Bridging the gap in transport project evaluation: Accounting for the inaccuracies in demand forecasts and construction costs estimations

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http://www.concept.ntnu.no/english/

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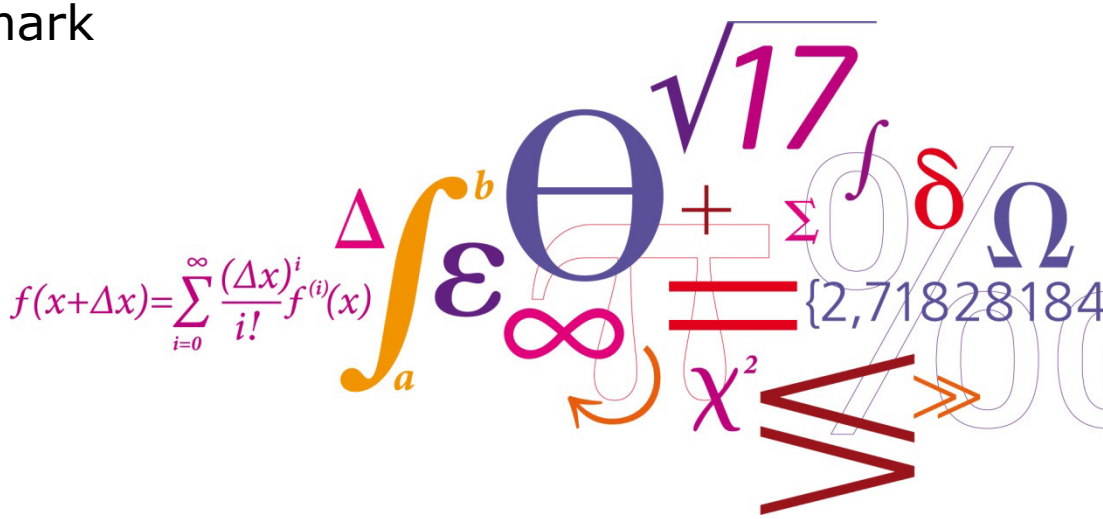
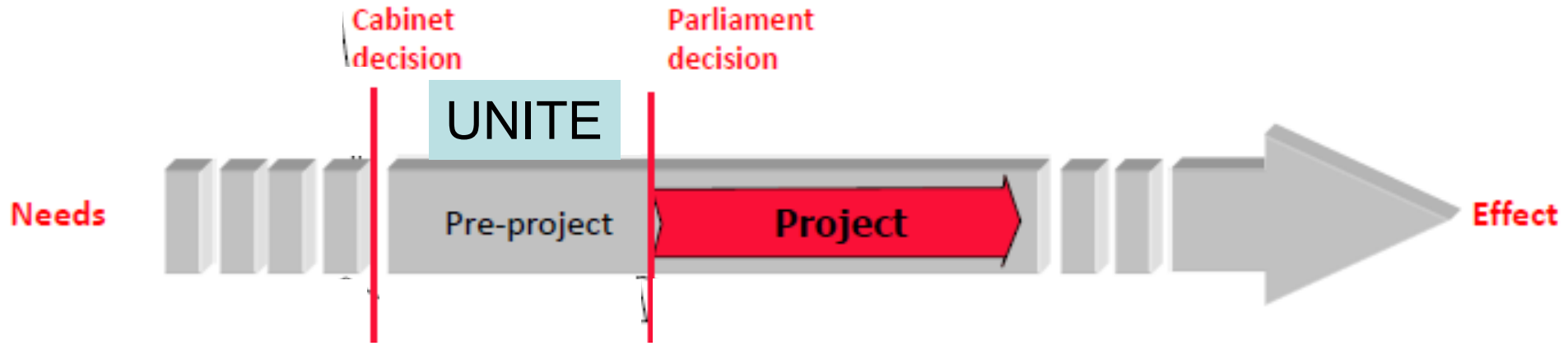
CONCEPT Symposium
Friday September 26th 2014



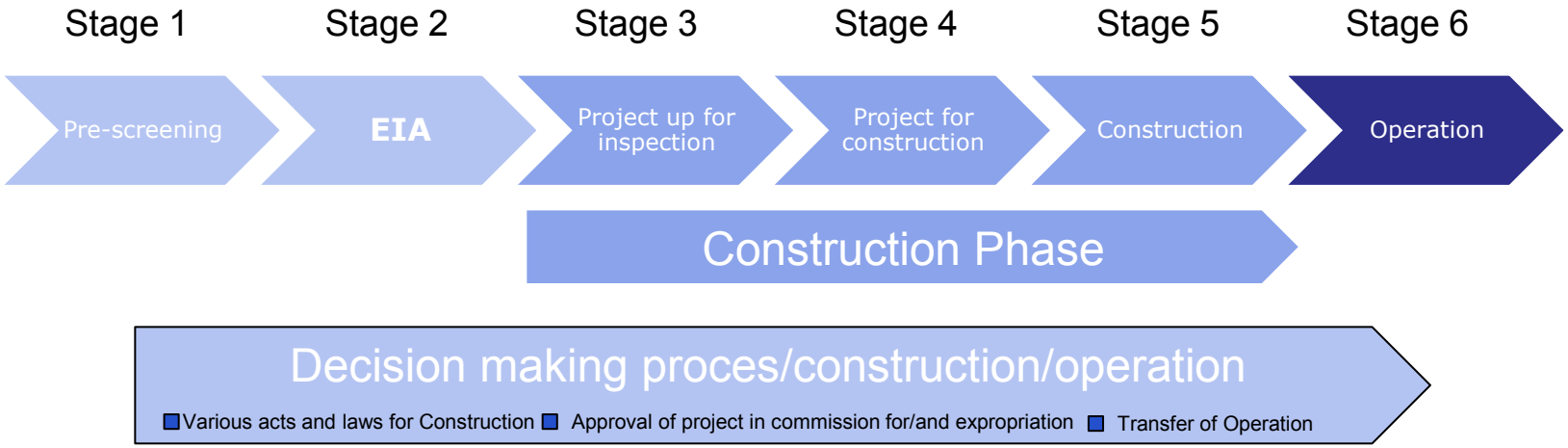
DTU Transport
Department of Transport

Background



- Quality Assurance Schme QA1 and QA2
- The following will lie in between – seeking to ensure reliable and valid CBA, investment cost and benefits (demand)

Assessment of Transport infrastructure in DK



- In between stage 2 and 3 lies the Finansial analysis and socio-economic analyses that are of interest

- However, politician CAN make shortcuts – i.e. skip one of the three steps put up before

Construction of Danish system

Current version from 2003: Manual for Socio-economic analysis in the Transport Sector

Current version from 2010: Socio economic assessment of Environmental projects

Current version from 2005: Guideline on socio-economic analyses in the Energy Sector

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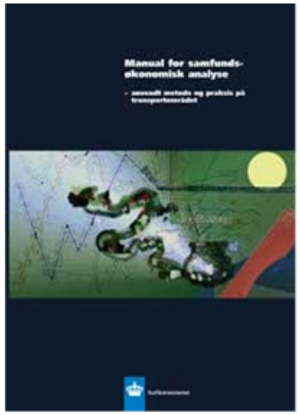


Working with uncertainty

- Cost overrun and benefit shortfall
- Introduction of a new construction law
- The UNITE project has constructed a decision support model and database to support the latter.
- Huge uncertainties in cost and demand estimation still exists
  - Obviously not only for transport infrastructure projects
- Impacts that are ”hard to quantify” are not treated
  - Predict and Provide regime

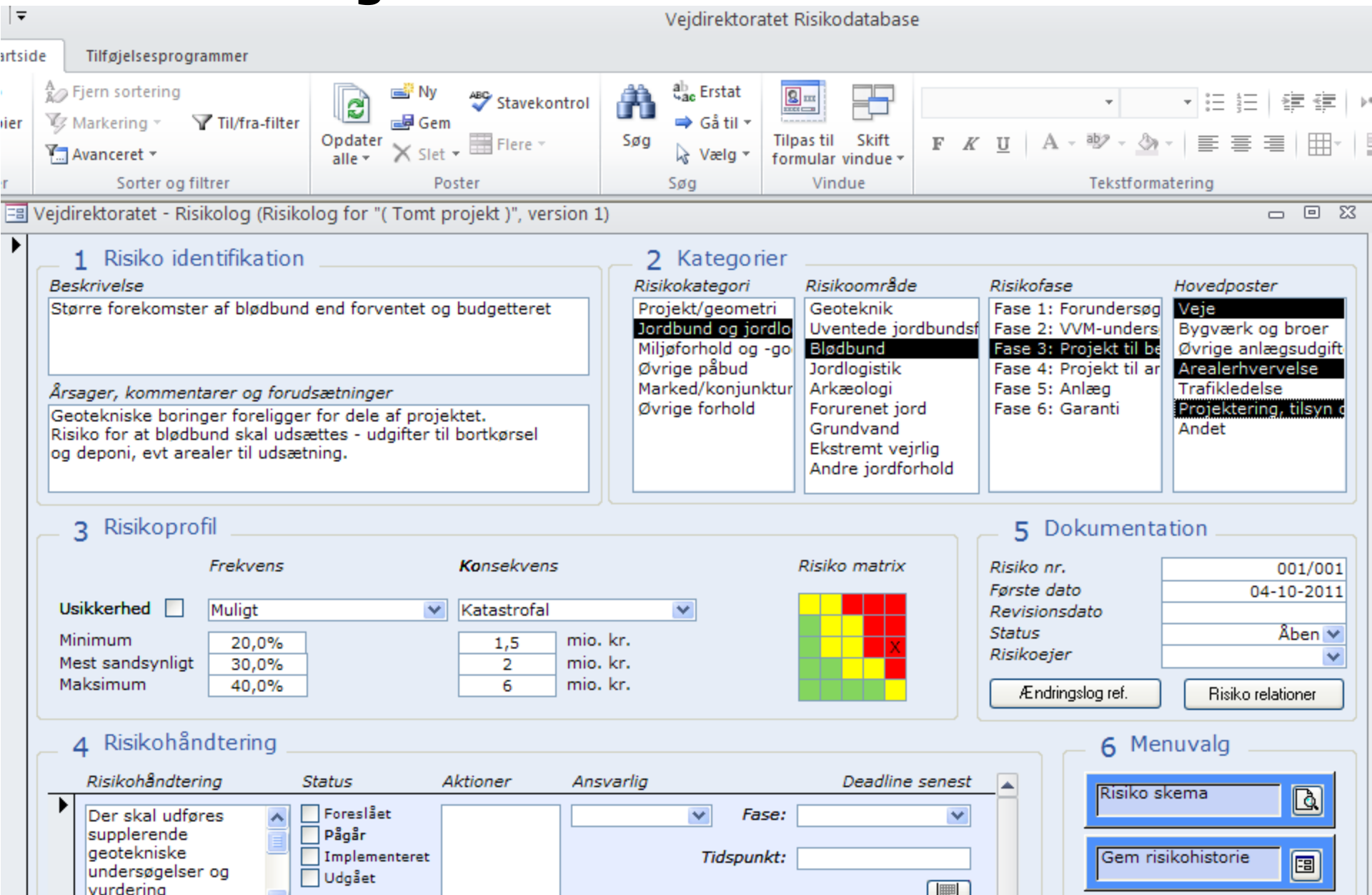
Eurovision song contest in CPH 2014 - Cost overrun 77 mio DKK (budget of 34 mio DKK)

