Validating Goal Models via Bayesian Networks

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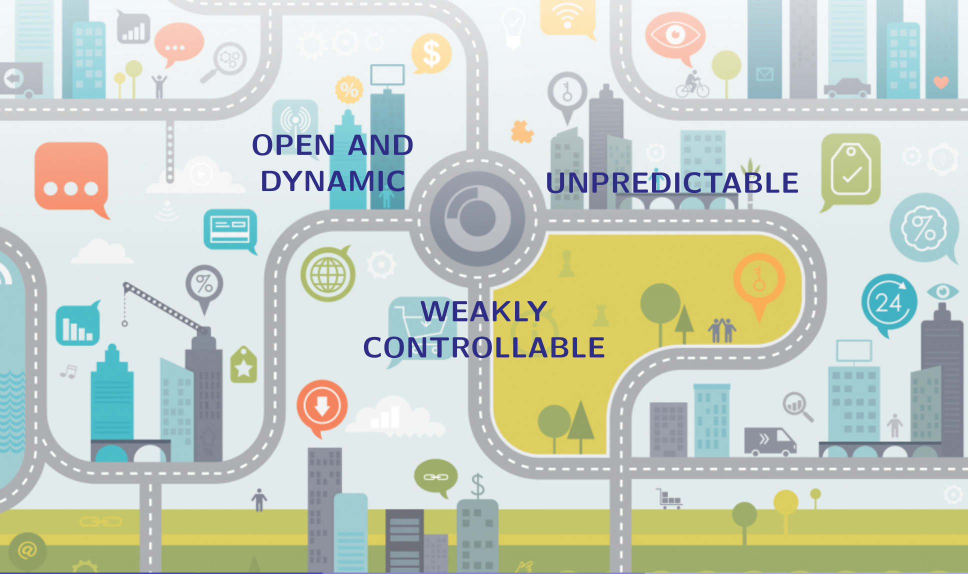
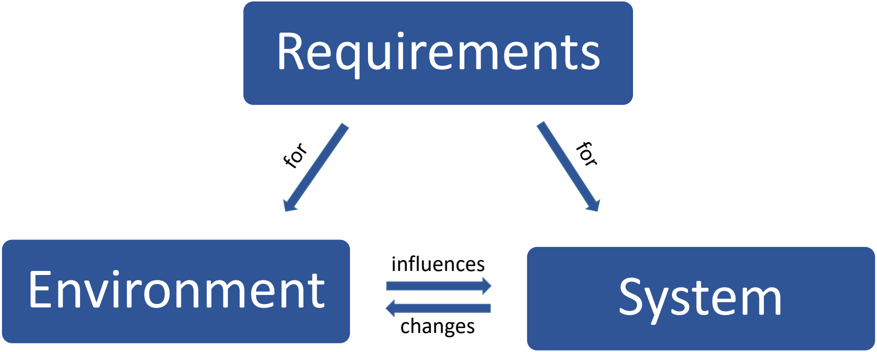
Designing modern software systems is complex

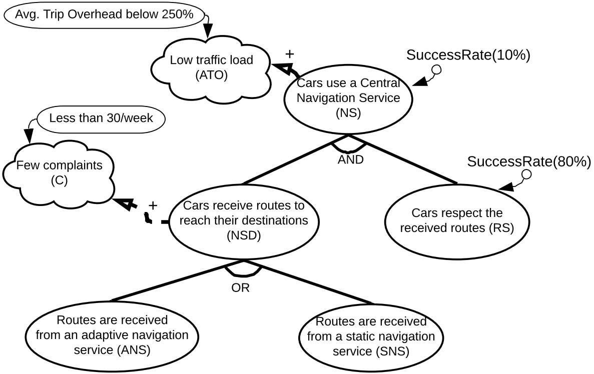
The challenge of Socio-Technical Systems

