image building for communities**
  - **…**

Longer term impact

p. 29

enhanced Telecom Operations Map



- Standardized by TMF: ITU-T M.3050
- AB process decomposition model
  - **Process model, not state model!**
  - **Grouping**
    - Vertical: purpose of the processes
    - Horizontal: where those processes are taking place
  - **Decomposition: notional level 0 to maximum of 3 levels**
    - NOT the goal to address detailed processes and procedures of an enterprise
- Out of scope
  - **Rainy day scenarios**
  - **Dynamic aspects**

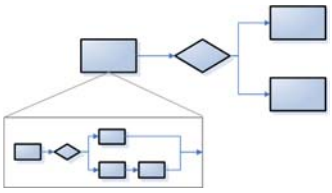
p. 30

Hierarchical process architecture

Scope

Subdivide problem

Costs/ revenues



- Different level of processes
  - Level 0: business activities
  - Level 1: process groupings
  - Level 2: core processes
  - Level 3: business process flows
  - Level 4: operational process flows
  - Level 5: detailed process flows

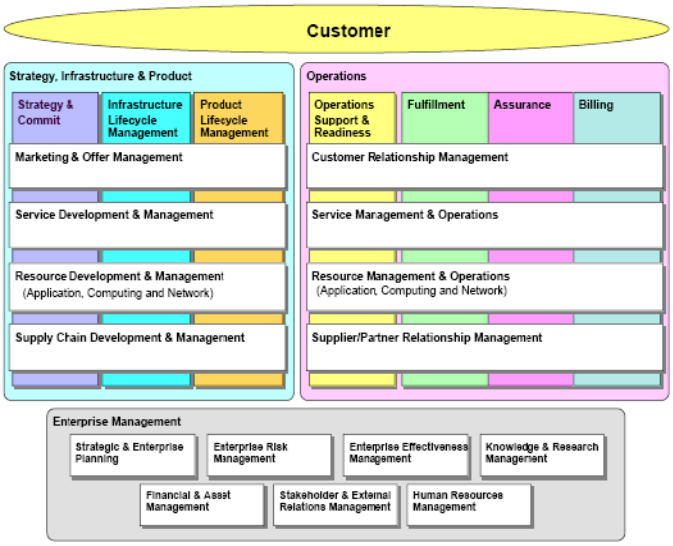
p. 31

enhanced Telecom Operations Map

Scope

Subdivide problem

Costs/ revenues



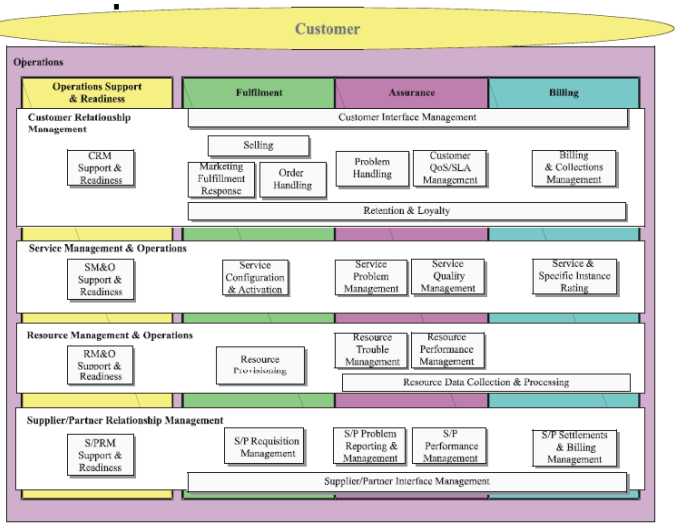
p. 32

eTOM OPS: level 0, 1, 2 processes

Scope

Subdivide problem

Costs/ revenues

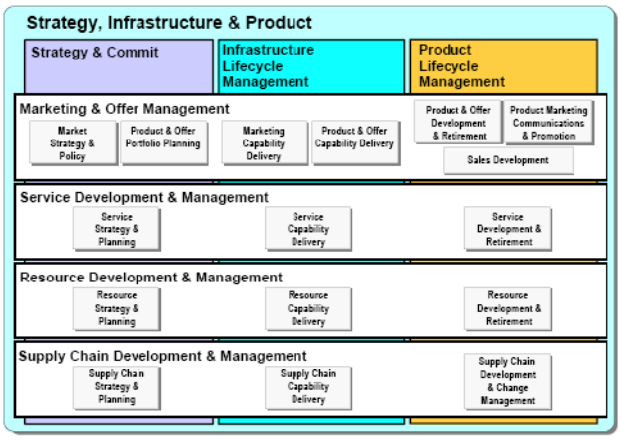


eTOM SIP: level 0, 1, 2 processes

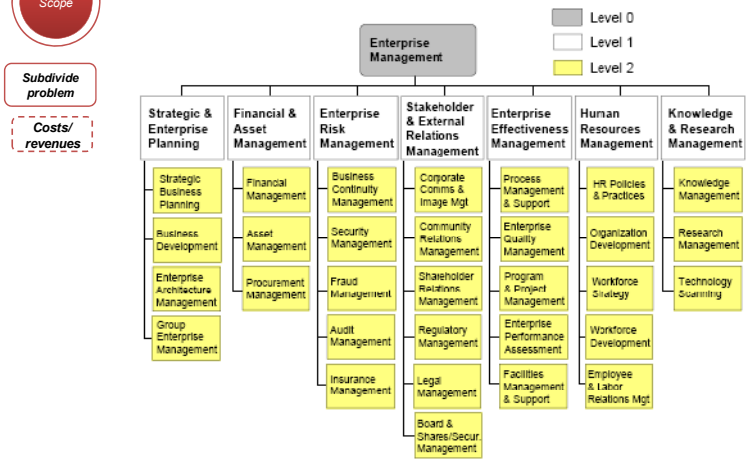
Scope

Subdivide problem

Costs/ revenues



eTOM EM: level 0, 1, 2 processes

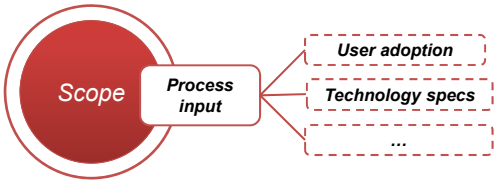


Scope

Subdivide problem

Costs/ revenues

Process input
required before actual modeling starts



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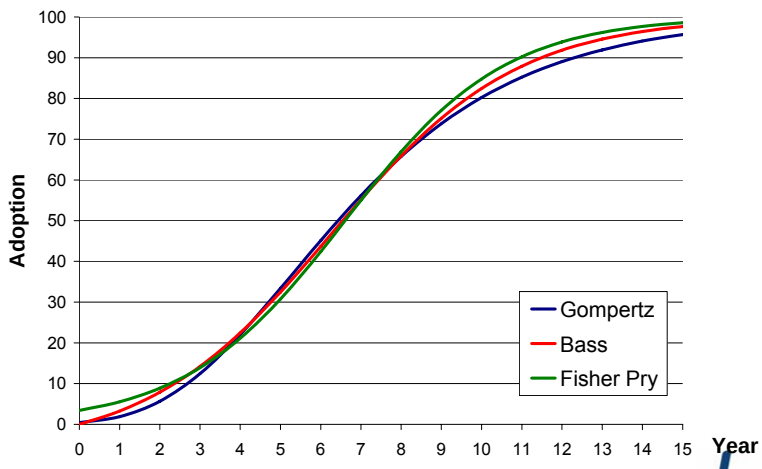
Scope

Process input

User adoption

Different user adoption models exist

Cumulative market share: S-shaped curve



p. 37

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Scope

Process input

User adoption

Bass

Adoption forecasting formula

$$S(t) = m \cdot \frac{1 - e^{-(p+q)t}}{1 + \frac{q}{p} e^{-(p+q)t}}$$

m = market potential

p = innovation coefficient

q = imitation coefficient

p. 38

Scope

Process input

User adoption

Gompertz
Adoption forecasting formula

$$S(t) = m \cdot e^{-e^{-b(t-a)}}$$

m = market potential

a = inflection point (at 37% adoption)

b = slope impacting factor

p. 39

Scope

Process input

User adoption

Fisher-Pry
Adoption forecasting formula

$$S(t) = m \cdot \frac{1}{1 + e^{-b(t-a)}}$$

m = market potential

a = inflection point (at 50% adoption)

b = slope impacting factor

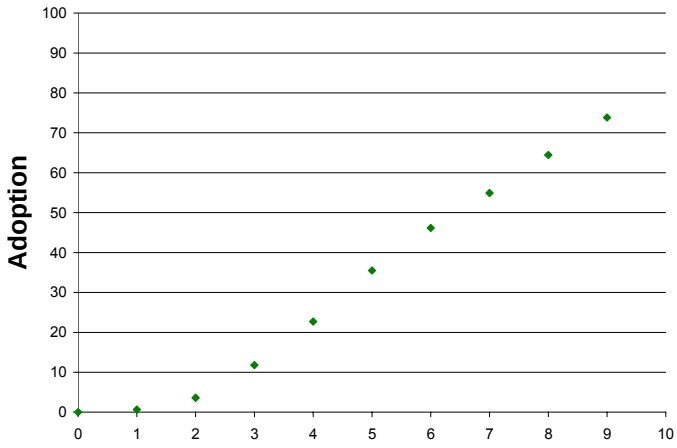
p. 40

Fitting to the data points and choosing the best model

Scope

Process input

User adoption



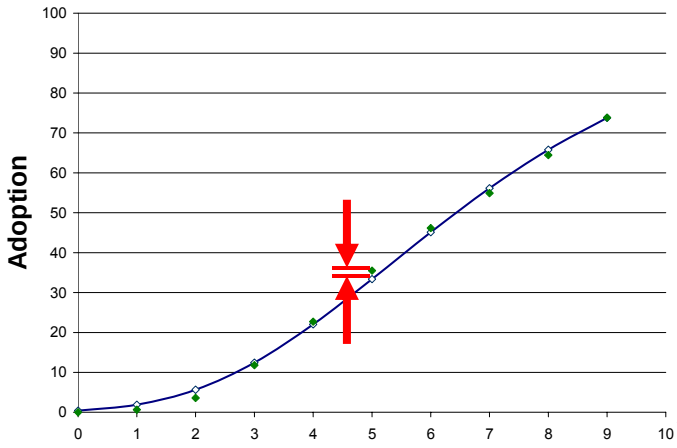
p. 41

According to the reliability of the model

Scope

Process input

User adoption



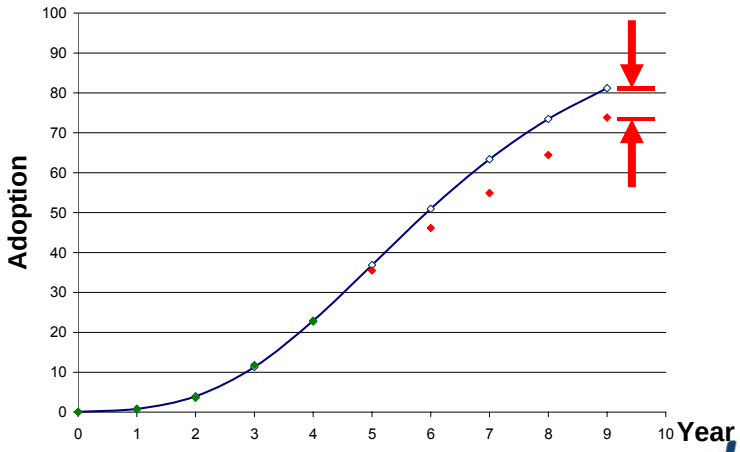
p. 42

And to the reliability of the forecasts

Scope

Process input

User adoption



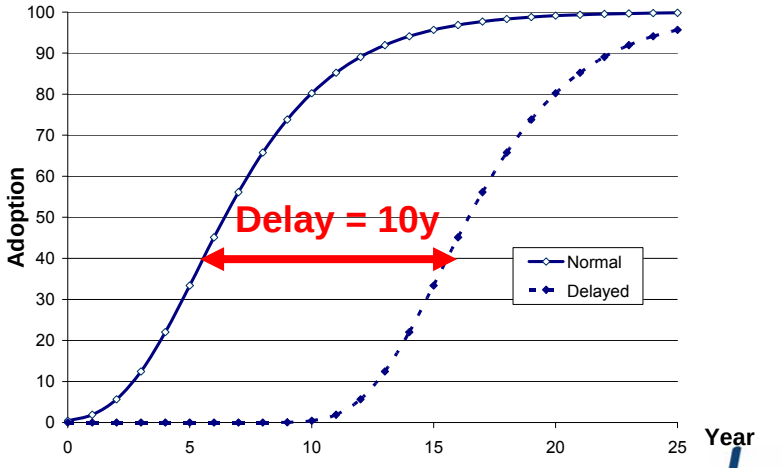
p. 43

What happens when delaying the rollout

Scope

Process input

User adoption



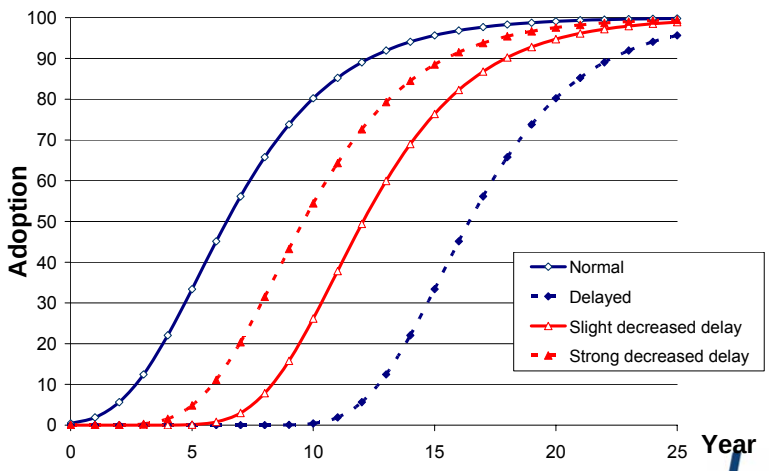
p. 44

We expect a less than linear increase in delay (e.g. word of mouth, technical evolution, etc.)