New principles in budgetting

- In 2007 it was decided to introduce new budgeting principles for construction projects. It was further decided that the principles first should be tested on the transport ministry area (road & rail)

- The key principles are:
  - Strenghtening the internal quality assurance of the estimated construction cost budget
  - New external quality assurance of the estimated construction cost budget (by an external cost budget (by an external consultant engaged by the Ministry of Transport Department).
  - A new ”change log”
  - A new risk management regime

Risk Management Database

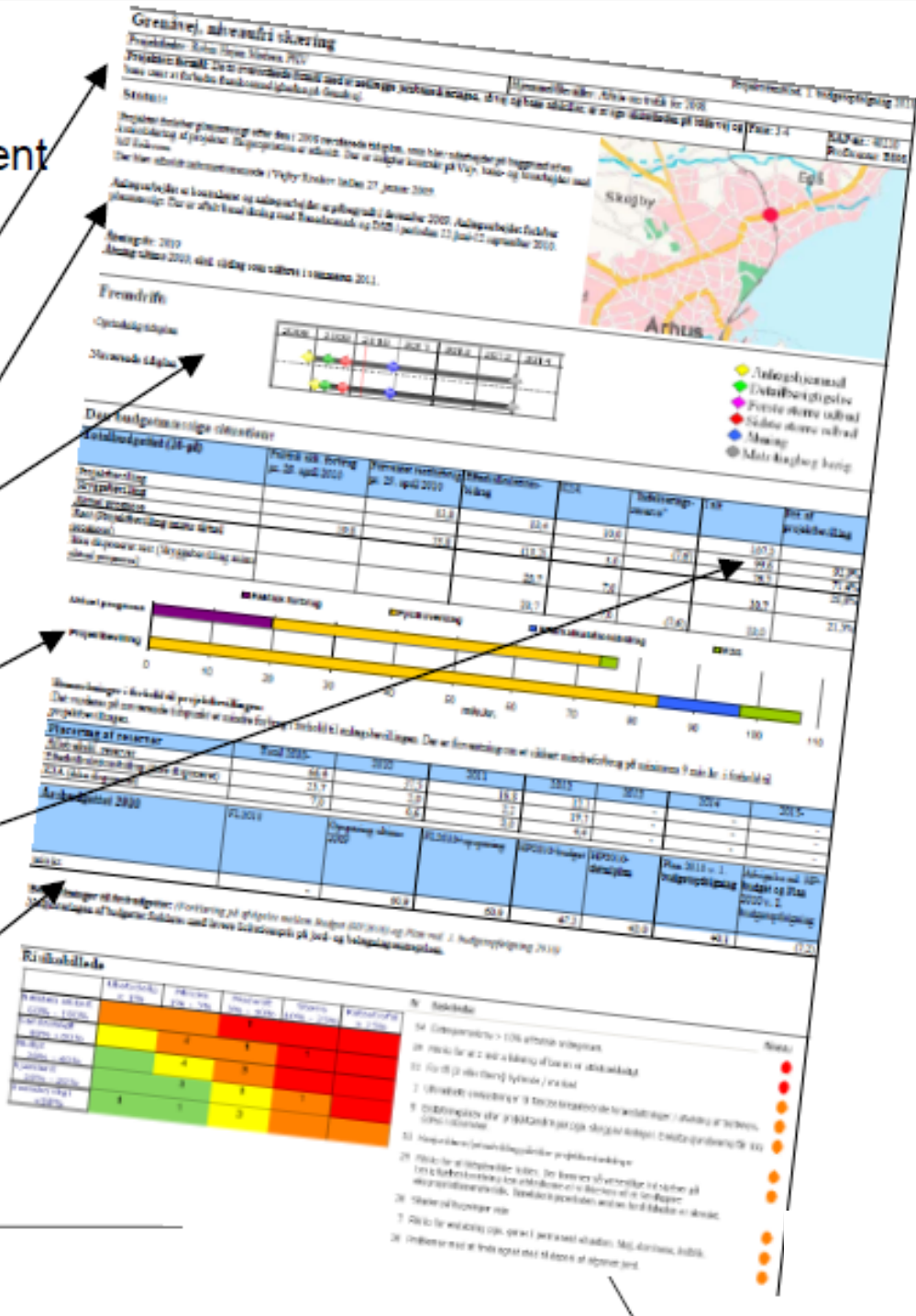


The ”One Pager”

Provides an overview for the management of the current status of each project concerning:

- Master data (Construction Law, Appropriation, Purpose, Opening year)
- Status from the Project Manager
- Timeline with milestones
- Project budget vs. Appropriation
- ”Shadow Appropriation” (the estimated future appropriation in the future price index)
- Current vs. Initial annual budget

Risk matrix and Top 10 risks



Change Log

Type Name Number Resume Fase Main budget element Financing Initiated by Category Status

ÆNDRINGSLOG

Ændrings-type	Ændring	Ændrings-nummer	Ændringsresume	Fase	Overslag ændring i alt	Finansiering				Initieret af												Ændrings-kategori			Ændringsstatus			
Ny teknologi					0																							
	I alt				0	0,00	0,00	0,00	0,00																			
Kvalitet / Påbud	Forlodseksspropriation	6815-3-01	Forlodseksspr. af 2 ejendomme	3	-0,03	-0,03														x	x			7. sep. 2006	7. sep. 2006		7. sep. 2006
	Stioverføring	6815-3-02	Stioverføring ved Bodholtvej	3	3,14			3,14		x											x			27. okt. 2005	27. okt. 2005		27. okt. 2005
	Adgangsvej i Pårup	6815-3-06	Adgangsvej inddrejdes i projektet	3	0,30			0,30		x											x			27. okt. 2005	27. okt. 2005		27. okt. 2005
	Linjebesigtigelsesformet.	6815-3-07	Data for formetning er ændret	3	0,00															x	x			23. jan. 2006	23. jan. 2006		23. jan. 2006
	Forlodseksspropriation	6815-3-08	Forlodseksspr. af 3 ejendomme	3	1,94	1,94														x	x			27. jun. 2006	27. jun. 2006		27. jun. 2006
	Udledning af vejvand	6815-3-09	Ændrede betingelser for Funder Å	3	1,06			1,06		x											x			15. sep. 2006	15. sep. 2006		1. aug. 2007
	§20 godkendelse	6815-3-10	Opgørelse af bilag IV-arter	3															x		x			15. sep. 2006			
	Forlodseksspropriation	6815-3-11	Forlodseksspr. af 1 ejendom	3	2,66	2,66																		15. nov. 2006	15. nov. 2006		15. nov. 2006
	Adgangsvej i Pårup	6815-3-12	Adgangsvej tages ud af projektet	3	-0,30			-0,30												x	x			15. apr. 2007	15. apr. 2007		15. apr. 2007
	Adgangsvej i Pårup	6815-3-13	Eksisterende adgang opgraderes	3	0,30			0,30												x	x			15. apr. 2007	15. apr. 2007		15. apr. 2007
	Dalbro ved Funder Å	6815-3-15	Opdateret m2 pris på dalbroen	3	79,69				79,69						x						x			15. aug. 2007			
	I alt				88,66	4,47	4,50	0,00	79,69																			
Konjunkturer																												
	I alt				0	0,00	0,00	0,00	0,00																			
Andre / Mangelfuld vurdering	Bro ved Tegligårdsvej	6815-3-03	Bro forlænges over rampekiler	3	1,76	1,76							x								x			27. okt. 2005	27. okt. 2005		27. okt. 2005
	Ravnholtlundvej	6815-3-04	Forlænges til Guldforhovedvej	3	0,72			0,72					x								x			27. okt. 2005	27. okt. 2005		27. okt. 2005
	Nyt grundkort	6815-3-05	Opdateret jordbudget for motorvej	3	12,28	12,28							x								x			27. okt. 2005	27. okt. 2005		27. okt. 2005
	Ældelik for dalbroen	6815-3-14	Justering af tracee	3	0,00								x								x			15. maj 2007	15. maj 2007		15. maj 2007
	Støjskærm på dalbro	6815-3-16	Ændring af højden fra 3m til 1m	3									x								x			26. sep. 2007			
	I alt				14,76	14,04	0,72	0,00	0,00																			
Øvrige																												
	I alt				0	0,00	0,00	0,00	0,00																			
Entreprise-regulering																												
	I alt				0	0,00	0,00	0,00	0,00																			
					103,42	18,51	5,22	0,00	79,69																			

The UNITE-DSS Decision Support Model

Determinstic Calculation

1) Cost-benefit analysis

↓

Results: Point estimates in terms of NPV, BCR, IRR

2) New act for Infrastruc-ture construction

↓

Impact: Investment costs (30% increase)

↓

Results: Point estimates in terms of NPV, BCR, IRR

Stochastic Calculation

3) RCF: Reference Class Forecasting

↓

Impact: Demand forecasts & Construction costs

↓

Determination of Beta-PERT & Erlang distributions

↓

Determination of inputs to the distributions

↓

Results: Certainty graphs and certainty values

4) RSF: Reference Scenario Forecasting

↓

Impact: Demand forecasts

↓

Determination of Scenario grid and triple estimates

↓

Determination of inputs to the distributions

↓

Results: Certainty graphs and certainty values

5) SIA: Stochastic impact assessment (non-monetary)

↓

Impacts: Strategic impacts (Non-Monetary)

↓

Selection and ranking of criteria, pair-wise comparisons

↓

Discrete distributions from stakeholder involvment

↓

Results: Alternative solution probability distributions for SIA scores

The UP Database (UNITE Project Database)

Inaccuracy in Construction Cost Estimates

Year of Acceptance | Year of Operation

Initial Cost | Actual Cost | Currency & Price level

Inaccuracy in Demand Forecasts

Year of Acceptance | Year of Operation

Initial Demand | Actual Traffic | Traffic Model used

Project Name Type & ID | Country | Economic Situation | Data Source | U (difference): Before vs. After