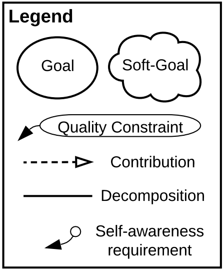


Requirements engineers make assumptions



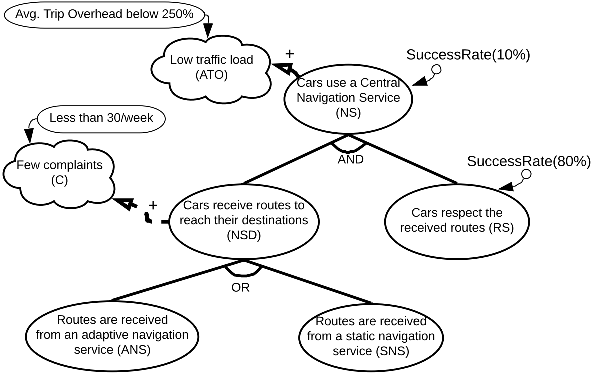
Goal Models assumptions

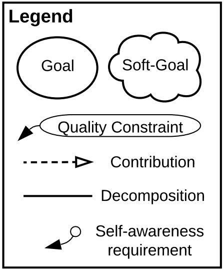




Goal Models assumptions

Softgoal achievement assumption

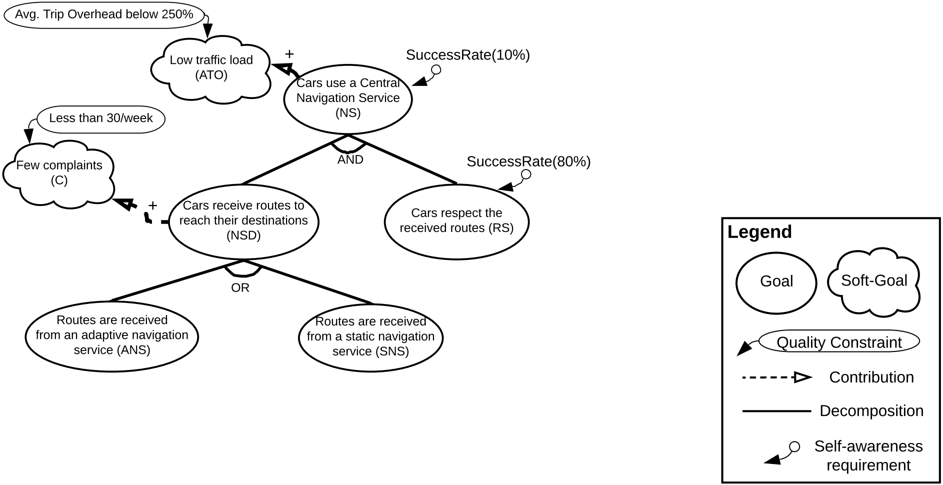




Goal Models assumptions

Softgoal achievement assumption

Contribution assumption

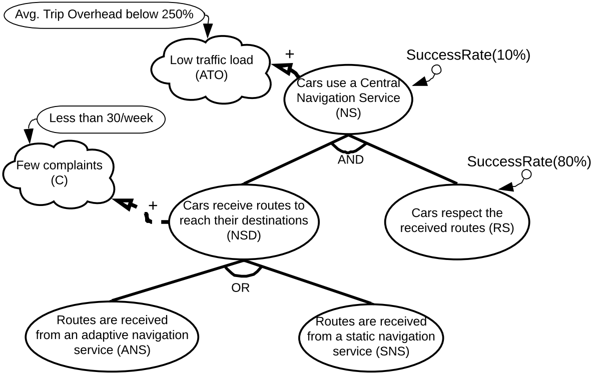


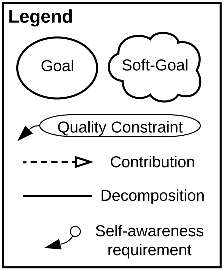
Goal Models assumptions

Softgoal achievement assumption

Contribution assumption

AND-decomposition assumption