Scope

Process input

User adoption



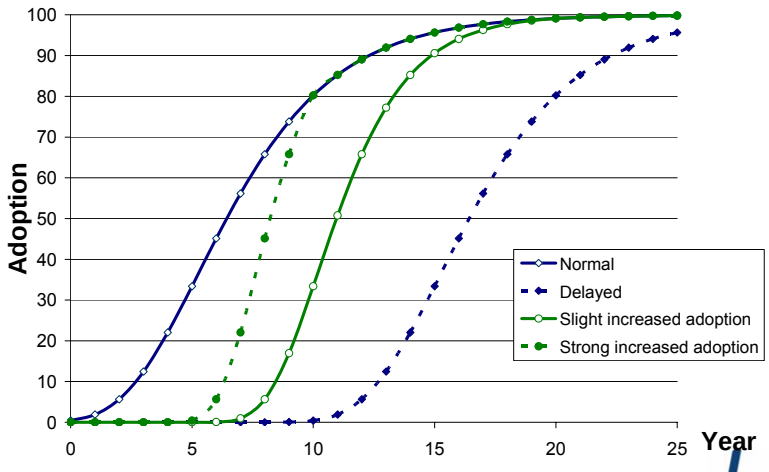
p. 45

We expect a stronger take-up

Scope

Process input

User adoption



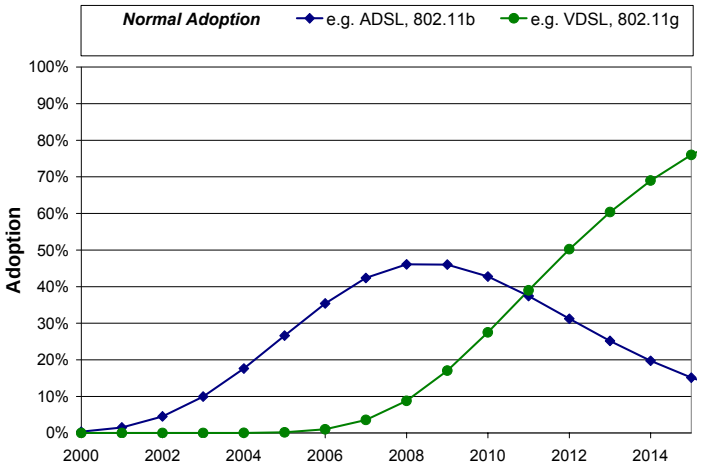
p. 46

Influence of momentary influences
(e.g. analog switch-off)

Scope

Process input

User adoption



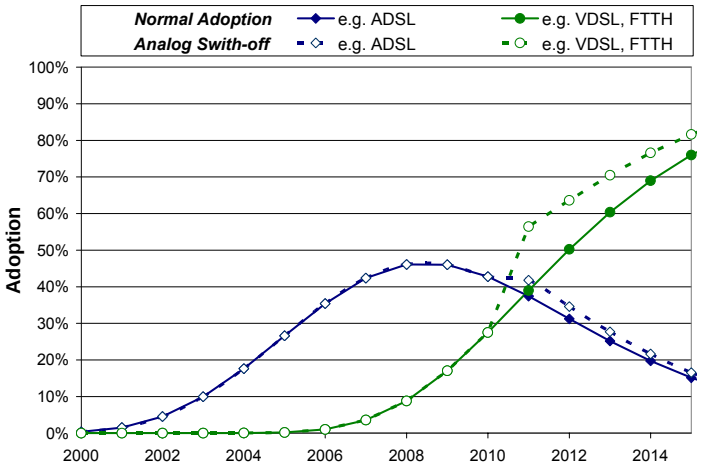
p. 47

Analog switch-off might push adoption in one year to the full market-potential

Scope

Process input

User adoption



p. 48

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Scope

Process input

Technology specs

Existing site locations
for mobile/wireless networks

- *Operational sites*
- *Sites under construction*
- *Construction permit requested*

Source: http://www.sites.bipt.be/

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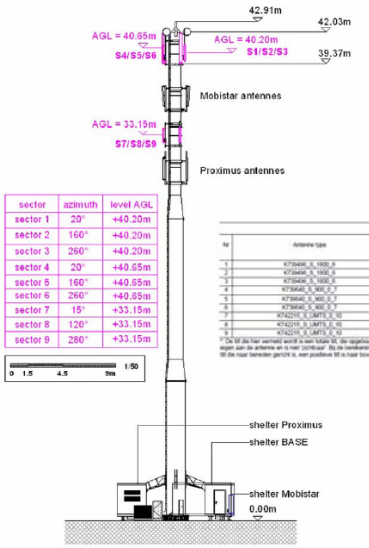
Scope

Process input

Technology specs

Detailed infrastructure information
for mobile/wireless networks



sector	azimuth	level AGL
sector 1	20°	+40.20m
sector 2	160°	+40.20m
sector 3	260°	+40.20m
sector 4	20°	+40.65m
sector 5	160°	+40.65m
sector 6	260°	+40.65m
sector 7	15°	+33.15m
sector 8	120°	+33.15m
sector 9	280°	+33.15m

Antennes

Source: http://www.sites.bipt.be/

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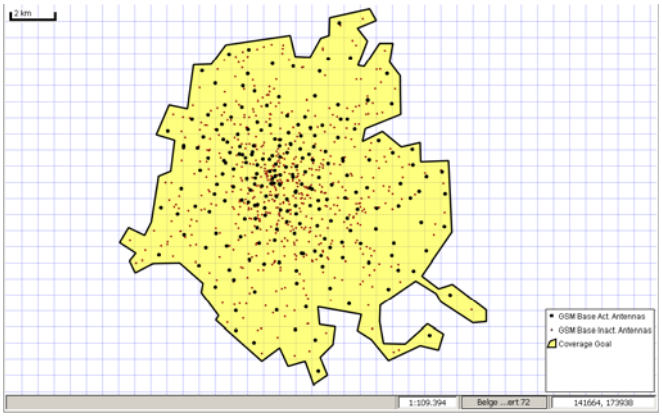
Processed information map
for mobile/wireless networks

Scope

Process input

Technology specs

Antenna locations for Brussels



Extra info per antenna:

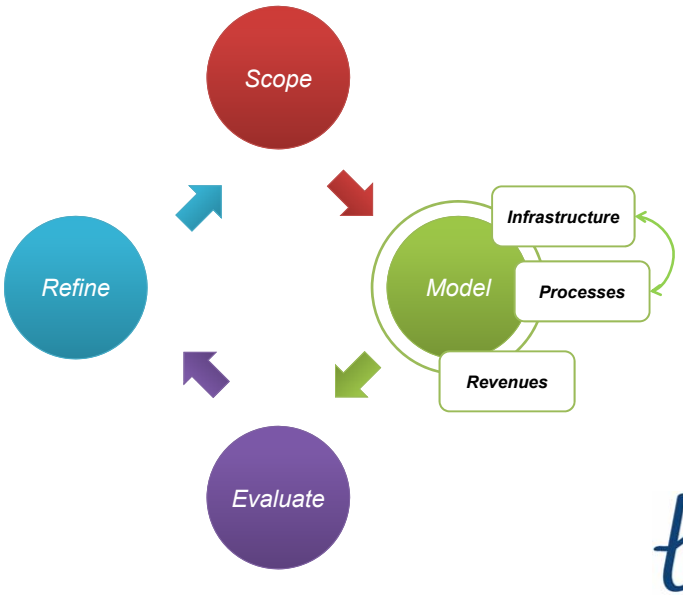
Location, operators, types, height, power, tilt, etc.

p. 51

Practical steps in techno-economic evaluation of network deployment planning

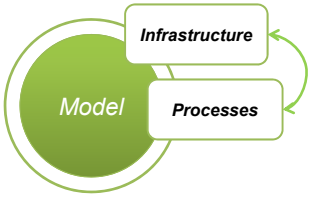
MODEL

Step 2: Model costs and revenues



p. 53

Model infrastructure and processes
using appropriate level of detail



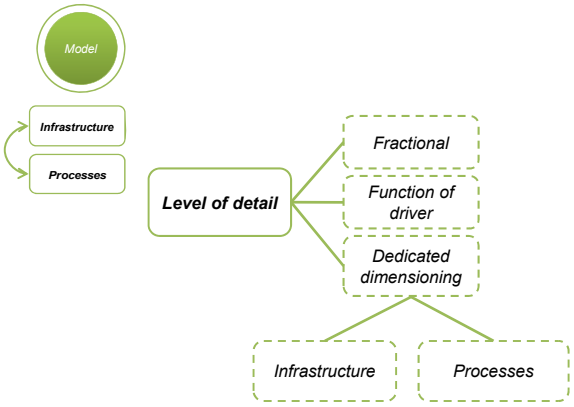
p. 54

Increasing level of detail

- Increase of focus
  - **On the most important points**
  - **By detailing one part at a time**
- Reducing size and complexity
  - **Calculations**
  - **Covered area or customer base**
- Zoom in on most important part
  - **By further subdividing this part**
  - **By detailing the calculation of this part**

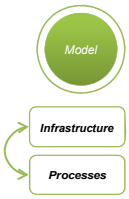
p. 55

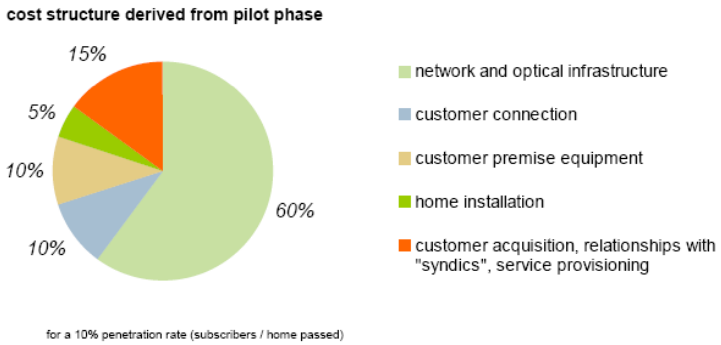
Level of detail in the different models



p. 56

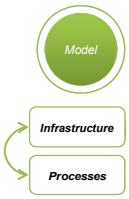
Fractional cost modeling

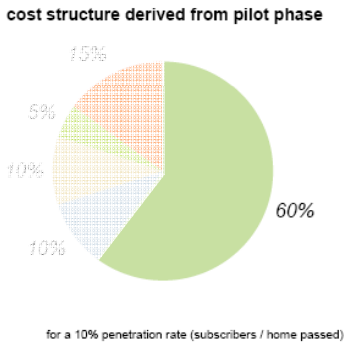




Source: Orange – from FTTH pilot to pre-rollout in France

Function of driver cost modeling





Examples of drivers:
- *installation length (50€/m)*
- *customer base (1k €/cust)*
- …

→ combinations possible

Wireless network dimensioning
Cell size calculation

Model

Infrastructure

Link budget calculation
(BS & CPE specs / antenna heights / margins / type of area / buildings)

& Propagation models
(E.g. Free space, Erceg, Hata …)

User density & service req.
(required bandwidth)

+

Technology performance
(attainable bandwidth)