UNITE DSS framework: Entry sheet

The Danish Council for Strategic Research

UNITE Decision Support System

** Link to the project's website*

DTU Transport
Institut for Transport

Project: Test project

*Project type *:*

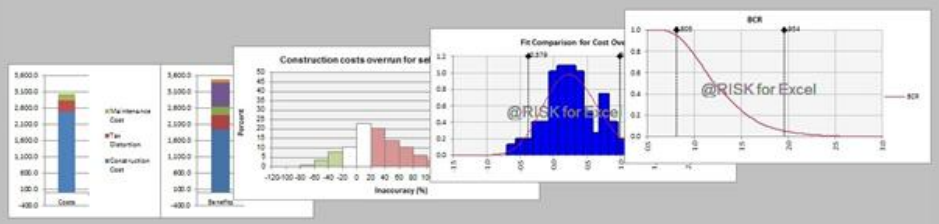
Road project ☐

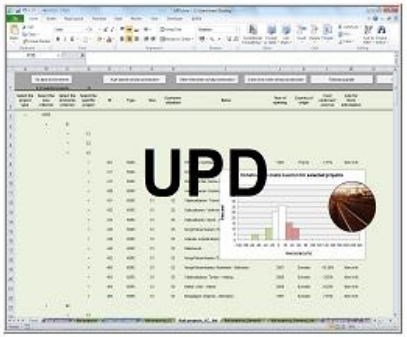
Rail project ☑

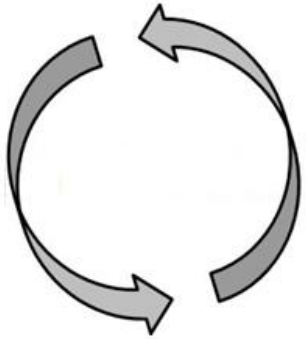
Fixed Link project ☐

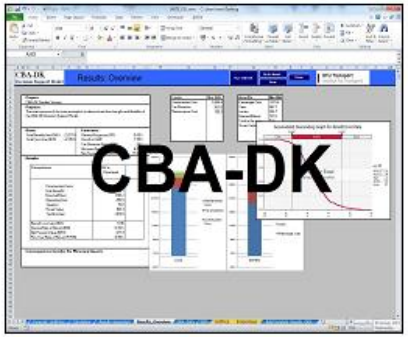
Undefined (using OB) ☐

Moving from single to interval results









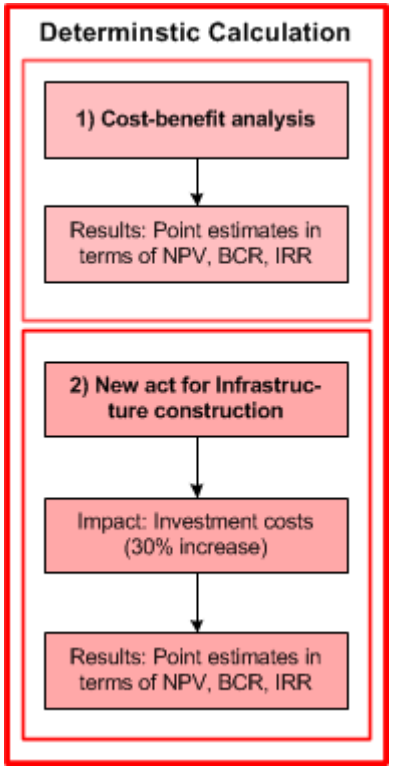
* If you wish to define your own group of reference projects select the major project type and go to UPD

Print the report of CBA results

Print the report of QRA results

The UNITE-DSS: Deterministic calculations

- The deterministic calculations are based upon:
  - Conventional CBA through various manuals (e.g. TRM 2003)
  - New act for infrastructure construction in Denmark
    - Uplifts for construction costs (based upon Flyvbjerg and COWI 2004)
  - MCDA for non-monetary impacts (based upon REMBRANDT and SMARTER)



Module 3: Non-Monetary impacts

- Evidently, the conventional CBA does not capture all relevant impacts to be assess

- Wider Economic Benefits are not included:
  - Agglomeration
  - Productivity
  - Labour

- Strategic effects are not included:
  - Accessibility
  - Network and Mobility
  - Sustainable development
  - Regional development
  - Economic development
  - Landscape

New Budgetting in Denmark

NOTAT

Transportministeriet

DEPARTEMENTET

Dato 20 oktober 2010
J. nr. 010-76

Center for Økonomi og HR

Ny anlægsbudgettering på Transportministeriets område, herunder om økonomistyringsmodel og risikohåndtering for anlægsprojekter

Anlægsoverslag			**583,10**	**59,96**	**643,06**
Korrektionstillæg A (K2-A) 10%	*Sum*				*64,31*
Ankerbudget / Bevilling					***707,37***
Heraf anlægsløn (4,6 %)	*Sum*	*32,54*			
Korrektionstillæg B (K2-B) 20%	*Sum*				*128,61*
Totalbevilling incl. central reserve					***835,98***

30%

Optimism Bias and uplifts

- Deriving uplifts is highly dependet on large data-sets
  - Flyvbjerg and COWI (2004) used a large database to derive uplifts

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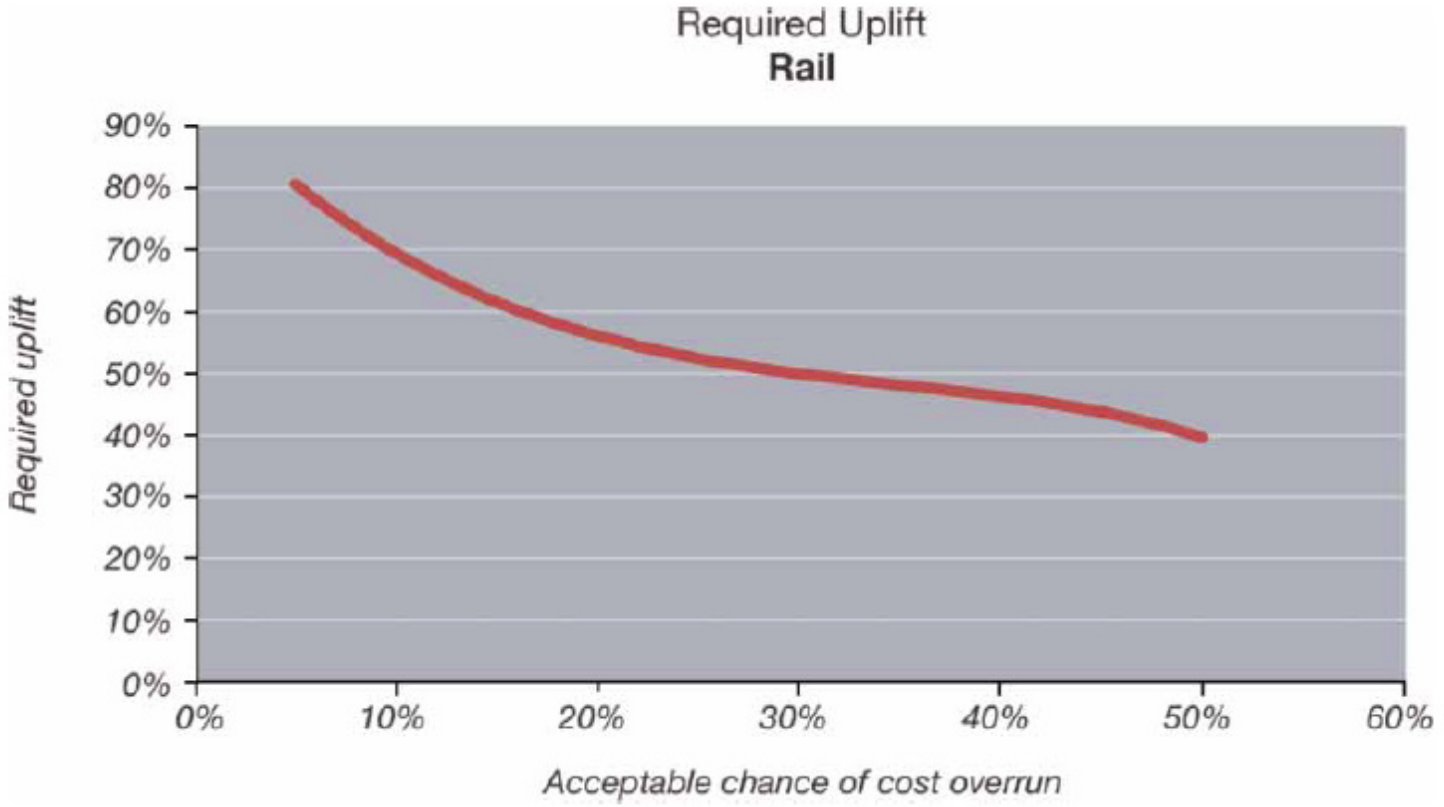
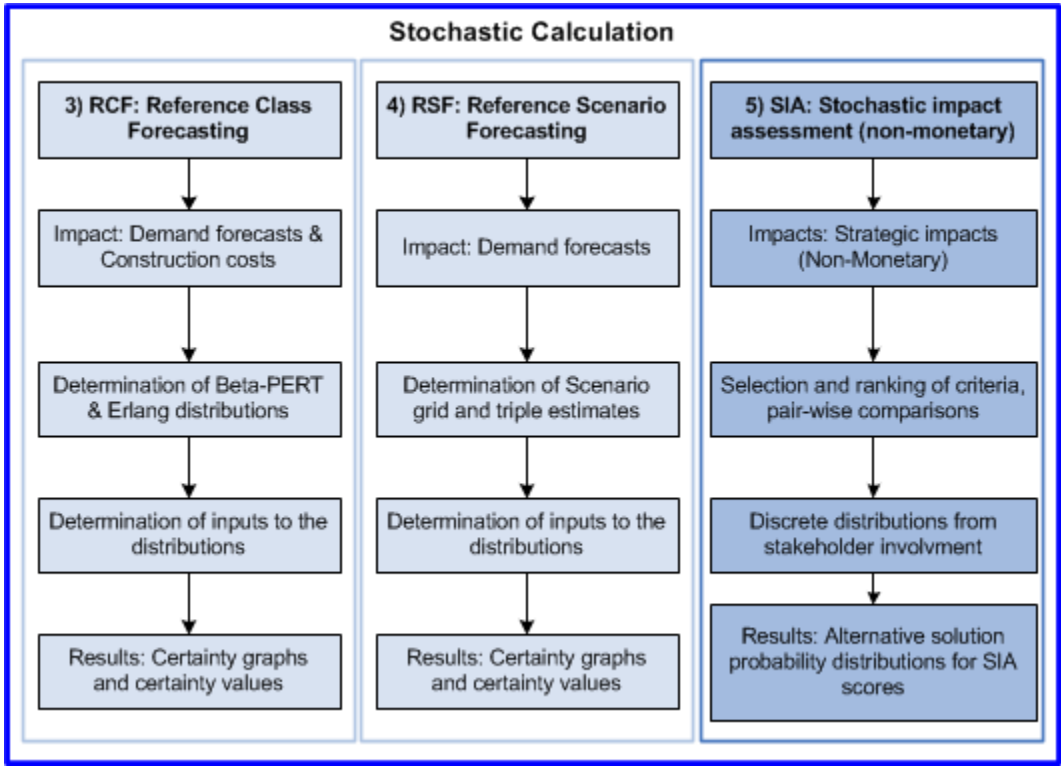