Goal Models assumptions

Softgoal achievement assumption

Contribution assumption

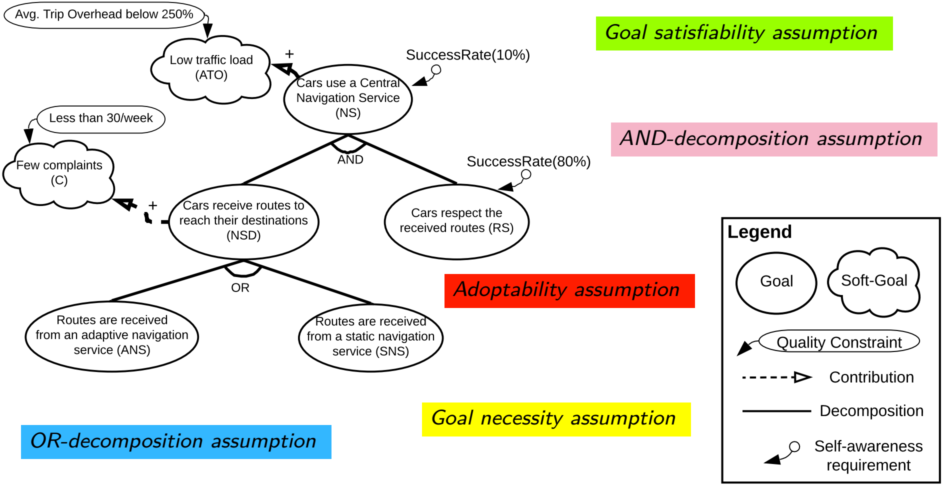
Goal satisfiability assumption

AND-decomposition assumption

Adoptability assumption

Goal necessity assumption

OR-decomposition assumption

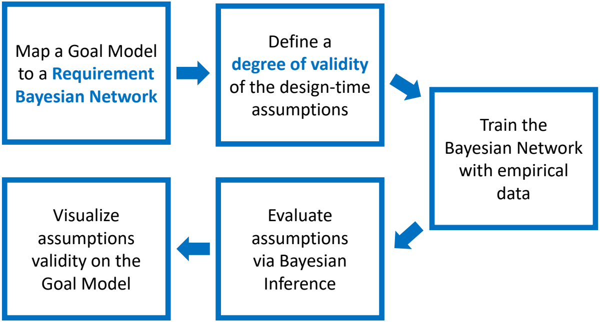


Validating Goal Models via Bayesian Networks

Research Question

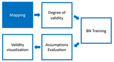
How to use Bayesian Networks to validate the assumptions in a goal model with empirical data?

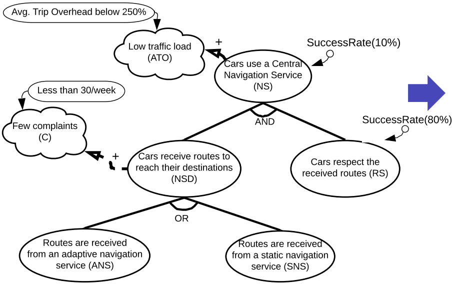
Approach:

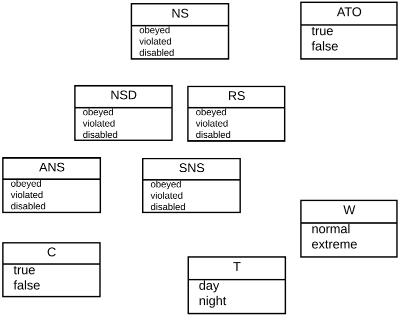


From Goal Model to Requirement Bayesian Network

Nodes

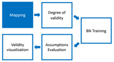


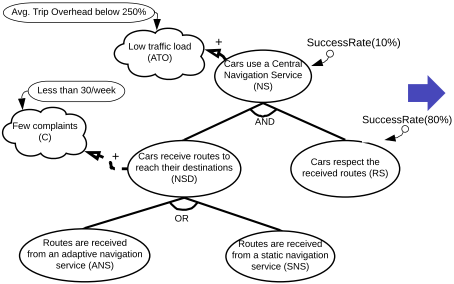


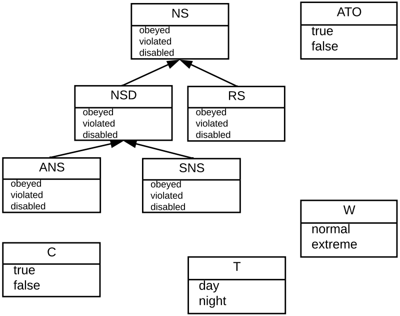


From Goal Model to Requirement Bayesian Network

Goals hierarchy

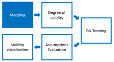


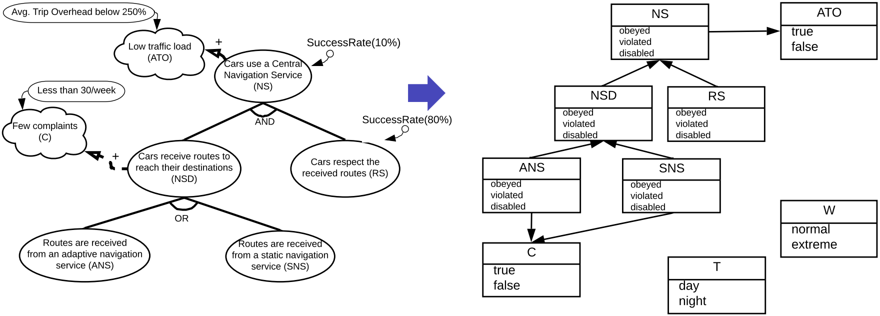




From Goal Model to Requirement Bayesian Network

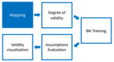
Contribution to soft-goals

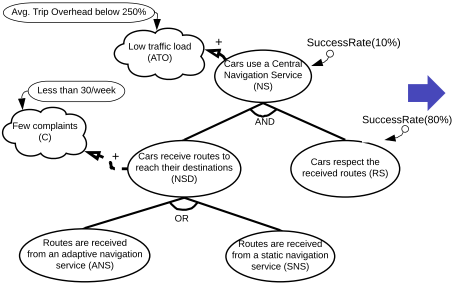


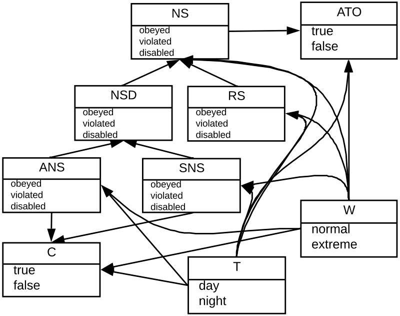


From Goal Model to Requirement Bayesian Network

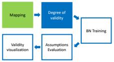
Operating contexts







Degree of validity of design-time assumptions

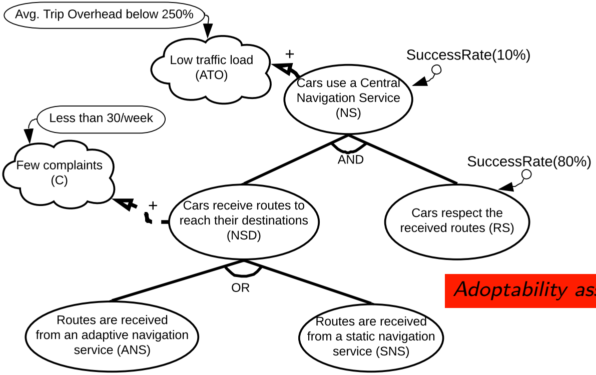


Softgoal achievement assumption

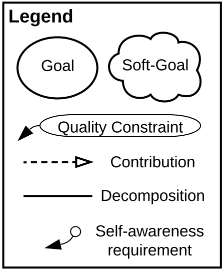
Contribution assumption

Goal satisfiability assumption

AND-decomposition assumption



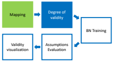
Adoptability assumption



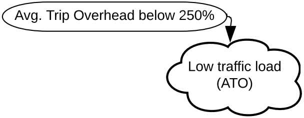
Goal necessity assumption

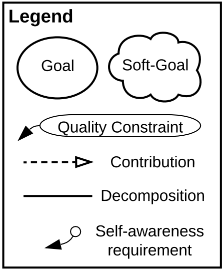
OR-decomposition assumption

Degree of validity of design-time assumptions



Softgoal achievement assumption
$\delta_G(S, \mathbf{c}) = P(S_{true} \mid \mathbf{c}) - P(S_{false} \mid \mathbf{c})$