PHYSICAL RANGE

SERVICE RANGE

Cell sizes

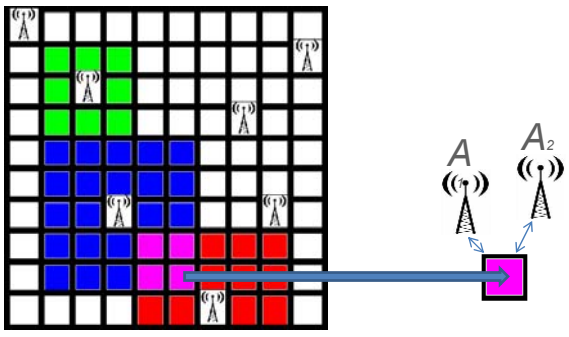
p. 59

Wireless network dimensioning
Methodology

Model

Infrastructure

1. Map (& reduce) all site-information (e.g. on grid)
2. Calculate range for each site installation
3. Select optimal sites for required coverage
4. Analyze the regions of overlap



p. 60

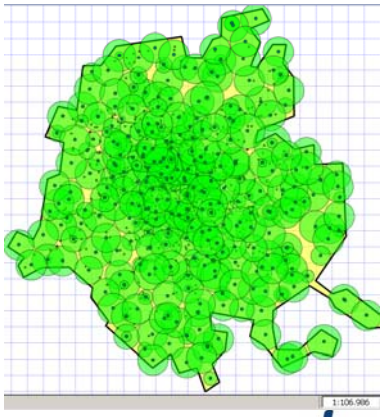
Wireless network dimensioning
Existing GSM operator in Brussels

Model

Infrastructure

Original coverage

Optimized solution



GSM: *71.4% cov., 409 ant.* *96.6% cov., 367 ant.*

3G: *36.9% cov., 193 ant.* *87.7% cov., 584 ant.*

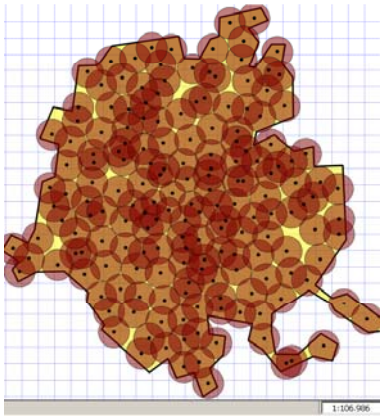
p. 61

Wireless network dimensioning
Greenfield dimensioning in Brussels

Model

Infrastructure

New GSM operator



96.8% coverage
177 antennas

New 3G operator

91.61% coverage
419 antennas

p. 62

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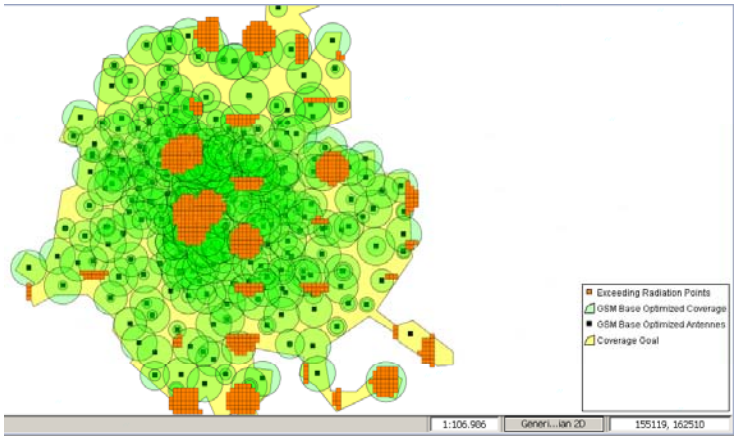
Model

Infrastructure

Wireless network exposure
taking regulation into account



Antenna power is set above its maximum for some locations

→ Exceeding exposure limits

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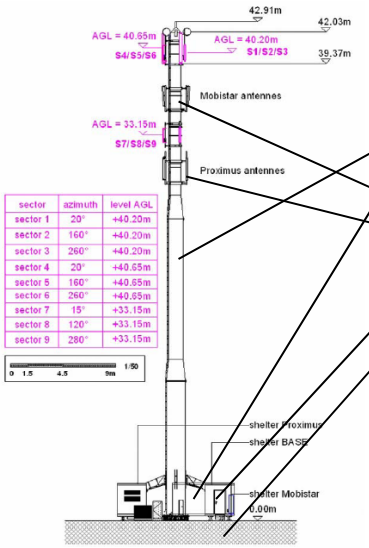
Model

Infrastructure

Wireless network dimensioning
Bill of material



- *# sites*
- *# base stations*
- *# antennas*
- *# sectors*

- *Shelter*
- *Backhaul connection equipment*

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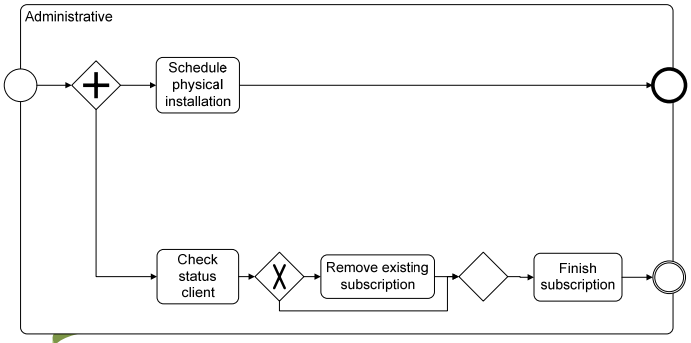
Process based cost modeling



Standards: BPMN, XPDL

- Two calculation methods
  - **Activity based costing (ABC)**
  - **Simulation based costing**

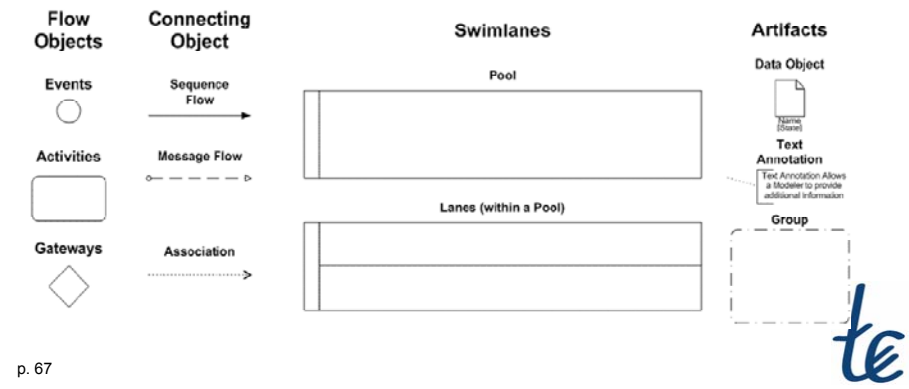
p. 65

BPMN: graphical format

- Business Process Modeling Notation
  - **a standardized graphical notation for drawing business processes in a workflow**
  - **developed by Business Process Management Initiative (BPMI)**
  - **now being maintained by the Object Management Group since the two organizations merged in 2005**

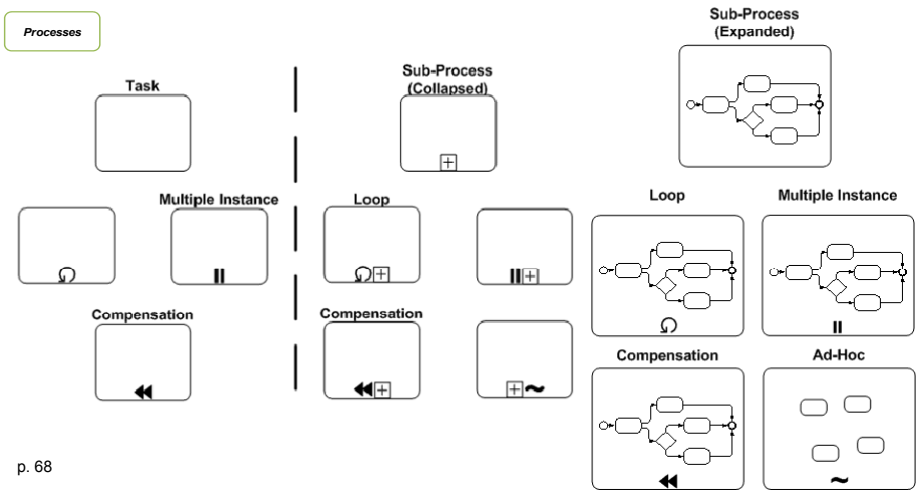
p. 66

Core BPMN Elements



p. 67

Activities
from Complete BPMN Elements



p. 68

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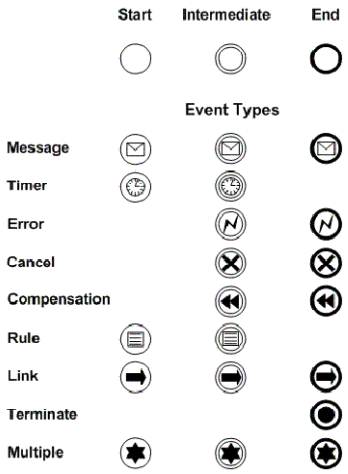
Model

Processes

Events
from Complete BPMN Elements



p. 69

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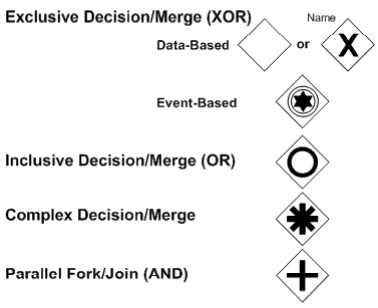
Model

Processes

Gateways
from Complete BPMN Elements



p. 70

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UNIVERSITEIT GENT

Model

Processes

Connections
from Complete BPMN Elements

p. 71

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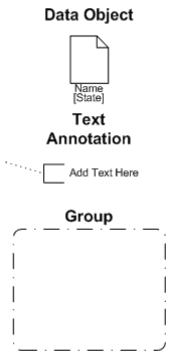
Model

Processes

Artifacts
from Complete BPMN Elements



p. 72

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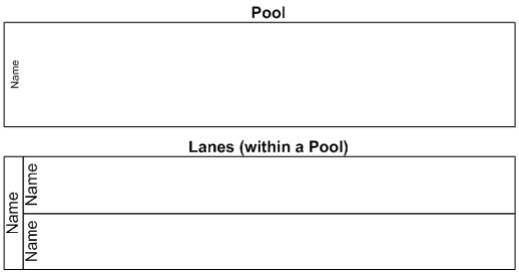
Model

Processes

Pools
from Complete BPMN Elements



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Model

Processes

XPDL: textual format

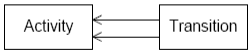
- XML Process Definition Language
  - **XML schema**
  - **declarative part of workflow**
- Format to interchange Business Process definitions between different workflow tools
  - **exchange the process design**
  - **both the graphics and the semantics**
    - contains coordinates -> saves graphical representation
- Standardized by the Workflow Management Coalition (WfMC)
- http://www.wfmc.org/standards/xpdl.htm !

Example Arc

XPDL Transition

```
<Activity Id="A"/>
<Activity Id="B"/>
<Transition
 From="A" To="B"/>
```

UML Representation



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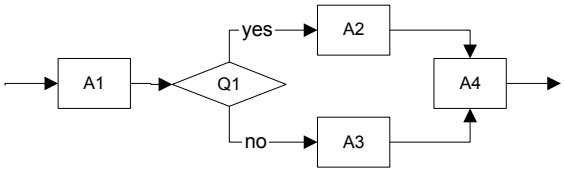
Activity-based costing

Model

Processes

1. time frame
2. costs (actions)
3. probabilities (questions)
4. entire process cost



$$costA1 + p \cdot costA2 + (1-p) \cdot costA3 + costA4$$

5. total OpEx cost for network scenario

p. 75

Define cost of an action

Model

Processes

- Straightforward approach:
  cost of action = time needed to perform action * wages of person taking care of it (incl. taxes)
- Several employee categories involved, with wages
  - **administrative personnel**
  - **technicians**
  - **engineers**
  - **sales people**
- Total cost of personnel
  = wages + *training + tools and transport*
  = wages (1 + *weight factor*)
  weight factor per category:
  e.g. technicians need more tools than administrative personnel

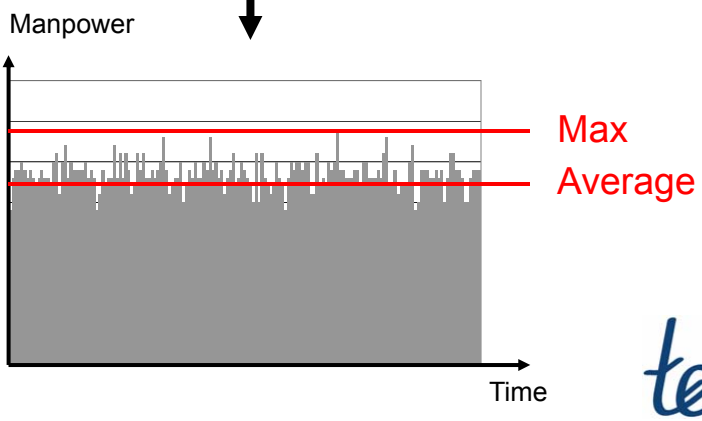
p. 76

Simulation based costing
Example: repair process simulation

Model

Processes

Model + simulation



p. 77

Where will the input come from?