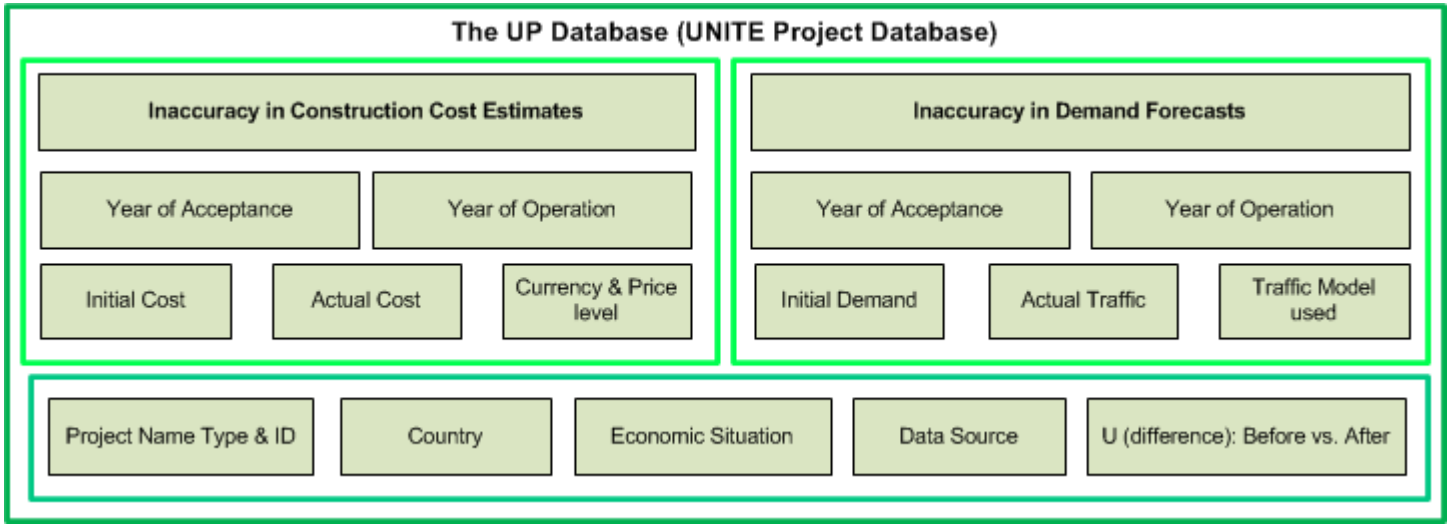
The UNITE-DSS: Stochastic calculations

- The stochastic calculations are based upon:
  - ➢ Reference Class Forecasting entailing specific data (UPD database)
  - ➢ Determination of suitable distributions: data fitting
  - ➢ Monte Carlo simulation and quantitative risk analysis
  - ➢ Provided both on demand and cost inaccuracies as well as non-monetary effects



The UP Database: Inaccuracies

- The UP Database is compiled upon data w.r.t.:
  - ➢Inaccuracy in Construction Cost Estimates
  - ➢Inaccuracy in Demand Forecasts
- Consists of almost 200 transport related projects (from 1969-2009) from UK, Sweden, Norway, Holland and Denmark



UPD Database: Entry sheet

UNITE: Uncertainties in Transport Project Evaluation (2009-2013)

This is the front sheet of the database collected during the scope of the research project UNITE funded by the Danish Strategic Research Council (DSF).

The database currently consists of inaccuracies concerning construction costs and demand forecasts for ex-post transport infrastructure projects divided into respectively *Road*, *Rail* and *Fixed Links*.

Road projects

Construction costs

Demand forecasts

Rail projects

Construction costs

Demand forecasts

Fixed Link projects

Construction costs

Demand forecasts

Optimism Bias

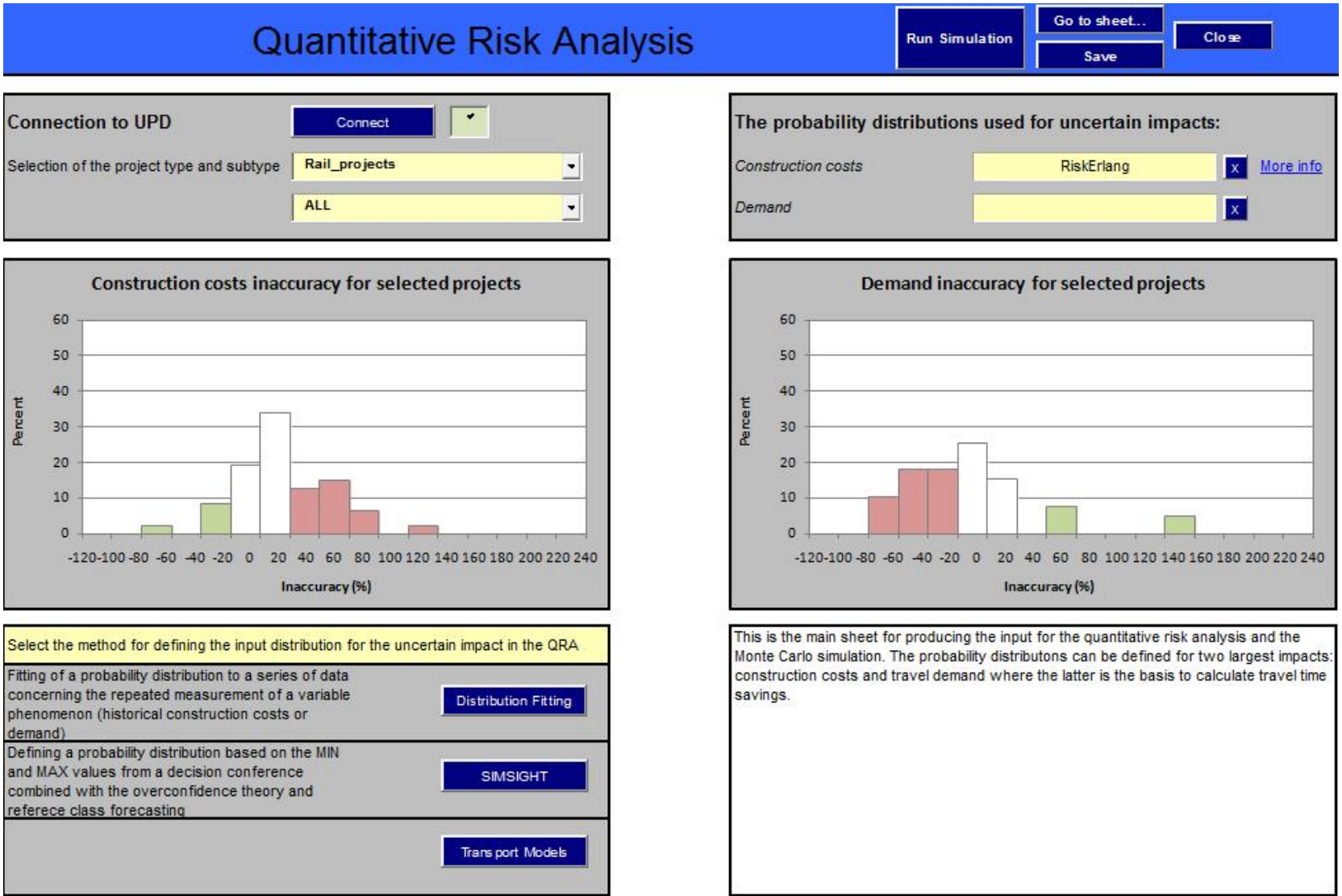
Number of projects	Construction costs data	Demand forecasts data	Optimism bias*
Road projects	117	122	20
Rail projects	47	39	11
Fixed Link projects	15	15	5
Total	**179**	**176**	**36**

* The number of projects experienced both construction cost overrun and demand underrrun.

Reported demand forecast inaccuracy

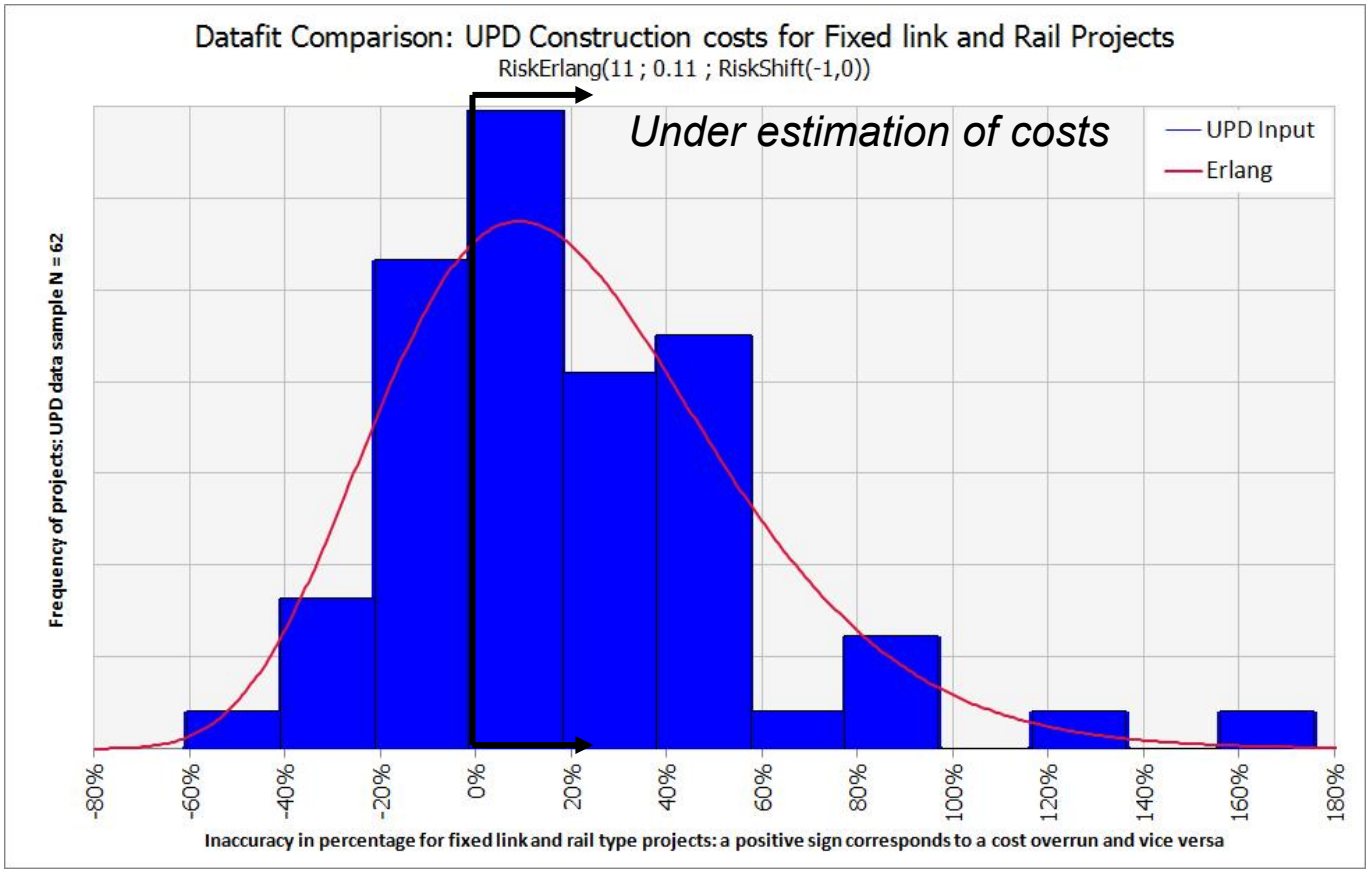
Author(s)	Projects opened	Area	Sample	Mean	Std. dev.
Mackinder & Evans (1981)	1970s	United Kingdom	Road: 44	-7%	N/A
National Audit Office (1988)	1980s	United Kingdom	Road: 128	+8%	43
Pickrell (1990)	1980s	United States	Rail: 9	-65%	17
Fouracre et al. (1990)	1980s	Developing countries	Rail: 9	-44%	26
Flyvbjerg et al. (2005)	1970s-1990s	Global	Road: 183 Rail: 27	+10% -40%	44 52
Department of Transportation (2007)	1990s	United States	Rail: 19	-37%	31
Department of Transportation (2008)	2000s	United States	Rail: 18	-16%	59
Bain (2009)	N/A	Global	Toll: 104	-23%	26
Button et al. (2010)	1970s-2000s	United States	Rail: 44	-21%	58
Parthasarathi & Levinson (2010)	1960s-2000s	Minnesota	Road: 108	+6%	41
Highways Agency (2011)	2000s	United Kingdom	Road: 62	+3	21
Welde and Odeck (2011)	2000s	Norway	Toll: 25 Road: 25	-3% +19%	22 21
Nicolaisen (2012)	1970s-2010s	Scandinavia + United Kingdom	Road: 146 Rail: 31	+11% -18%	35 33