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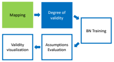
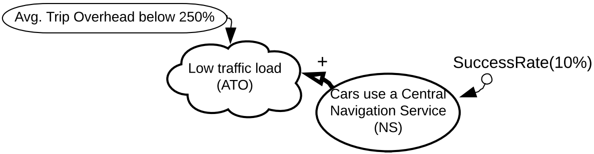
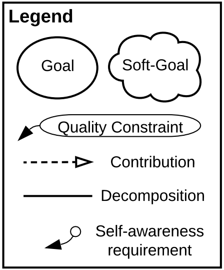


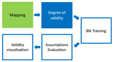


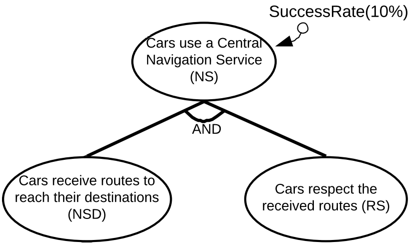
Contribution assumption

$$\delta_C(S, G, \mathbf{c}) = P(S_{true} \mid G_{ob} \wedge \mathbf{c}) - P(S_{true} \mid G_{viol} \wedge \mathbf{c})$$



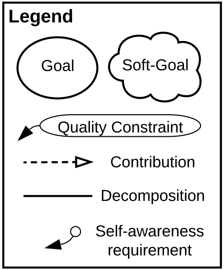
Degree of validity of design-time assumptions



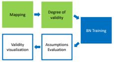


AND-decomposition assumption

$$\delta_{AND}(G, \mathbf{c}) = P(G_{ob} \mid \mathbf{G'}_{ob} \wedge \mathbf{c}) - P(G_{ob} \mid \mathbf{g} \wedge \mathbf{c})$$



Feasibility Evaluation with CrowdNav Traffic Simulation



- CrowdNav simulator: medium-size city (Eichstädt), 450 streets, 1200 intersections.
- 90% of cars: SUMO default routing algorithm.
  10%: centralized navigation service.
- Extended CrowdNav:
  - support to both adaptive and static navigation services
  - instrumentation of the simulator for requirements monitoring

- Simulations of scenarios with 4 different operating contexts
- Dataset from log of requirements monitoring
- ca. 4.6 million rows

Feasibility Evaluation with CrowdNav Traffic Simulation

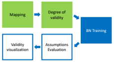
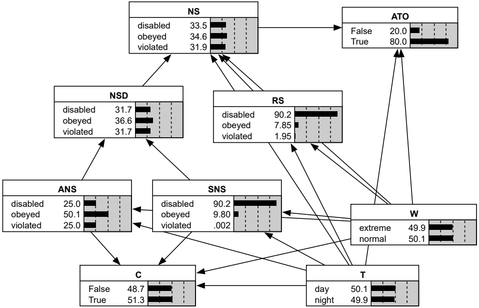
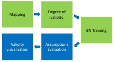


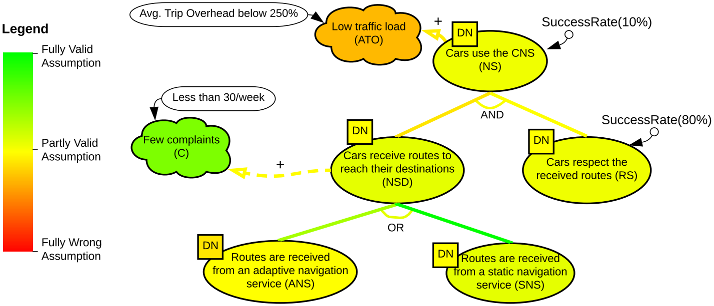
Table: Part of the dataset used to train the BN

W	T	NS	NSD	ANS	SNS	RS	ATO	C
norm	night	viol	ob	dis	ob	viol	T	T
norm	day	ob	ob	ob	dis	ob	F	F
norm	day	ob	ob	viol	dis	viol	F	F
extr	night	viol	ob	dis	ob	ob	T	T
extr	day	ob	dis	dis	dis	dis	T	F
extr	day	ob	ob	dis	ob	viol	T	F
...								