Model

Infrastructure

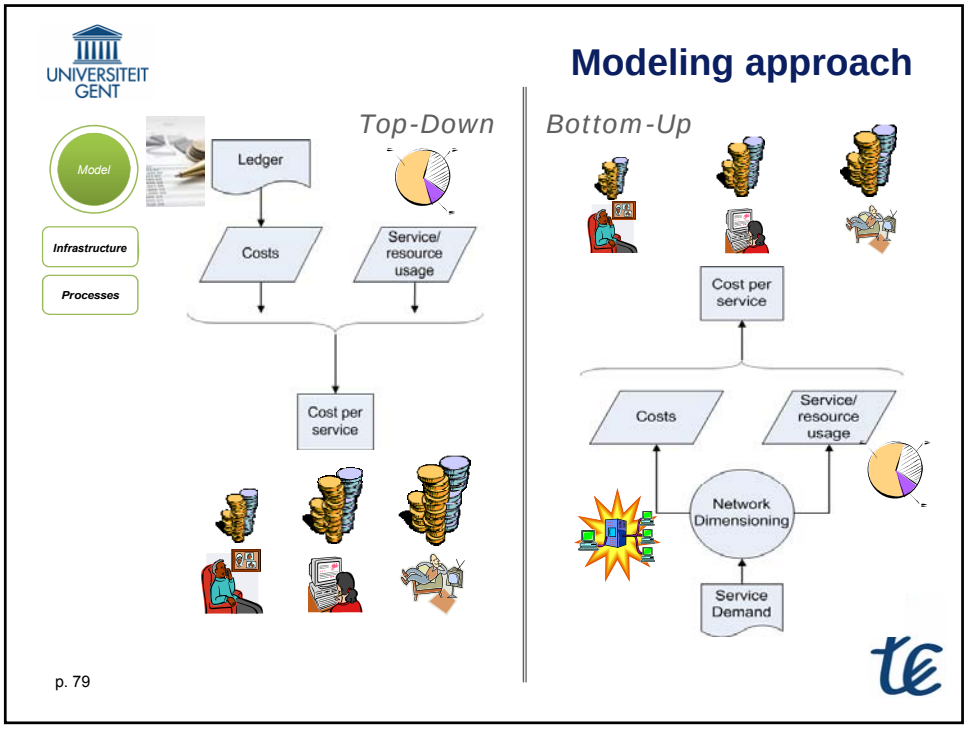
Processes

Top-down

Bottom-up

Approach

p. 78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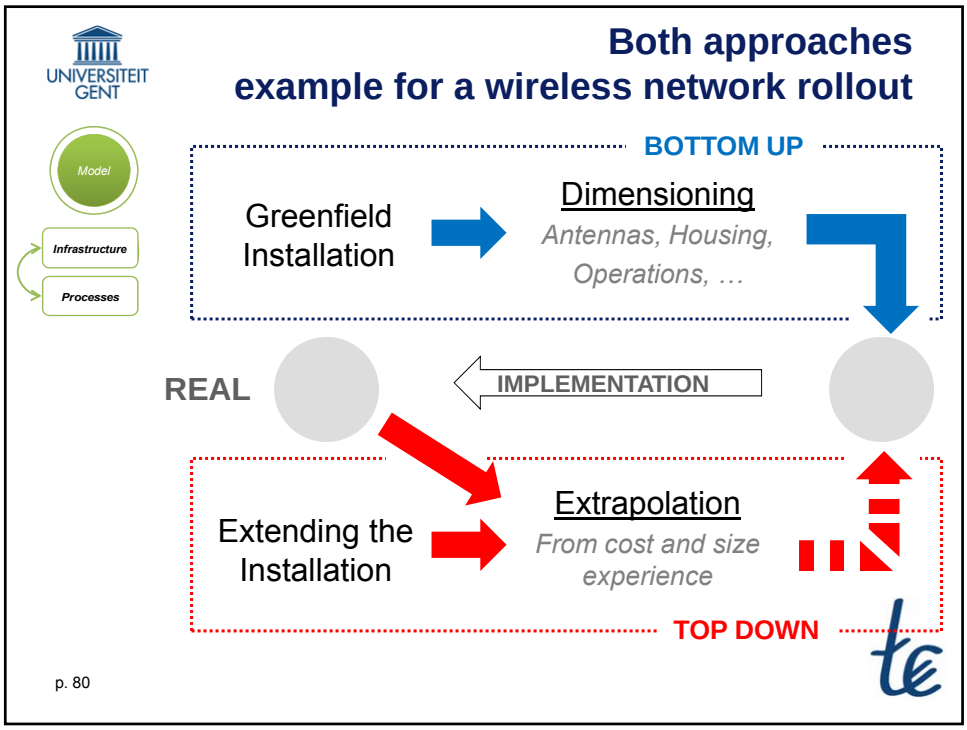
Modeling approach
Top-Down
Bottom-Up
Model
Infrastructure
Processes
Ledger
Costs
Service/ resource usage
Cost per service
Network Dimensioning
Service Demand
p. 79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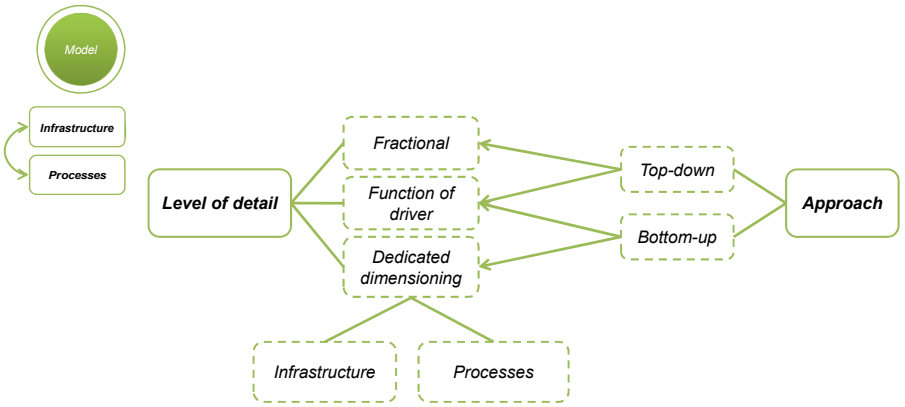
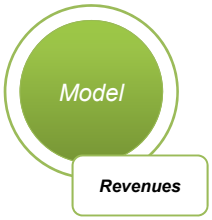
Both approaches
example for a wireless network rollout
Model
Infrastructure
Processes
BOTTOM UP
Greenfield Installation
Dimensioning
Antennas, Housing, Operations, …
REAL
IMPLEMENTATION
Extending the Installation
Extrapolation
From cost and size experience
TOP DOWN
p. 80

Approach versus level of detail



p. 81

Model revenues
in a similar way as costs



p. 82

Direct revenues

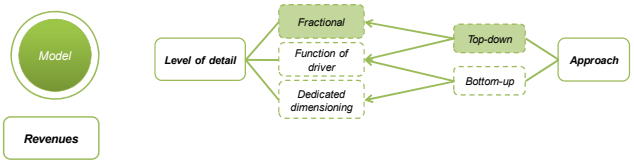
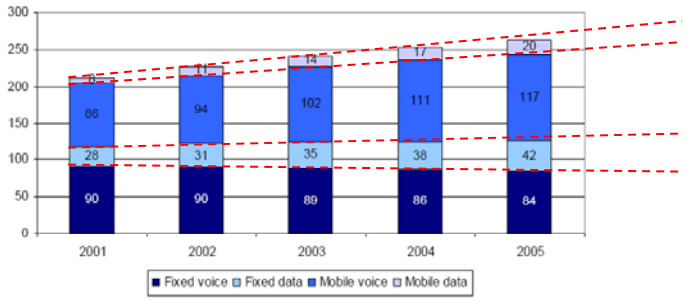


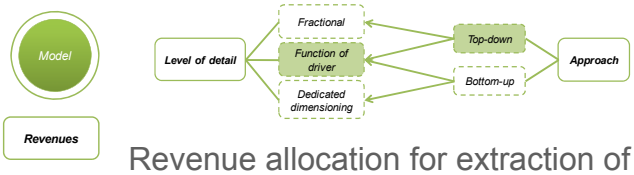
Figure 14: Telecom services revenues in EU-25, 2001-2005
EUR billions



Source: IDATE from national regulation authorities

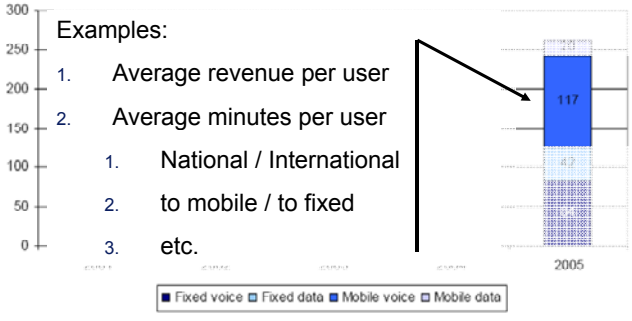
p. 83

Direct revenues



Revenue allocation for extraction of input revenues

Figure 14: Telecom services revenues in EU-25, 2001-2005
EUR billions



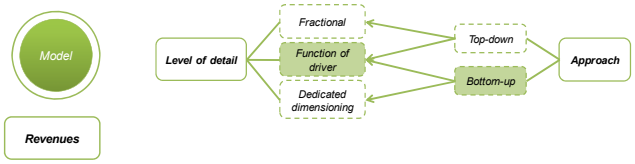
Examples:

1. Average revenue per user
2. Average minutes per user
    1. National / International
    2. to mobile / to fixed
    3. etc.

Source: IDATE from national regulation authorities

p. 84

Direct revenues

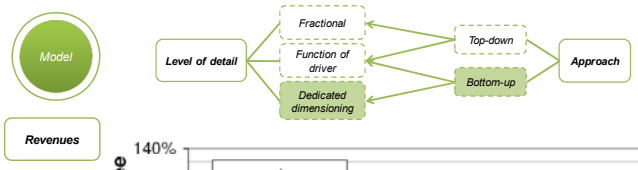


- Estimate revenues by using “simple” formulae
- Example

Subscribers x (subscription rate)
Subscribers x (avg. number of VoD / subs.)
Advertisement revenues +
Revenues for IPTV service

p. 85

Pricing

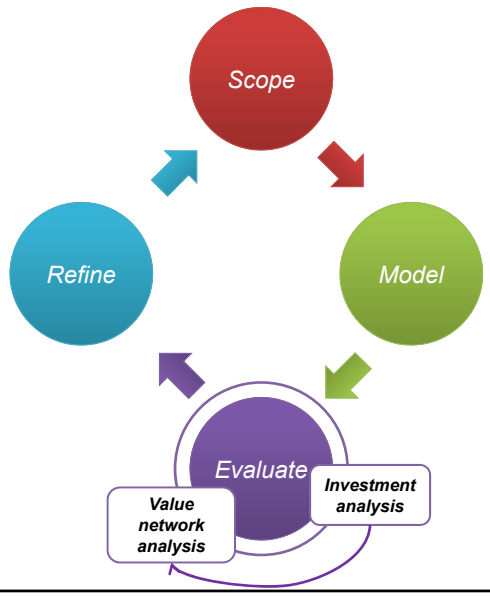


p. 86

Practical steps in techno-economic evaluation of network deployment planning

EVALUATE

Step 3: Evaluate the project



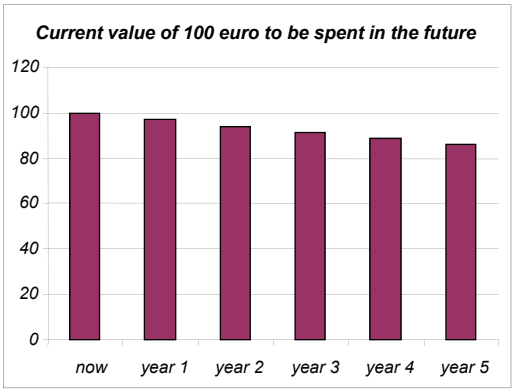
p. 88

Present value of future cash flows

Evaluate

$$C = \frac{F}{(1+i)^n}$$

where
- C = current value
- F = future expense
- r = rate of return (discount rate)
- n = years into the future



p. 89

Defining Rate of Return
Capital Asset Pricing Model (CAPM)