Connection from UPD to UNITE-DSS



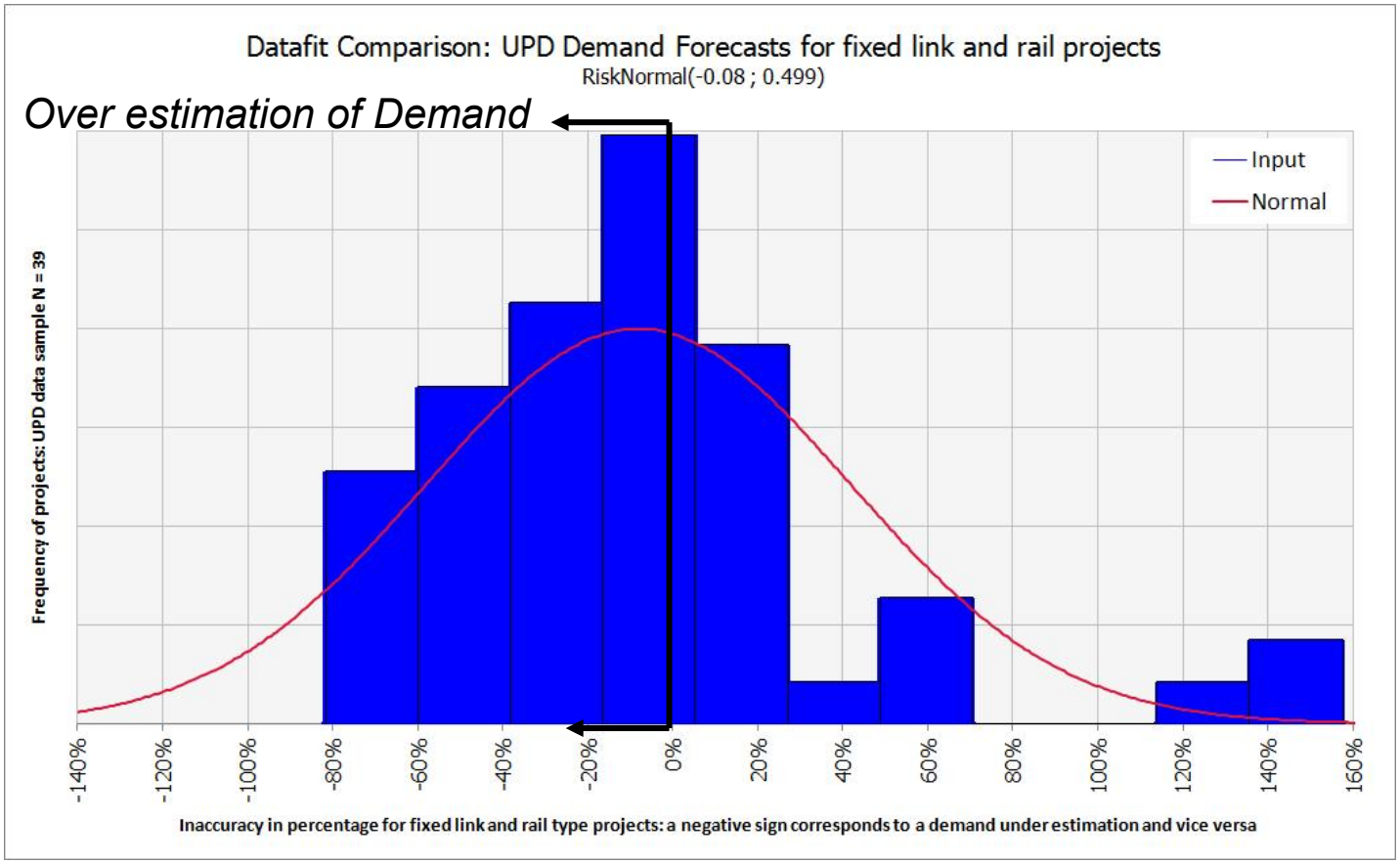
The UNITE Project Database (UPD): Cost

- The convention used is as follows: $$U = \frac{\left(\left(X_{actual} - X_{forecasted}\right) \times 100\right)}{X_{forecasted}}$$



The UNITE Project Database (UPD): Demand

- The convention used is as follows: $$U = \frac{\left(\left(X_{actual} - X_{forecasted}\right) \times 100\right)}{X_{forecasted}}$$



Explanations for the inaccuracies

Cost Overruns: Explanations and Causes				
TECHNICAL	ECONOMICAL	PSYCHOLOGICAL	POLITICAL	SELECTION BIAS
Forecasting errors Inadequate models, plans, structures, etc. ('honest' errors)	Deliberate underestimations such as lack of incentives, resources, etc.	Optimism Bias and cautious attitudes towards risks and uncertainties	Strategic overestimations of benefits and underestimations of costs from planners	Bias will inevitably occurs whenever ex-ante predictions are related to the decisions on whether to implement a project or not

- Extensive literature supports each explanation/cause given
  - This research is not to prove or disgard any of the above – but merely to assist in the decision-making process

- Current effort looks into the Transport appraisal framework (as presented in the beginning)
  - How can we avoid such bias???

Case Study selection

Case Study	Mode	Most expensive Alt.
Elsinore-Helsingborg Fixed link	Car/Rail	1.5 bill. € (4 alt.)
Rail Baltica Connection	Rail	2.4 bill. € (3 alt.)
Appraisal of Runways in Nuuk	Air	330 mio € (3 alt.)
Frederikssund Motorway	Car	615 mio € (4 alt.)

- Case study 1: A new connection between Denmark and Sweden
- Case study 2: A new Railway corridor through the three Baltic countries to Poland
- Case study 3: Extension or new construction of new runway in Nuuk, Greenland
- Case study 4: An upgrade/new construction of road in the northern part of Zeeland, Denmark.

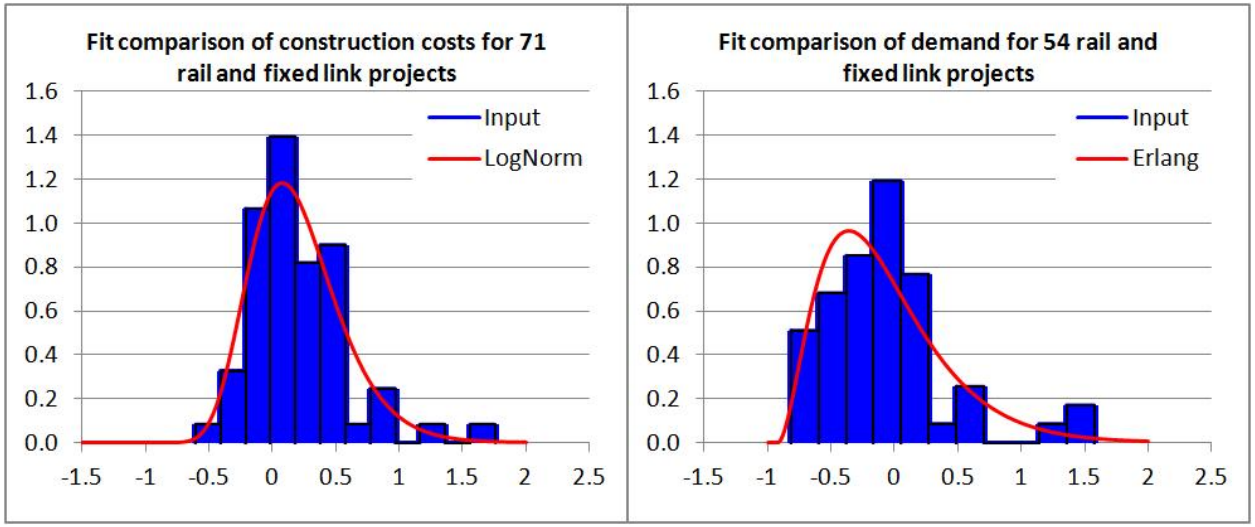
Deterministic Calculation: CBA

HH-Connection (alternatives)	Cost (bill. €)	BCR	BCR (incl. 'uplifts')	NPV (bill. €)
Alternative 1	1.0	1.50	0.97	0.72
Alternative 2	0.715	0.16	0.10	-0.86
Alternative 3	1.5	2.71	1.75	3.7
Alternative 4	0.78	3.08	1.98	2.3