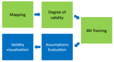
Feasibility Evaluation with CrowdNav Traffic Simulation

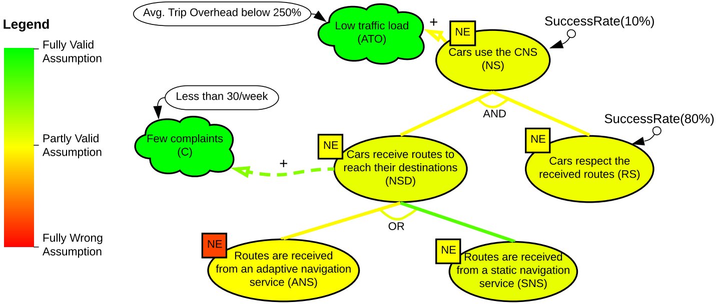




Assumption	Validity
$\delta_S(NS, \mathbf{dn})$	0.0580
$\delta_S(NSD, \mathbf{dn})$	0.1006
$\delta_S(ANS, \mathbf{dn})$	1.71E-05
$\delta_S(SNS, \mathbf{dn})$	0.1002
$\delta_S(RS, \mathbf{dn})$	0.0596
$\delta_G(ATO, \mathbf{dn})$	-0.2730
$\delta_G(C, \mathbf{dn})$	0.5079
$\delta_C(ATO, NS, \mathbf{dn})$	-0.0743
$\delta_C(C, NSD, \mathbf{dn})$	-0.0136
$\delta_{AD}(NS, NSD, \mathbf{dn})$	-0.1007
$\delta_{AD}(NS, RS, \mathbf{dn})$	0.0025
$\delta_{AD}(NSD, ANS, \mathbf{dn})$	0.3541
$\delta_{AD}(NSD, SNS, \mathbf{dn})$	1
$\delta_{AND}(NS, \mathbf{dn})$	0.0187
$\delta_{OR}(NSD, \mathbf{dn})$	0.1002
$\delta_{AC}(NS, \mathbf{dn})$	-0.0067
$\delta_{AC}(NSD, \mathbf{dn})$	-0.0040
$\delta_{AC}(ANS, \mathbf{dn})$	-0.1002
$\delta_{AC}(SNS, \mathbf{dn})$	-0.0032
$\delta_{AC}(RS, \mathbf{dn})$	-0.0018