Evaluate

$$E(R_i) = R_f + \beta_{im}\left(E(R_m) - R_f\right)$$

where

$E(R_i)$	expected return on the capital asset
R_f	risk-free rate of interest
β_{im}	sensitivity of the asset returns to market returns
R_m	expected return of the market
$E(R_m) - R_f$	the *market premium* or *risk premium*

➔In telecom,
rate of return varies between 10% and 20%

p. 90

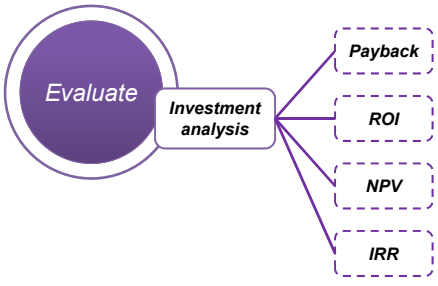
Investment decisions

Evaluate

- Cash flows used:
  - **Incremental, operational, after taxes, economical lifetime**

p. 91

Investment analysis
for static case uses traditional techniques



p. 92

(Discounted) payback time

Evaluate

Investment analysis

Payback

- **Payback time =**
  time needed to pay back initial investment

Obj.
- Payback time <= Maximum accepted payback time

+
- Indicates risk: shorter payback time = smaller risk
- Easy to use

-
- Does not take into account CFs after payback period

p. 93

Return On Investment (ROI)

Evaluate

Investment analysis

ROI

- **Return on investment = ROI =**

$$\frac{\text{average future annual cash flow}}{\text{initial investment (average over economic lifetime of project)}}$$

Obj.
- ROI >= minimum required ROI

+
- Takes into account CFs after payback time
- Takes into account size of the project (size of cash flows)

-
- Does not take into account timing of CFs

p. 94

Net Present Value (NPV)

Evaluate

Investment analysis

NPV

- **Present value of all cash flows in the investment project, discounted using the minimum required return on investment**

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t}$$

Obj.

- NPV >= 0

+

- Takes into account all CFs
- Takes into account timing
- Takes into account size of the project (size of cash flows)

-

- Dependent on considered lifetime (t)
- Does not penalize huge intermediate losses

p. 95

Internal Rate of Return (IRR)

Evaluate

Investment analysis

IRR

- **Internal rate of return = discount ratio for which present value of expenses equals present value of revenues**

$$\sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t} = 0$$

Obj.

- IRR >= required minimum

+

- Takes into account all CFs
- Takes into account timing of CFs (time value)

-

- Does not take into account size of the project
- Problems
- Multiple rates of return in case CFs exhibits 2 changes of sign
- Mutually exclusive projects (NPV and IRR give opposite advice

p. 96

NPV compared to IRR

- Two mutually exclusive projects

	CF0	CF1	NPV (r=0)	IRR
Small budget	-1 euro	1.5 euro	0.5 euro	50%
Large budget	-10 euro	11 euro	1 euro	10%

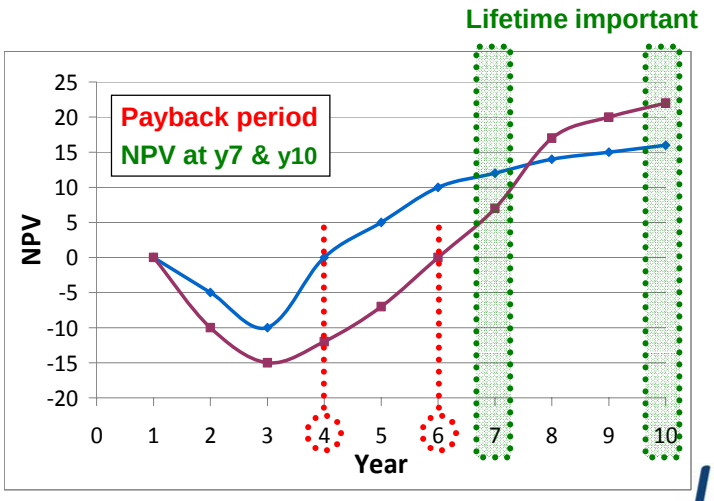
- NPV ≠ IRR
- Explanation: incremental IRR
  - **small budget project is beneficial**
  - **beneficial to invest additionally?**

	CF0	CF1	NPV (r=0)	IRR
Large budget instead of small budget	-10 – (-1) = -9 euro	11-1.5 = 9.5 euro	0.5 euro	0.5/9 = 5.55..%

➔ follow NPV

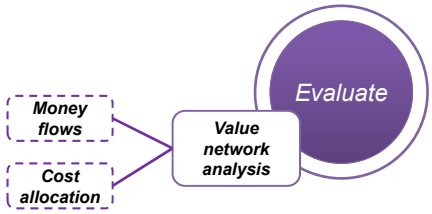
p. 97

Comparing two projects using multiple methods



p. 98

Value network analysis
adds quantitative results to business model



p. 99

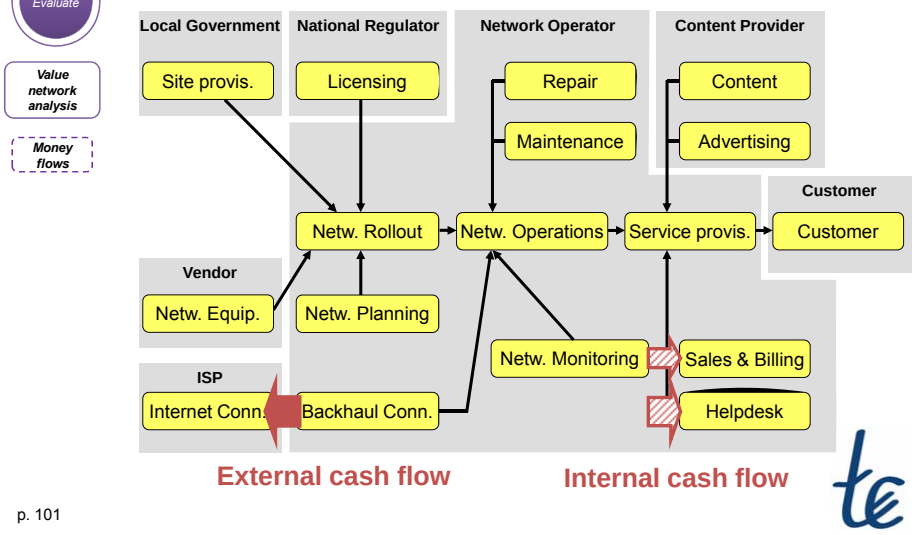
Value network analysis
allows to compare different models

- Third party model
  - Basic model with a lot of cash flows between actors
  - Suited for successful business cases, but can be very risky for projects requiring high investments
- Integrator model
  - Integrator makes deals with a lot of actors in the field
  - Project lead by the integrator who shares in the profits
- Consortium model
  - A lot of costs can be saved
  - Negotiation needed for revenue allocation, depending on the considered investment efforts from each party

p. 100

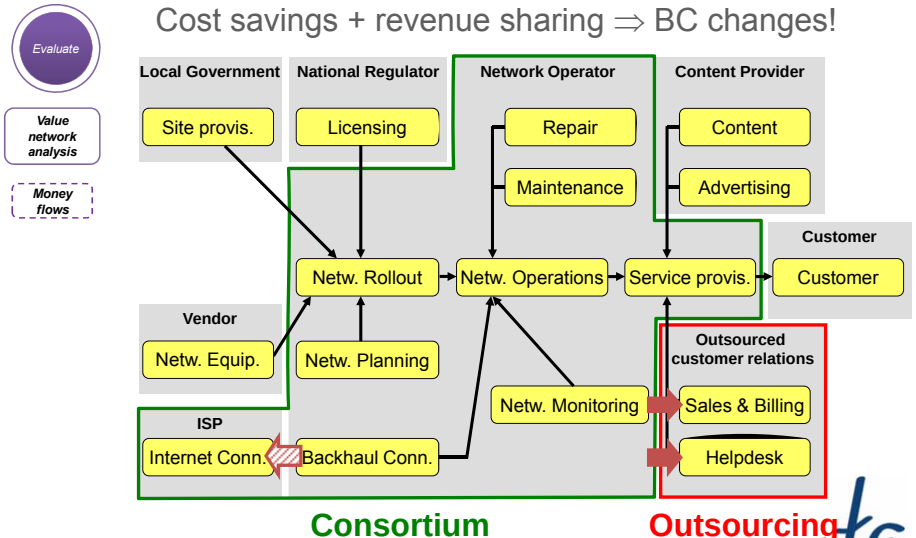
Value network analysis
for a wireless network

Cost savings + revenue sharing ⇒ BC changes!



Value network analysis
for a wireless network

Cost savings + revenue sharing ⇒ BC changes!



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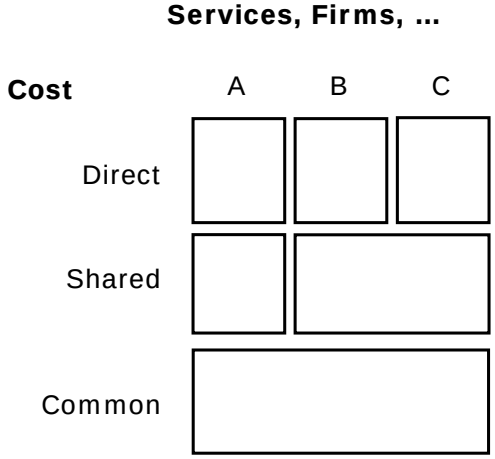
Evaluate

Value network analysis

Cost allocation

When different services, firms or … share part of their costs..



p. 103

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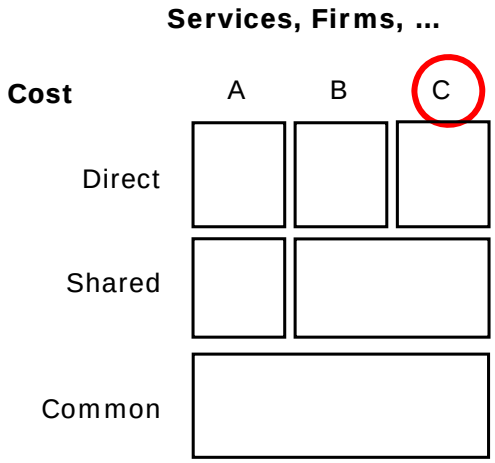
Evaluate

Value network analysis

Cost allocation

..it is often necessary or useful to know which part of the cost is linked to which service