- Construction costs – by far the largest contributor of costs

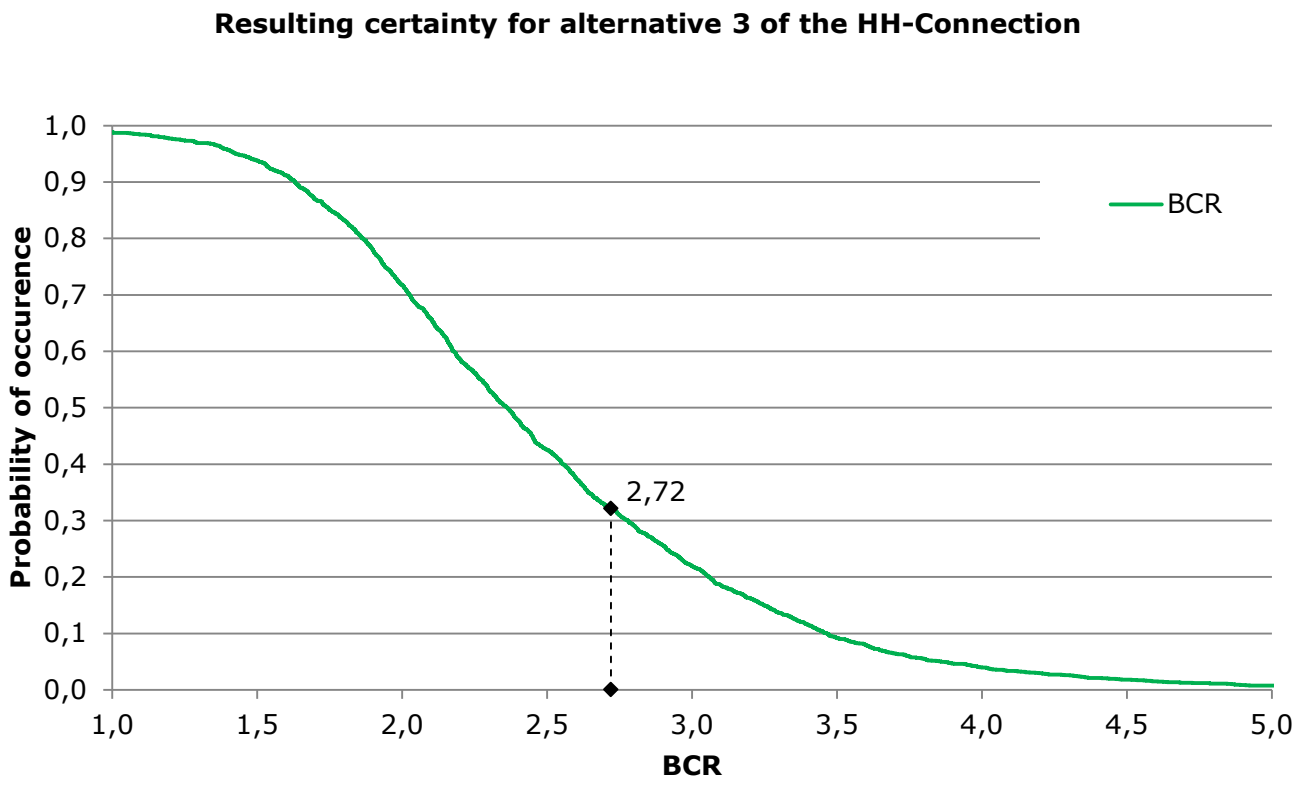
- User Benefits – by far the largest contributor of benefits
  - Consists of Ticket revenue and time savings
  - Relies on the prognosis of future number of passengers i.e. demand forecasts (rough assumption)

Correspondance with the UP Database



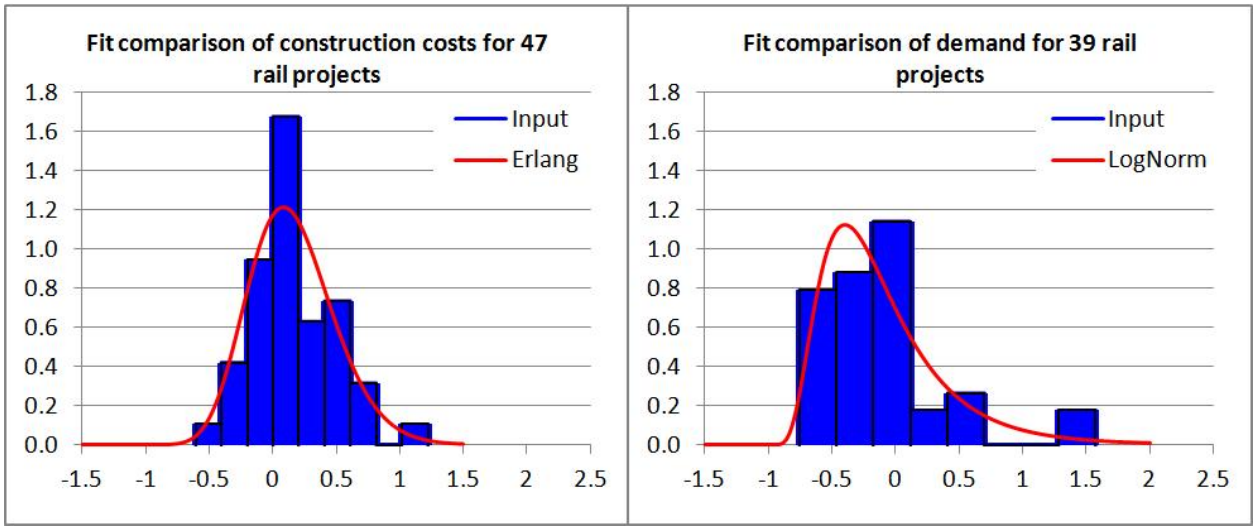
- Fit comparison of construction costs for 71 rail and fixed link projects and fit comparison of demand for 54 rail and fixed link projects used as input for assessment of alternative 3 for the HH-connection

Results (RCF): Monte Carlo simulation

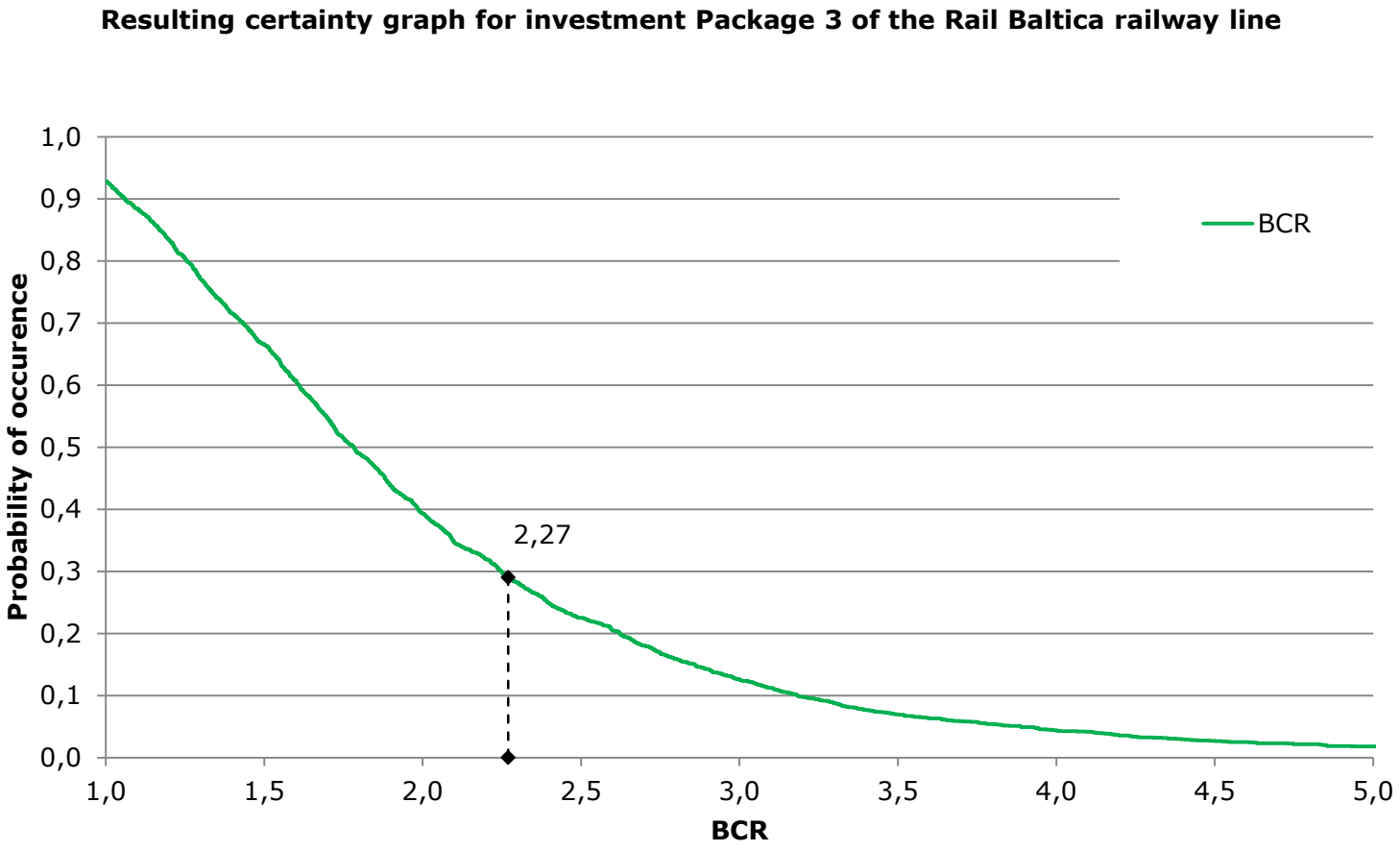


Rail Baltica case study: Deterministic Calculation and Datafit

Rail Baltica (alternatives)	Cost (bill. €)	BCR	BCR (incl. 'uplifts')	NPV (bill. €)
Investment package 1	1.0	2.92	N/A	2.4
Investment package 2	1.5	2.65	N/A	3.4
Investment package 3	2.4	2.27	N/A	4.3