Feasibility Evaluation with CrowdNav Traffic Simulation

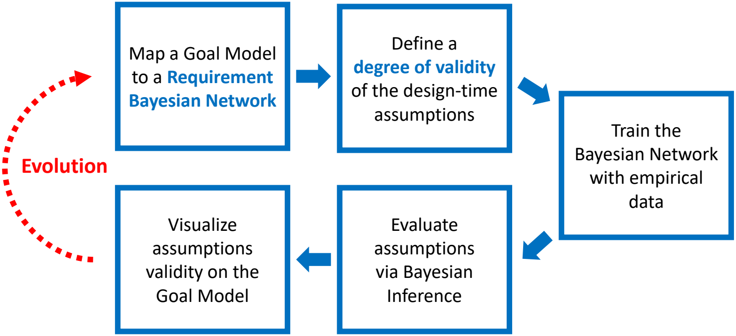




Assumption	Validity
$\delta_S(NS, \mathbf{ne})$	0.0675
$\delta_S(NSD, \mathbf{ne})$	0.0946
$\delta_S(ANS, \mathbf{ne})$	-6.43E-05
$\delta_S(SNS, \mathbf{ne})$	0.0940
$\delta_S(RS, \mathbf{ne})$	0.0581
$\delta_G(ATO, \mathbf{ne})$	0.9999
$\delta_G(C, \mathbf{ne})$	0.9998
$\delta_C(ATO, NS, \mathbf{ne})$	9.12E-06
$\delta_C(C, NSD, \mathbf{ne})$	0.4776
$\delta_{AD}(NS, NSD, \mathbf{ne})$	-0.0018
$\delta_{AD}(NS, RS, \mathbf{ne})$	0.0025
$\delta_{AD}(NSD, ANS, \mathbf{ne})$	-0.0252
$\delta_{AD}(NSD, SNS, \mathbf{ne})$	0.6684
$\delta_{AND}(NS, \mathbf{ne})$	-0.0376
$\delta_{OR}(NSD, \mathbf{ne})$	0.0939
$\delta_{AC}(NS, \mathbf{ne})$	-4.84E-05
$\delta_{AC}(NSD, \mathbf{ne})$	0.0028
$\delta_{AC}(ANS, \mathbf{ne})$	-0.7336
$\delta_{AC}(SNS, \mathbf{ne})$	0.0024
$\delta_{AC}(RS, \mathbf{ne})$	-0.0014

Discussion and Future Work

Summary



Future Work

- Evaluation of scalability and usefulness
- Additional analysis techniques (e.g., sensitivity analysis)
- Automated evolution of requirements

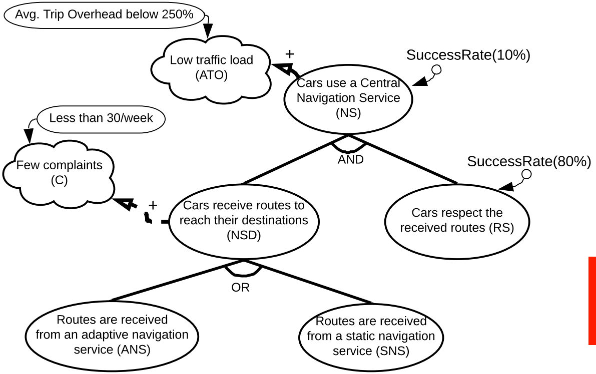
Thank you for your attention.

Davide Dell'Anna
d.dellanna@uu.nl

Degree of validity of design-time assumptions

Softgoal achievement assumption
$\delta_G(S, \mathbf{c}) = P(S_{true} \mid \mathbf{c}) - P(S_{false} \mid \mathbf{c})$

Contribution assumption
$\delta_C(S, G, \mathbf{c}) = P(S_{true} \mid G_{ob} \wedge \mathbf{c}) - P(S_{true} \mid G_{viol} \wedge \mathbf{c})$



Goal satisfiability assumption
$\delta_S(G, \mathbf{c}) = P(G_{ob} \mid \mathbf{c}) - P(G_{viol} \mid \mathbf{c})$

AND-decomposition assumption
$\delta_{AND}(G, \mathbf{c}) =$
$P(G_{ob} \mid \mathbf{G'}_{ob} \wedge \mathbf{c}) - P(G_{ob} \mid \mathbf{g} \wedge \mathbf{c})$

Adoptability assumption
$\delta_{AD}(G, G', \mathbf{c}) =$
$P(G_{ob} \mid G'_{ob} \wedge \mathbf{c}) - P(G_{ob} \mid G'_{viol} \wedge \mathbf{c})$

OR-decomposition assumption
$\delta_{OR}(G, \mathbf{c}) = P(G_{ob} \mid \mathbf{g1ob} \wedge \mathbf{c}) - P(G_{ob} \mid \mathbf{go} \wedge \mathbf{c})$

Goal necessity assumption
$\delta_{AC}(G, \mathbf{c}) =$
$P(\mathbf{S}_{true} \mid G_{act} \wedge \mathbf{c}) - P(\mathbf{S}_{true} \mid G_{dis} \wedge \mathbf{c})$