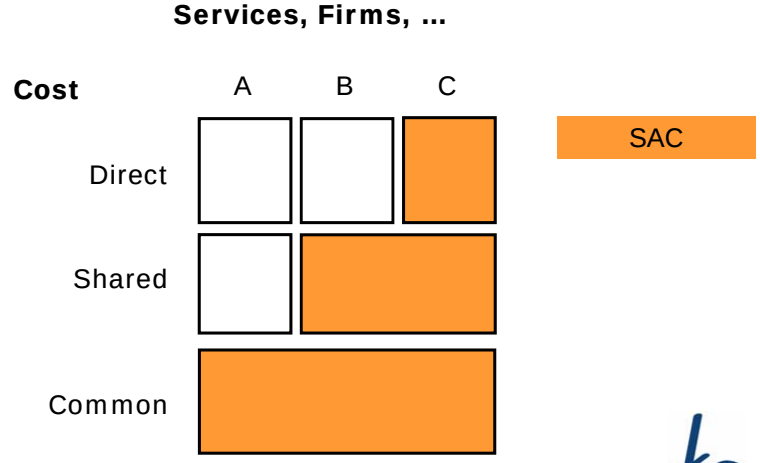
p. 104

Stand Alone Cost
allocates as a stand-alone installation

Evaluate

Value network analysis

Cost allocation



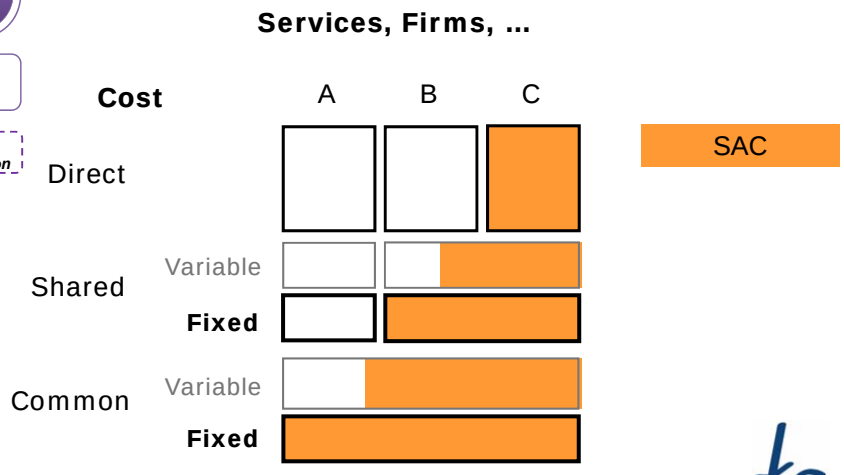
p. 105

Stand Alone Cost
allocates as a stand-alone installation

Evaluate

Value network analysis

Cost allocation



p. 106

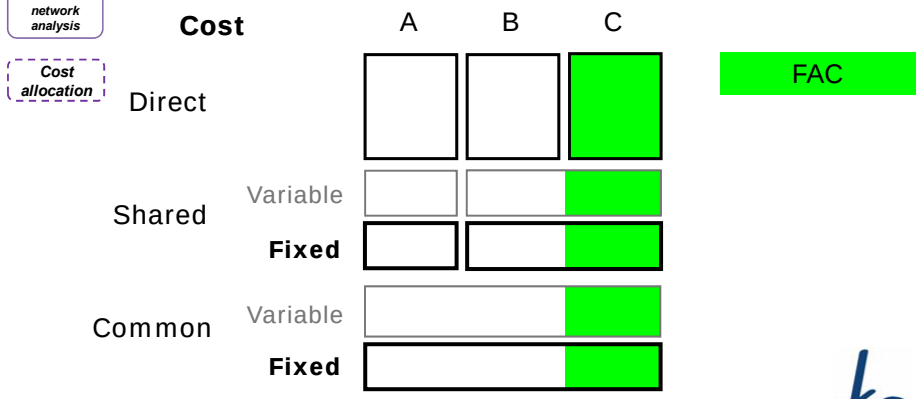
Fully Allocated Cost
allocates the costs more "fairly"

Evaluate

Value network analysis

Cost allocation

Services, Firms, …



p. 107

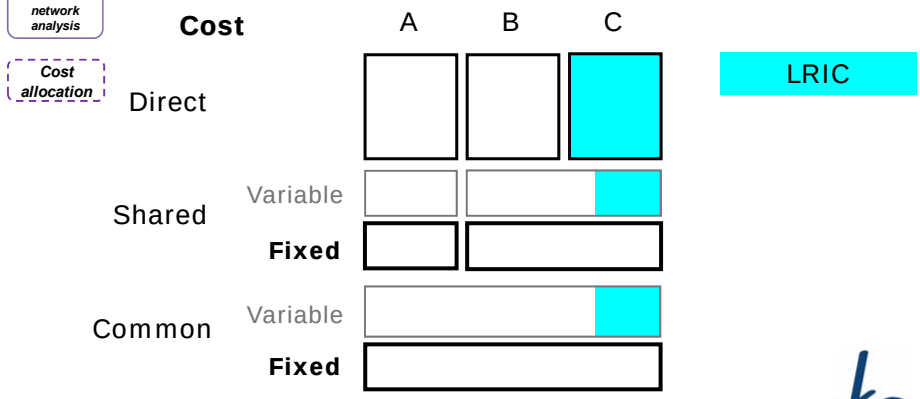
Long Run Incremental Cost
allocates only the incremental costs

Evaluate

Value network analysis

Cost allocation

Services, Firms, …



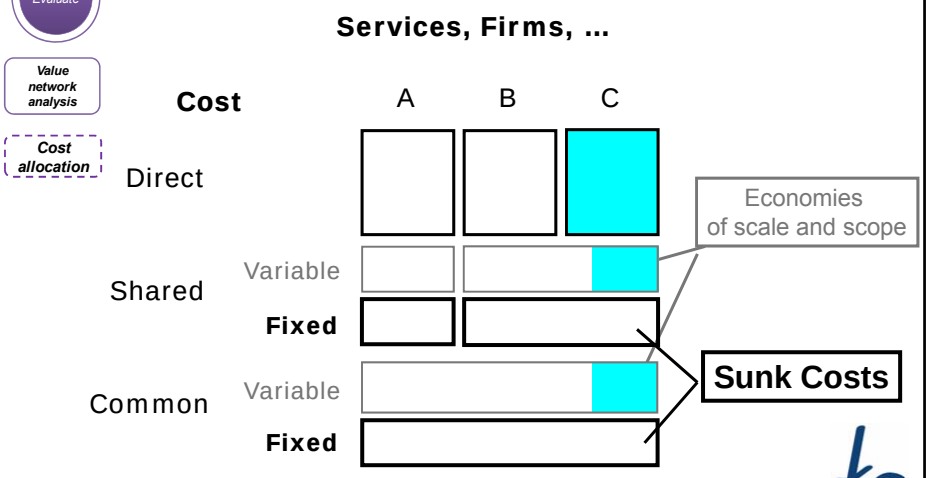
p. 108

Long Run Incremental Cost
allocates only the incremental costs

Evaluate

Value network analysis

Cost allocation



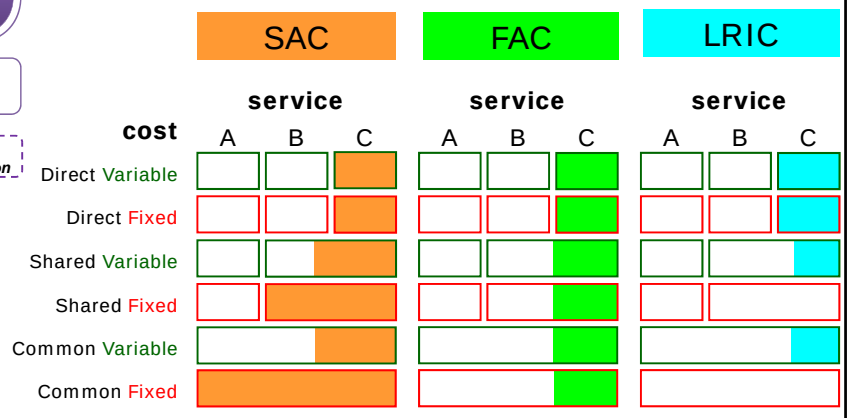
p. 109

An overview
from highest to lowest allocated cost

Evaluate

Value network analysis

Cost allocation



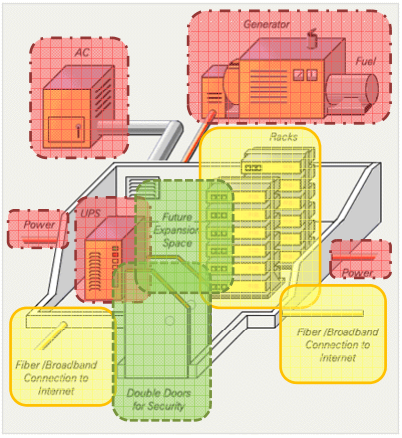
p. 110

Cost allocation
example for a data center

Evaluate

Value network analysis

Cost allocation



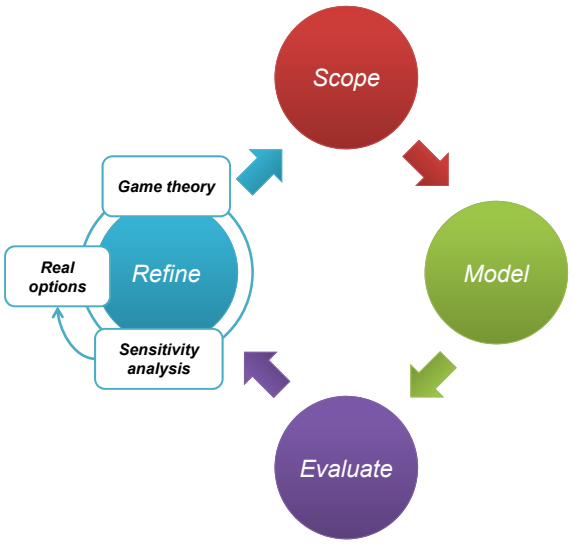
- **Direct Variable**: Maintenance, replacement, extensions, etc.
- **Direct Fixed**: Specific software and hardware, Installation, etc.
- **Shared Variable**: Servers installed, Software-licenses, etc.
- **Shared Fixed**: Telecom cabling and equipment, Backbone connection, etc.
- **Common Variable**: Powering, Cooling, etc.
- **Common Fixed**: Housing, Management, Licenses, etc.

p. 111

Practical steps in techno-economic evaluation of network deployment planning

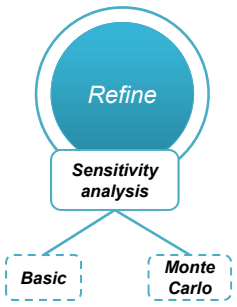
REFINE

Step 4: Refine the results



p. 113

Sensitivity analysis
indicates impact of uncertainty



p. 114

Sensitivity analysis

- Problem: a lot of uncertain input parameters
  - **Adoption parameters (end adopt., adopt. speed)**
  - **Cost parameters (CapEx, OpEx)**
  - **Revenue parameters (optimal tariff)**
- Goal: determining the impact of these parameters
  - **Discarding the parameters with a marginal impact**
  - **Giving extra attention to the important parameters**

Refine

Sensitivity analysis

Basic

Basic sensitivity analysis

- Varying one parameter at a time
- Holding the other parameters fixed

⇒ First indication of the impact of each of the input parameters

- Much-used measure for this impact
  - **Normalized contribution p_j of each parameter j to the variance σ_j^2 of the outcome**

$$p_j = \frac{\sigma_j^2}{\sum_{j=1}^{m} \sigma_j^2} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_{ij}-\mu)^2}{\sum_{j=1}^{m}\left(\frac{1}{n}\sum_{i=1}^{n}(x_{ij}-\mu)^2\right)} = \frac{\sum_{i=1}^{n}(x_{ij}-\mu)^2}{\sum_{j=1}^{m}\sum_{i=1}^{n}(x_{ij}-\mu)^2}$$

Refine

Sensitivity analysis

Basic

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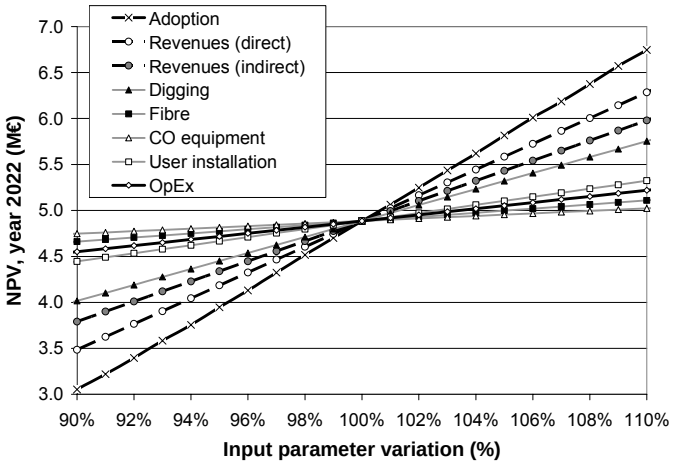
Refine

Sensitivity analysis

Basic

Basic sensitivity analysis
Example: FTTH network



p. 117

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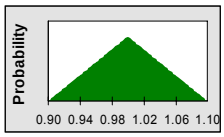
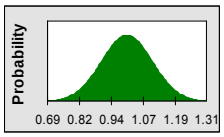
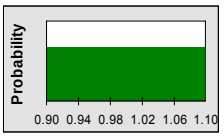
Refine

Sensitivity analysis

Monte Carlo

Sensitivity by Monte Carlo simulations
based on probability for uncertainties

Triangular	Gaussian	Uniform
		
Minimum: 0.90 Likeliest: 1.00 Maximum: 1.10	Mean: 1.00 Std. Dev.: 0.10	Minimum: 0.90 Maximum: 1.10

p. 118

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Sensitivity by Monte Carlo simulations
Points of attention