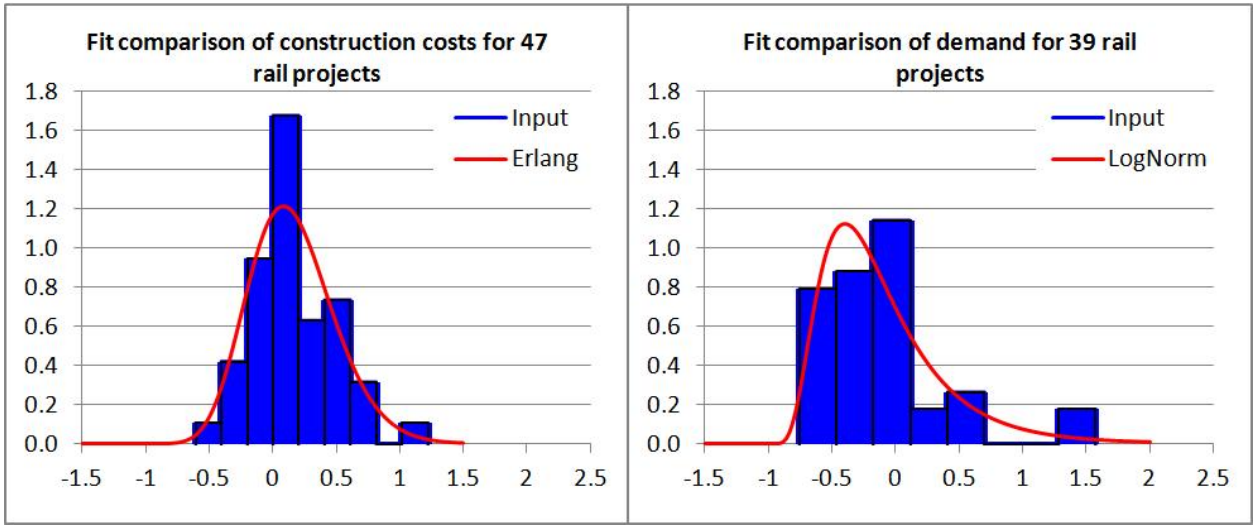


Results (RCF): Monte Carlo simulation

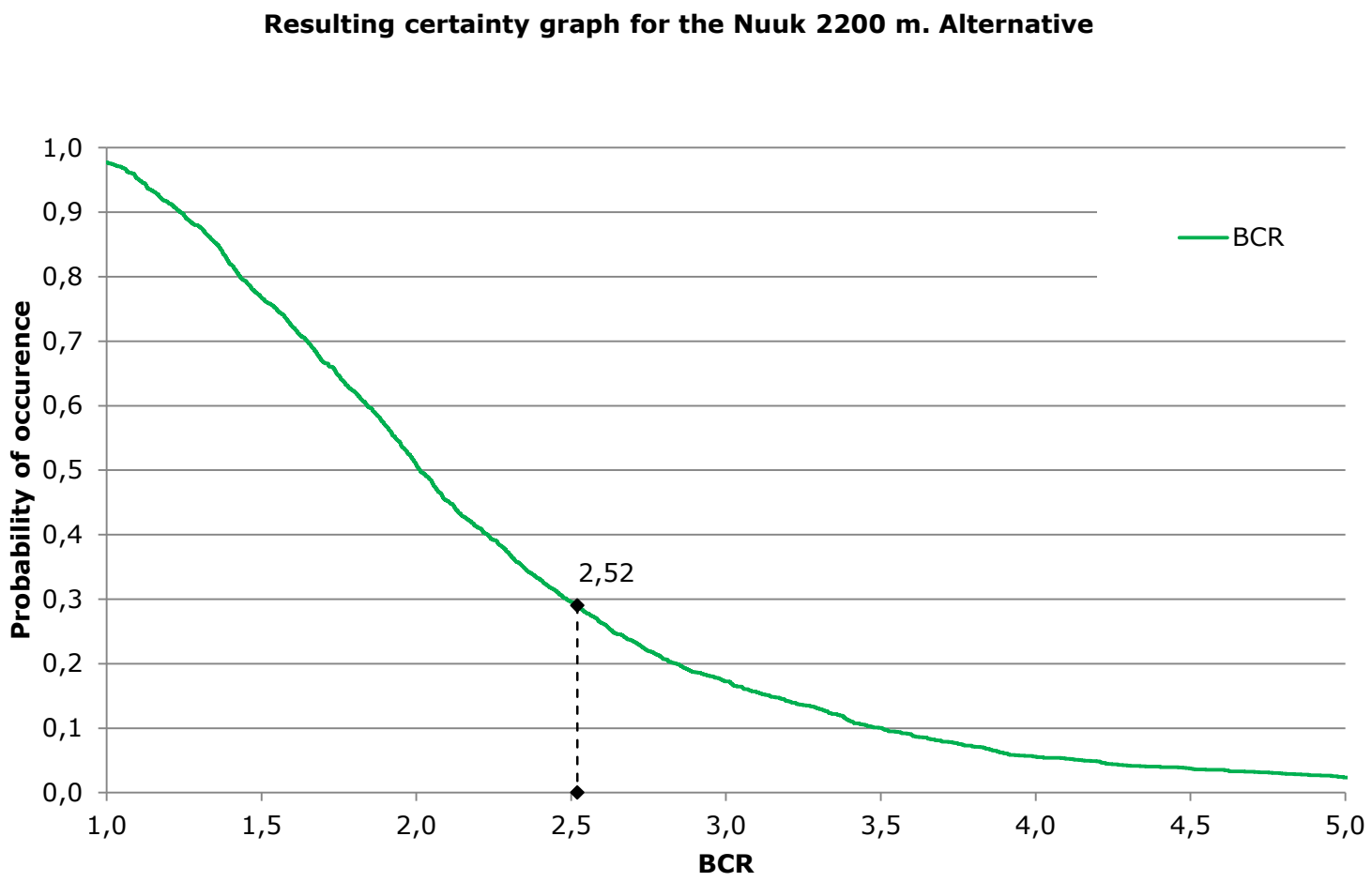


Runway alternatives in Nuuk, Greenland: Deterministic Calculation and Datafit

Runways in Nuuk (alternatives)	Cost (bill. €)	BCR	BCR (incl. 'uplifts')	NPV (bill. €)
Nuuk 1800	0.8	2.46	N/A	1.2
Nuuk 2200	1.1	2.52	N/A	1.7
Nuuk 3000	2.5	0.83	N/A	-0.4

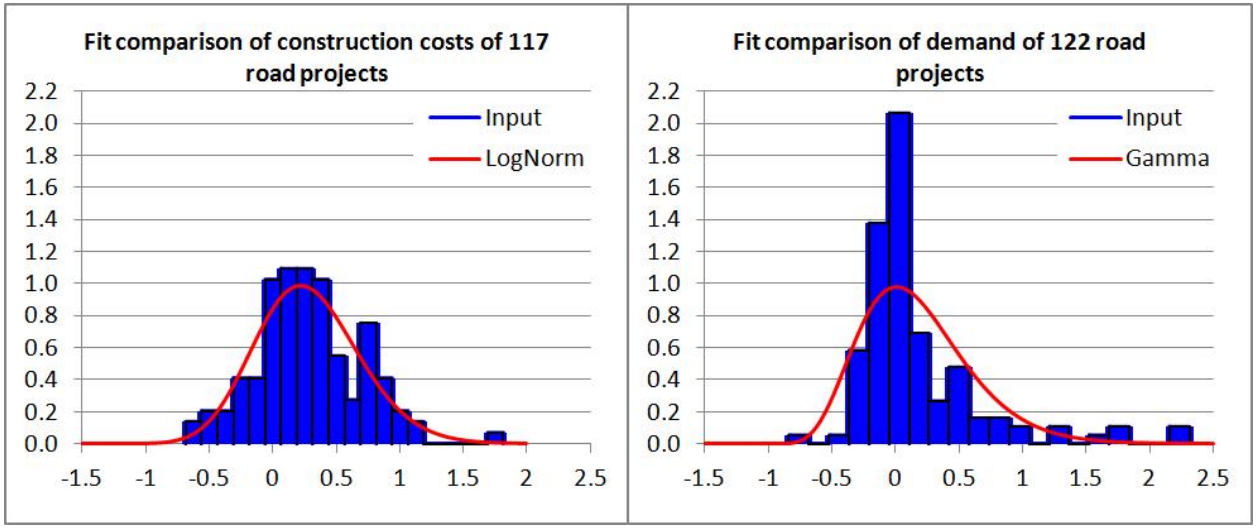


Results (RCF): Monte Carlo simulation

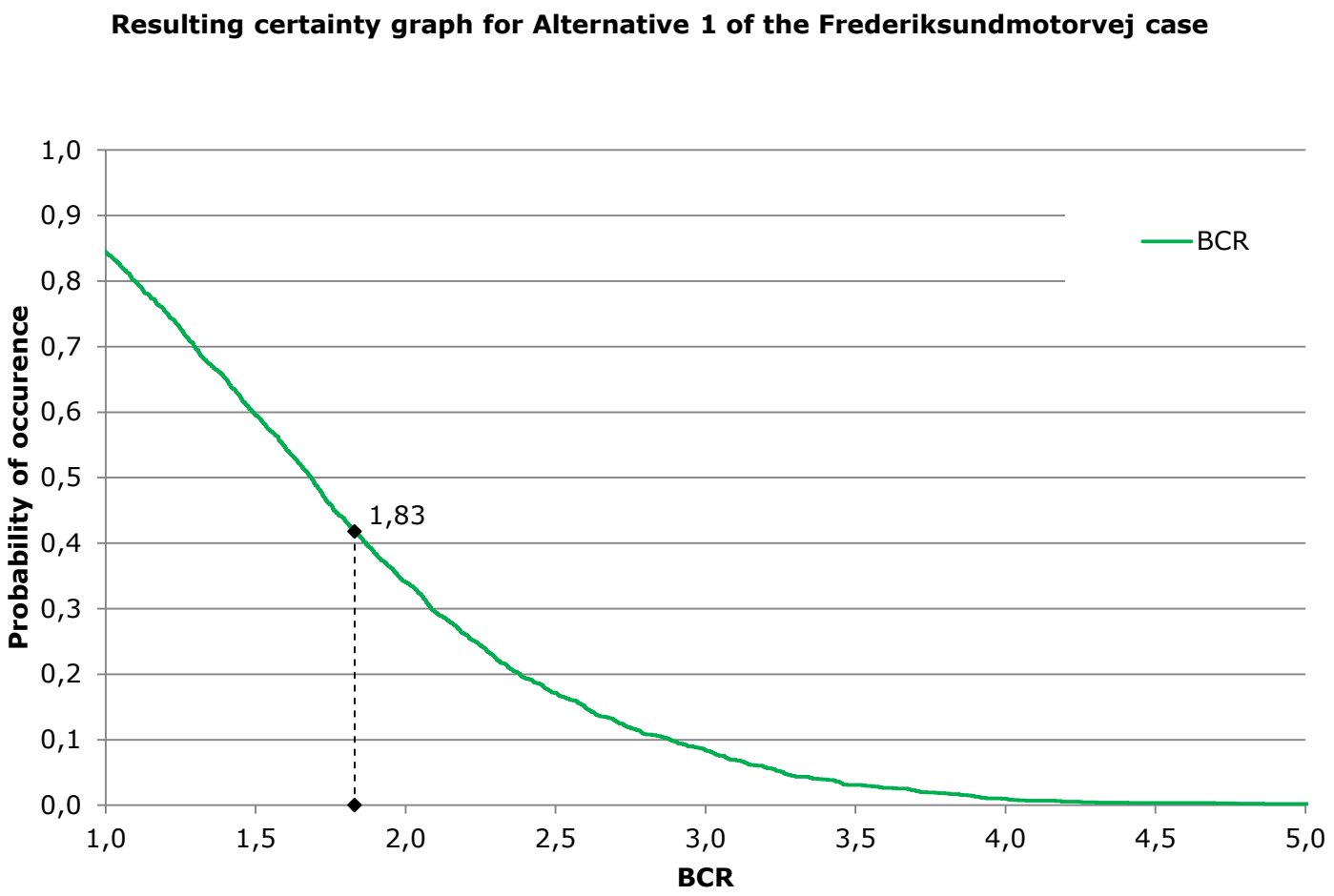


Frederikssund Motorway Case study: Deterministic Calculation and Datafit

Frederikssund (alternatives)	Cost (bill. €)	BCR	BCR (incl. 'uplifts')	NPV (bill. €)
Alternative 1	2.5	1.83	N/A	3.1
Alternative 2	3.4	1.22	N/A	1.1
Alternative 3	4.7	0.73	N/A	-2.0
Alternative 4	2.3	0.29	N/A	-2.4



Results (RCF): Monte Carlo simulation



Summary of results

Case study	BCR Conventional	CC PDF to fit	Demand PDF to fit	Certainty of orig. BCR	Certainty of feasibility
HH-Connection (Alternative 3)	2.72	LogNormal	Erlang	31%	99%
Rail Baltica (Alternative 3)	2.27	Erlang	LogNormal	29%	92%
Airport in Nuuk (Nuuk 2200)	2.52	Erlang	LogNormal	29%	97%
Frederikssund (Alternative 1)	1.83	LogNormal	Gamma	40%	83%

- Further work should be made in terms of an ex-post analysis of the projects.
  - Unfortunately are none of the above projects determined yet

Conclusions

- Feasibility risk assessment can be carried out by using historical experience stemming from RCF in order to obtain **interval results**
- An important aspect in RCF and UNITE is to set and validate input parameters. Hence, **empirical data** enter the assessment.
- Development of a more **generic tool/framework** to comprise model uncertainties and inaccuracies across disciplines
- Clearly vital to include uncertainties within socio-economic analyses in order to **validate results**

Perspectives

- Recovering of further data (UPD) with regard to both the **demand forecast uncertainty as well as the construction costs** through large-scale research study

- **Ex-post analyses** on projects that have been constructed – currently under development (Viability).