Refine

Sensitivity analysis

Monte Carlo

- Questions:
  - **Which is the most-suited distribution?**
  - **Over which range are the parameters varied?**
- Possible sources of information
  - **Information from historical data**
    - Stock information on vendors
    - Cost-erosion figures
  - **Information from fitting reliability**
    - e.g. deviation from optimal fitting to a fitting over first 50% of the data-points
  - **Commonly used example ("benchmark")**
    - Gaussian, standard deviation = 10% (compared to mean value)
    - Can be refined by adapting some distributions in a next step

p. 119

Sensitivity by Monte Carlo simulations
Most interesting results

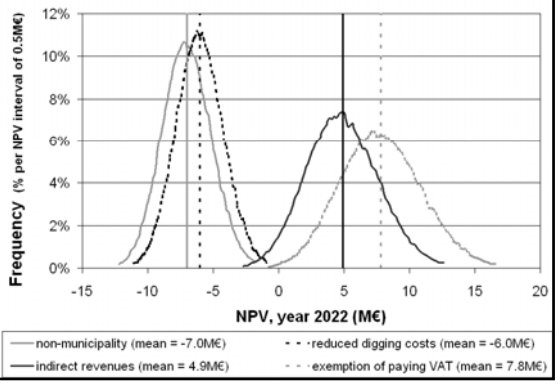
Refine

Sensitivity analysis

Monte Carlo

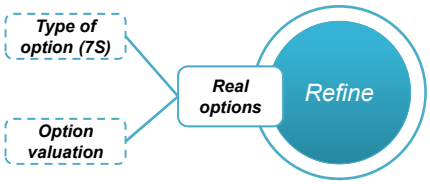
- Impact of uncertain parameters on the outcome (e.g. normalized contribution of each parameter to the variance of the outcome)
- Forecast of the outcome distribution
- Multi-year trend analysis of the outcome

E.g.: NPV forecast for an FTTH rollout considering different business models



p. 120

Real options
allow to value flexibility to react to uncertainty



p. 121

Real options as an extension of NPV

- Weak aspect of NPV evaluation
  - **Assumes strict planning, with no flexibility**
- Real projects
  - **Anticipate on changing market circumstances**
- Solution: “real options thinking” principle

p. 122

Origin: financial options

Refine

Real options

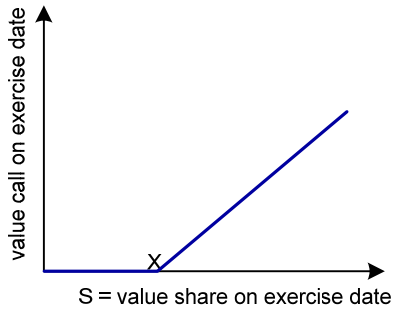
An option gives the buyer
the right to buy or sell
an asset
for a predetermined exercise price
over a limited time period.

p. 123

Value of call option on exercise date

Refine

Real options



p. 124

Value of call option on exercise date

Refine

Real options

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

p. 125

Financial versus real options

Refine

Real options

Type of option (7S)

	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

p. 126

Types of options: 7S framework

Refine

Real options

Type of option (7S)

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

p. 127

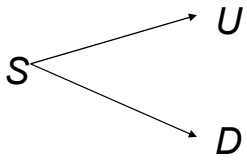
Option valuation: binomial method

Refine

Real options

Option valuation

- For European call option
- Assumes 2 possible end values



- Can be expanded for more time periods: software needed

p. 128

Option valuation: Black and Scholes

- 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**
  - **stock prices *S* follow Brownian motion (random walk)**
    dS = μSdt + σSdw

p. 129

Option valuation: simulation

- Introduces a flexible planning in the calculations
- Applicable on any type of option
- Start from description of static case (pre-defined planning)
  - **Indicate uncertainty**
  - **Indicate flexibility**
- Choose a "decision variable" to adapt the planning
  - **Evaluation parameters (e.g. NPV, IRR, payback time)**
  - **Uncertain input parameters (e.g. take rate, investment costs)**

p. 130

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Refine

Real options

Option valuation

Option valuation: Example

- Deploying parking sensor network in a city
  - **Two zones**
  - **Uncertainty factors:**
    - Future chance of getting caught
    - Sensor failure
    - …
- Starting small or large?
  - **Low vs. high investment?**
  - **Low vs. high payoff?**
- Base case:
  - **NPV calculation**

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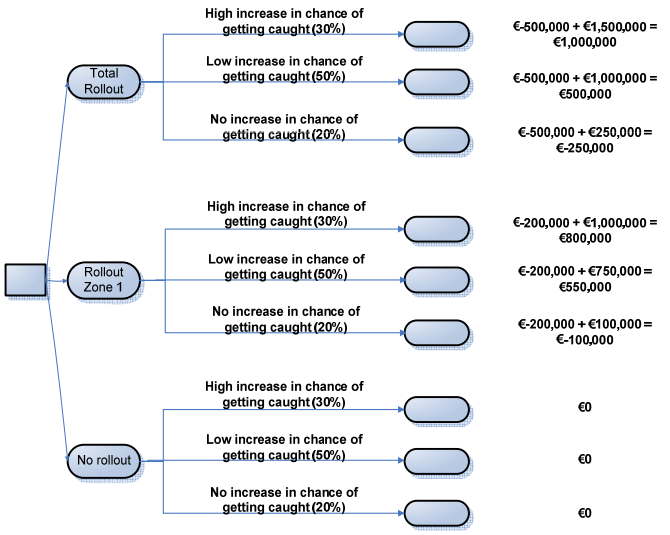
Refine

Real options

Option valuation

Base case: starting small or large?



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Base case: starting small or large?

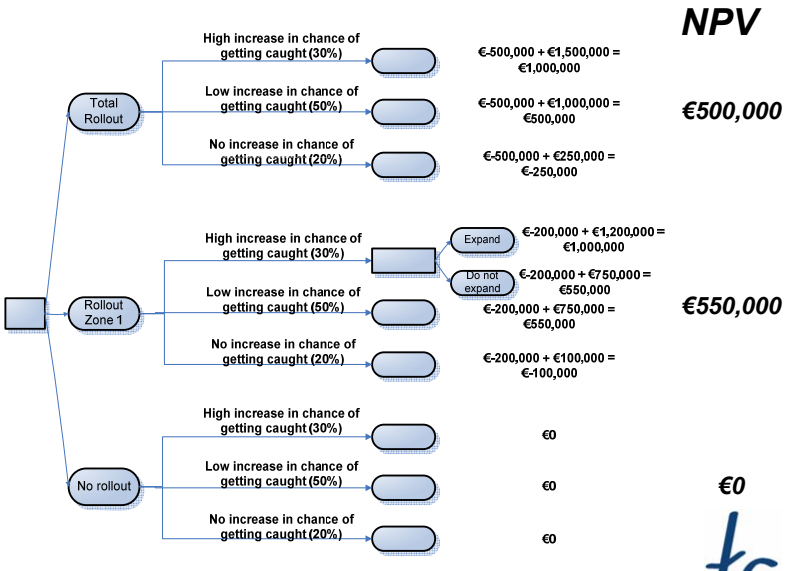
Refine

Real options

Option valuation

- Base case:
  - **Choose the total rollout**
- Option to expand:
  - **Start of small, evaluate expansion next year**
  - **Expansion means extra investment**
  - **Delayed expansion = missed payoffs**
  - **New NPV calculation**

Base case: starting small or large?



Base case: starting small or large?

Refine

Real options

Option valuation

- Now choose small rollout with expansion option
- Value expansion option:
  - **Value small rollout with option – total rollout without option**
  - **€550,000 - €500,000**
  - **€50,000**

Option valuation: simulation
Example: flexible rollout scheme, method

Refine

Real options

Option valuation

- Rollout of a Parking Sensor Network
  - **Project of 6 years**
  - **Year 0: rollout in zone 1**
  - **Flexibility: year of zone 2 rollout**
  - **Fast, normal and slow rollout speed**

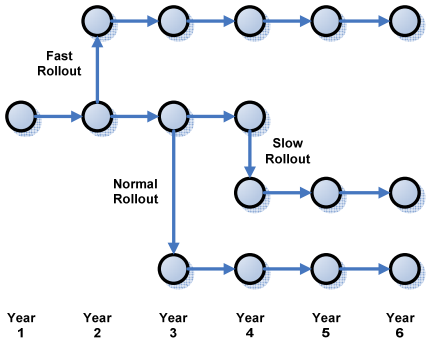
Option valuation: simulation

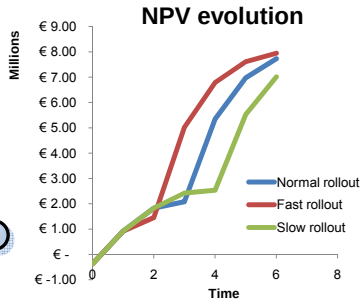
Example: flexible rollout scheme, method

Refine

Real options

Option valuation





p. 137

Option valuation: simulation

Example: flexible rollout scheme, method

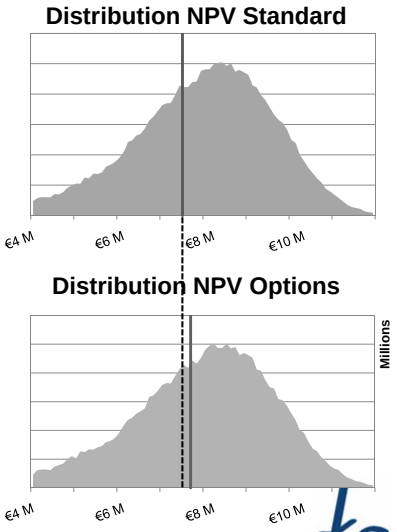
Refine

Real options

Option valuation

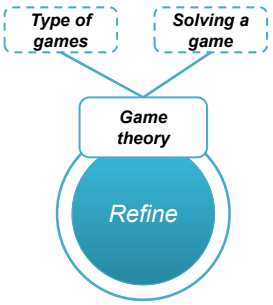
Simulation

- Implement **uncertainty**
  - **Distribution standard NPV**
  - **Mean = 7.52 million**
- Implement **flexibility**
  - **Choose best case**
    NPV = MAX(slow, normal, fast)
  - **Mean = 7.72 million**



p. 138

Game theory
models competition between different players



p. 139

Game theory

Game theory is a discipline aimed at modeling situations in which decision makers have to make specific actions that have mutual, possibly conflicting, consequences.

p. 140

Game theory

Refine

Game theory

1. **Modeling**
   Not real – but realistic model of interaction
2. **Decision makers**
   Any number of so-called "players" (though often 2)
   e.g. Operators, Vendors, Regulators, Customers, etc.
3. **Specific actions**
   Each player has dedicated actions (not the same)
   e.g.: Start or cease rollout, buyout competitor, …
4. **Mutual**
   Combined calculation model with interaction of players
   e.g.: competition for adoption, effects of EOS, etc.
5. **Possibly conflicting**
   Competitive and cooperative actions
   Final goal = optimize own utility within the game
6. **Consequences**
   Utility or payoff: valuation of the profit of each player
   e.g.: NPV, customer perceived value, cooperative profits, etc.

p. 141

Game theory comes in many different flavors

Refine

Game theory

Type of games

Cooperative	↔	Non Cooperative
Symmetric	↔	Asymmetric
Zero sum	↔	Non Zero Sum
Simultaneous	↔	Sequential
Perfect information	↔	Non Perfect Information
Infinite	↔	Finite
Discrete	↔	Continuous
Static	↔	Multi-stage
Meta Games		

p. 142

Visualization of a game theoretic model

Refine

Game theory

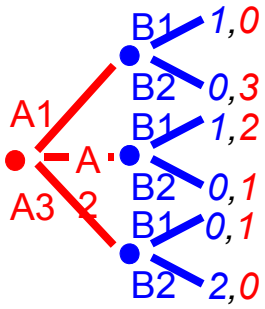
Type of games

Normal Form

Form

	A1	A2	A3
B1	1,0	1,2	0,1
B2	0,3	0,1	2,0

Extensive



p. 143

Visualization of a game theoretic model

Refine

Game theory

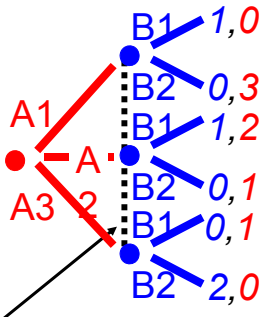
Type of games

Normal Form

Form

	A1	A2	A3
B1	1,0	1,2	0,1
B2	0,3	0,1	2,0

Extensive



Imperfect information

Player B does not know what player 1 has done

p. 144

Approaches towards finding an equilibrium

Refine

Game theory

Solving a game

Nash equilibrium

no player can gain by changing unilaterally his strategy

Iterated dominance

Dominance: *strategy better than another strategy independent of opponents*

Iterated: *iteratively removing dominated strategies*

Backward induction

Cut unrealistic branches from a multi-stage game tree moving in a recursive manner from the latest action to the first action