- The **combination between CBA and MCDA and QRA** is necessary in order to include non-monetary impacts in the assessment such as Wider economic benefits

- The linkage toward **non-monetary impacts** are currently under development – in a Sustainability perspective

Kjerkreit and Odeck (2013): Preliminary results

Project name	Benefits Deviation	Total costs Deviation	NPV (mill NOK) Ex ante	Ex post	Deviation	BC- ratio Ex ante	Ex post
Rv 23 Oslofjordforbindelsen	4 %	14 %	4563	4565	0 %	5,0	5,4
Ev 18 Rannekleiv - Temse	22 %	23 %	409	498	22 %	1,2	1,1
Rv 714 Hitra - Frøya	96 %	-38 %	-242	156	165 %	-0,9	0,9
Ev 134 Teigeland - Håland	60 %	4 %	-445	-418	6 %	-0,8	-0,7
Rv 62 Øksendalstunnellen	5 %	3 %	57	67	18 %	0,2	0,2
E8 Norkjosbotn-Laksvatnbukt	-13 %	24 %	-81	-219	-168 %	-0,2	-0,4
E18 Gutu-Helland-Kopstad	231 %	-3 %	-4066	-2022	50 %	-1,0	-0,5
E39 Kleivedammen-Andenes	54 %	-3 %	-144	-76	47 %	-0,5	-0,3
E134 Hegstad - [illegible]							1,4
Rv.616 Kolset - K							0,8
Rv.580 Hop- Midt							0,5
E18 Ørje- Eidsbe							2,0
E6 Akershus grei							0,4
Rv. 35 Lunner - G							0,3
E6 Halmstad - Pa							3,3
E18 Brokelandshei[illegible]							0,8
E39 Svegatjørn - Moberg	52 %	-13 %	-90	62	169 %	-0,3	-0,2
E18 Sekkelsten- Krosby	52 %	12 %	165	502	204 %	0,3	0,7
E6 Ny Svinesundforbindelse	14 %	5 %	811	1011	25 %	0,8	0,9
E6 Skjerdingstad - Jaktøyen	37 %	-8 %	-418	-186	56 %	-0,5	-0,2
Rv. 4 Reinsvoll - Hunndalen	66 %	47 %	149	315	111 %	0,7	1,1
Fv. 43 Aunevik - Bukkesteinen	26 %	62 %	-41	-118	-189 %	-0,2	-0,4

A tendency to underestimate costs (13 out of 22) BUT on the same
An underetimation of demand as well (20 out of 22)

Key trend in Norway however is:
That 17 out of 22 projects actually produce higher NPV ex-post

Would the same trend occur in Denmark….?

Perspectives

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Just released press update

Heunicke: Dynamiske effekter svækker troværdigheden

Af Hjalte Kragesteen (/transport/forfatter.aspx?id=4665) | 25. september 2014 kl. 1:00 | 0 kommentarer

SAMFUNDSØKONOMI: Transportminister Magnus Heunicke (S) mener, at forskningen i dynamiske effekter er for svag til, at man kan inddrage dem i samfundsøkonomiske analyser. Han afviser desuden, at medregning af dynamiske effekter automatisk vil gøre projekterne mere rentable.

Perspectives

- Recovering of further data (UPD) with regard to both the **demand forecast uncertainty as well as the construction costs** through large-scale research study

- **Ex-post analyses** on projects that have been constructed – currently under development (Viability)

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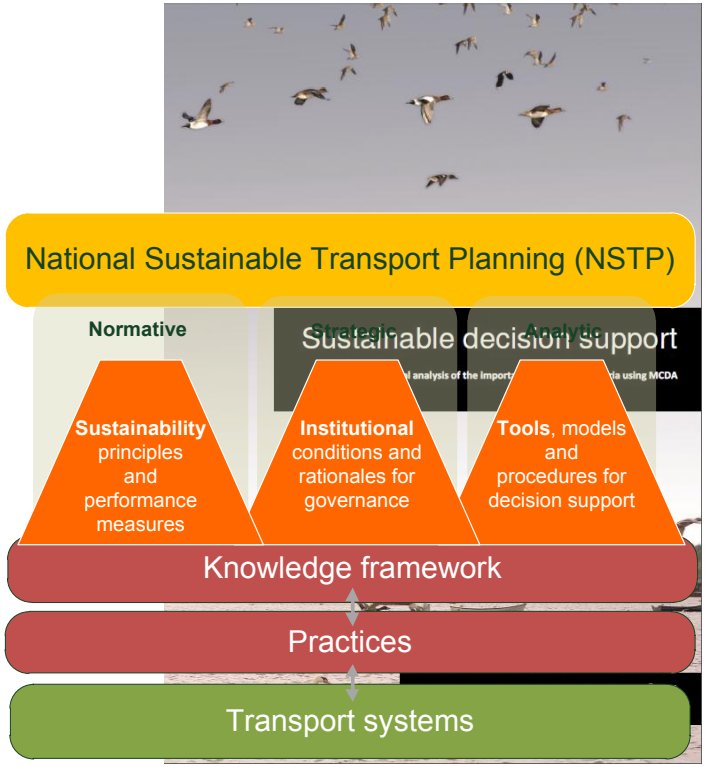
- The linkage toward **non-monetary impacts** are currently under development – in a Sustainability perspective

National Sustainable transport planning

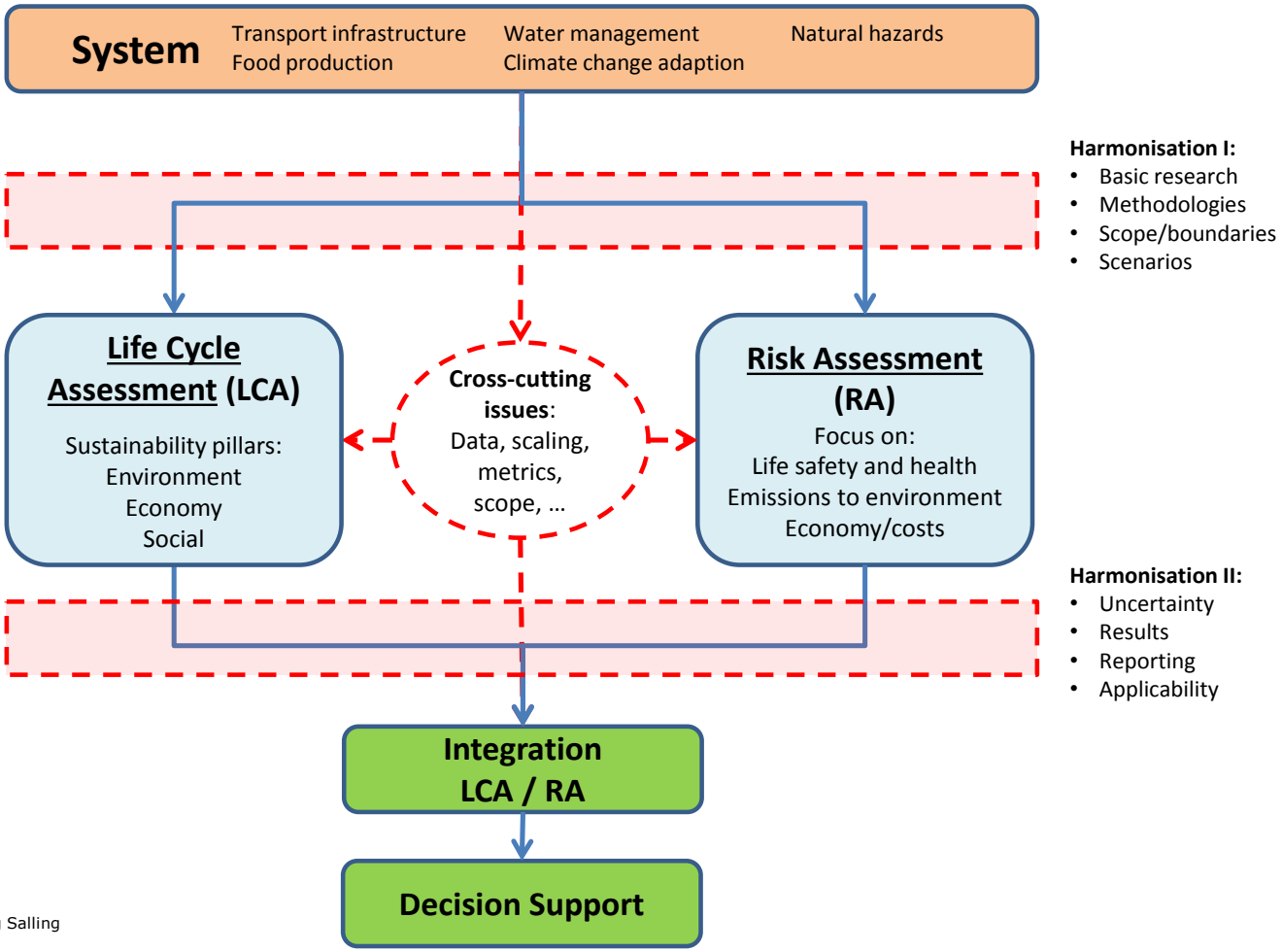
- **National Transport Planning** – i.e. construct overall strategies
  - Nation wide Road Pricing
  - Free Public Transport
  - Incentives for companies to move to the outer regions
  - Sustainable development….

- **Large research grant:** SUSTAIN project
  - Collaboration with institutions such as:
    - Copenhagen Business School
    - Monash University
    - Texas A&M University
    - Oxford University



GDSI: A framework for sustainability - and risk informed decision support

Sustainability- and risk-informed decision support



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QUESTIONS?

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