Example of iterated dominance

Refine

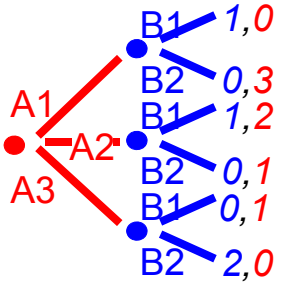
Game theory

Solving a game

Normal Form

	A1	A2	A3
B1	1,0	1,2	0,1
B2	0,3	0,1	2,0

Extensive Form



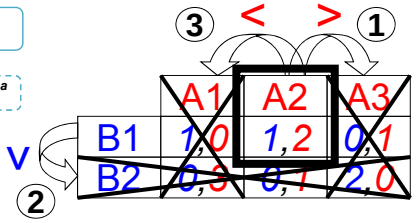
Iterated dominance (normal form)
Backward induction (extensive form)

Refine

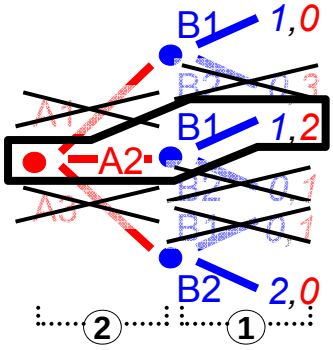
Game theory

Solving a game

Normal Form



Extensive Form



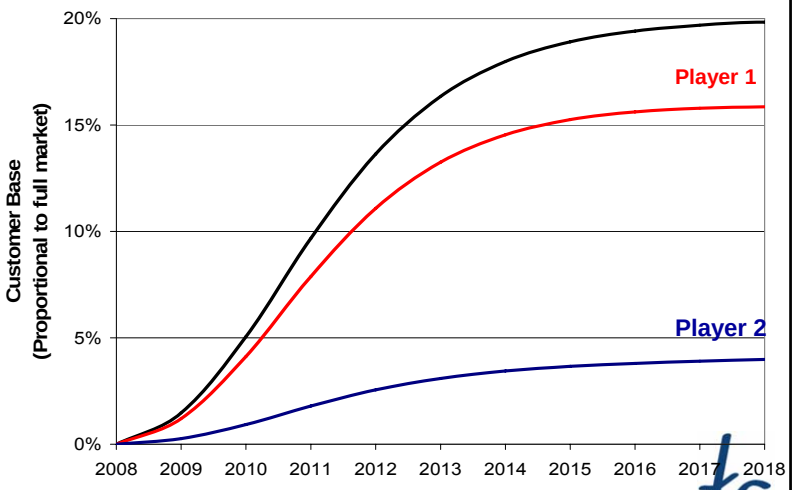
p. 147

Market for wireless network deployment

Refine

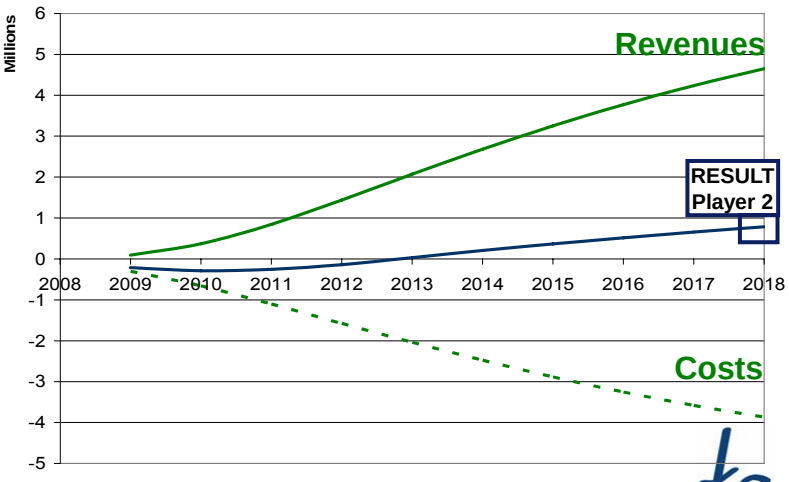
Game theory

Solving a game



p. 148

Result (NPV) = Revenues - Costs



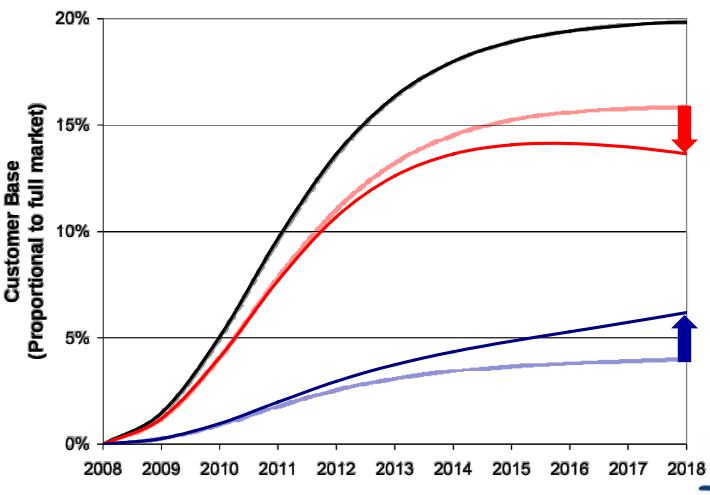
Refine

Game theory

Solving a game

p. 149

Player 1 increases his price



Refine

Game theory

Solving a game

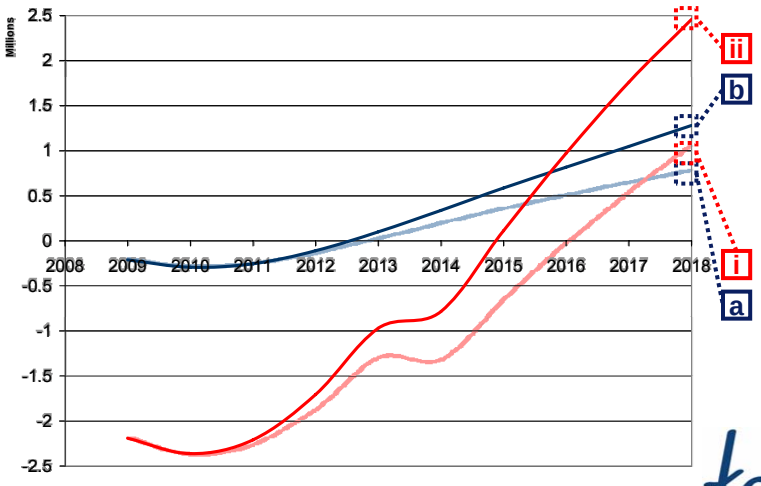
p. 150

Results (NPV) for the different scenarios
(original [i,a] & higher price p1 [ii,b])

Refine

Game theory

Solving a game



p. 151

Full matrix for both players strategies

Refine

Game theory

Solving a game

Player 1 \ Player 2	Low	High	...
...			
Low	i a		
High	ii b		
...			

p. 152

Playing the realistic game (iterated dominance), for two competing wireless access networks

Refine

Game theory

Solving a game

NPVs (M€) for different service prices: 1st iteration

Player 1: WiFi \ Price (€)	Player 2: 3G femtocells 22		23		24		25		26	
22	2.467	1.360	2.565	1.367	2.680	1.356	2.791	1.358	2.901	1.280
23	2.482	1.449	2.600	1.488	2.722	1.468	2.831	1.437	2.935	1.417
24	2.512	1.554	2.646	1.585	2.749	1.577	2.865	1.532	2.979	1.509
25	2.507	1.637	2.636	1.679	2.773	1.683	2.906	1.650	3.021	1.607
26	2.479	1.700	2.627	1.771	2.771	1.785	2.899	1.764	3.035	1.707

3G femto: *NPV 2_22 < NPV 2_23 & NPV 2_26 < NPV 2_25*

WiFi: *NPV 1_22,23 < NPV 1_24*

p. 153

Playing the realistic game (iterated dominance), for two competing wireless access networks

Refine

Game theory

Solving a game

After 2nd iteration ➔ example with 2 Nash Equilibria

Player 1: WiFi \ Price (€)	Player 2: 3G femtocells 22		23		24		25		26	
22										
23										
24			2.646	1.585	2.749	1.577	2.865	1.532		
25			2.636	1.679	2.773	1.683	2.906	1.650		
26			2.627	1.771	2.771	1.785	2.899	1.764		

3G femto: *NPV 2_25 < NPV 2_24*

WiFi: *NPV 1_26 < NPV 1_25*

p. 154

Practical steps in techno-economic evaluation of network deployment planning

TOOL OVERVIEW

Tools for infrastructure & cost modeling

Toolkit	application	license
OPNET SP Guru / IT Guru	Network planning and (cost-effective) optimization	Academic ed. Commercial
VPI OnePlan	Network design & planning Economic analysis	Commercial
TONIC	Techno-economic tool Spreadsheet based Including a cost database	Negotiation with IST-FP5 TONIC partners

p. 156

Tools for process modeling

Toolkit	BPMN	XPDL	license
CaseWise	As an extension	As an extension	Commercial, Free for TMForum members
Mega: MegaProcess	yes	yes	Commercial
IDS Scheer: ARIS	yes	yes	Commercial
MS Visio	yes	no	Commercial
Tibco business studio	yes	yes	Free

p. 157

Tools for process simulation

Toolkit	Graphical modeling	Open Source	License
GPSS	No	No	Free limited ed. Commercial
VenSim (including M-Wave model)	Yes	No	Free limited ed. Commercial
SimJava	No	Yes	Free
Ptolemy II	Yes	Yes	Free

p. 158

Tools used within refinement

Toolkit	Type	Open Source	License
Gambit	Game theory	Yes	Free
Jannealer	Optimization by means of Simulated annealing	Yes	Free
Linear programming tools (e.g. solver, mathlab, etc.)	Integer Linear Programming	Typically not	Commercial
Crystal Ball	Sensitivity analysis and RO by simulation	No	Commercial

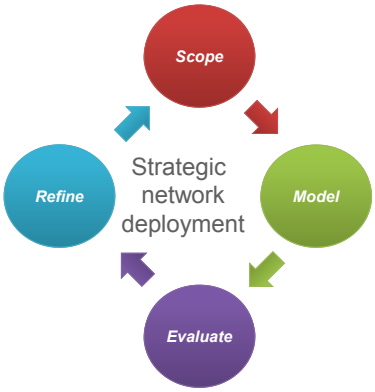
p. 159

Practical steps in techno-economic evaluation of network deployment planning

SUMMARY AND CONCLUSIONS

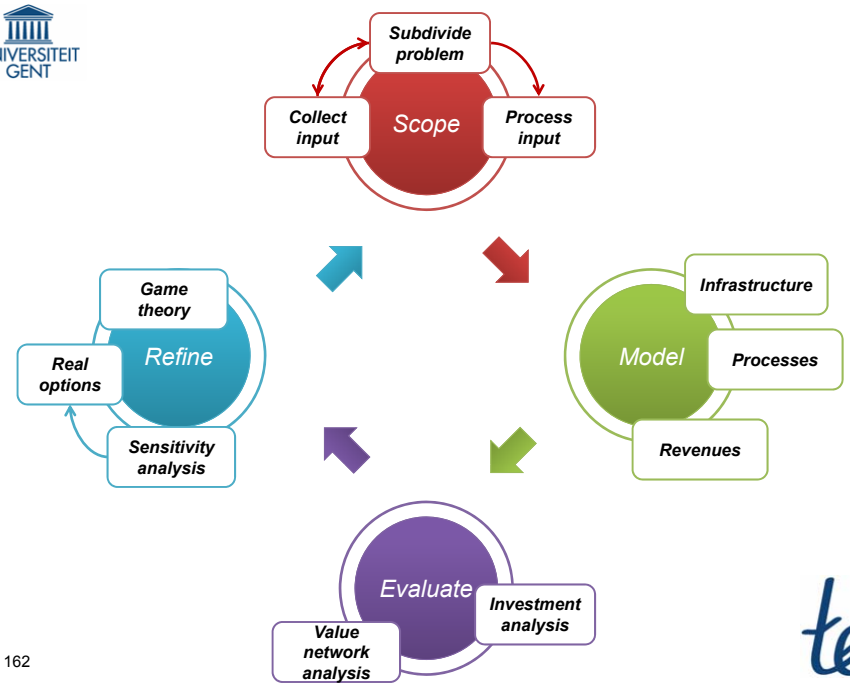
Practical steps in network deployment planning

- Overview different steps
- Models to be used



- Overall picture is important
  - Techno-economics: not only technology
  - Know impact of certain part in overall costs/revenues
- Choose required level of detail for the different parts
  - Focus on main cost driving aspects first
  - Don't get lost in detail

p. 161



p. 162

Practical steps in techno-economic evaluation of network deployment planning

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Thanks for your attention!

Any questions?

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