

Modelling interactions in complex systems – an air navigation service provider focussed approach

SESAR Innovation Days

Universidad Politécnica de Madrid
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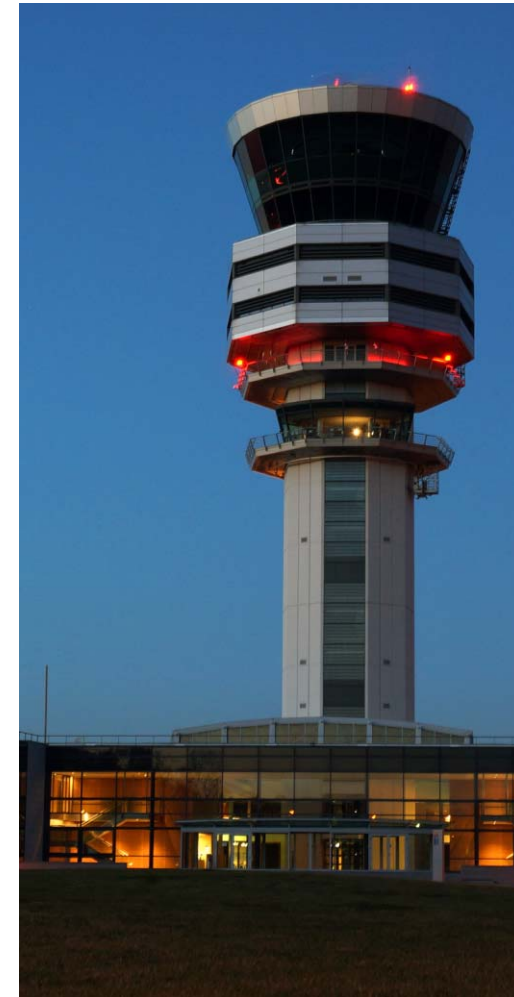
M. Kreuz, M. Schultz



Knowledge for Tomorrow

Outline

- Motivation
- Research question
- Choice of method
- Modeling approach
- Assessing interdependencies between relevant ANSP related parameters
- Conclusions

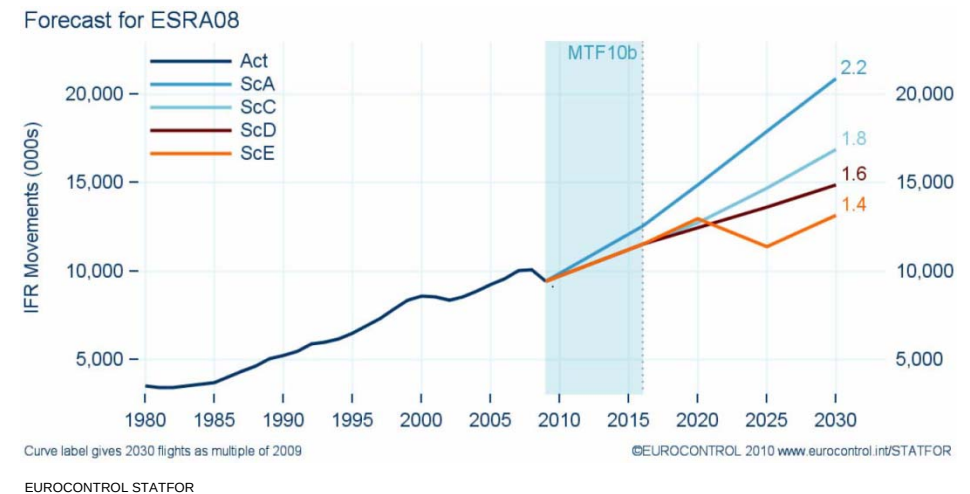


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Motivation (1|2)

- Setup of a performance scheme for navigations services and network functions within the Single European Sky (SES) Initiative
- European Commission adopted EU-wide performance targets within different reference periods (RP 1, 2012-2014 and RP 2, 2015-2019) of the performance scheme in order
 - to achieve greater transparency with respect to the determination of air navigation service charges and
 - to ensure to improve the cost efficiency of air navigation service providers (ANSP)



Motivation (2|2)

- Thresholds in RP1:
 - **Environment:** Reduction of 0,75% of the route extension in 2014 compared with 2009
 - **Capacity:** Maximum of 0,5 minute en-route ATFM delay per flight for the whole year 2014
 - **Cost-Efficiency:** Target is a set of three en-route determined unit rates expressed in €2009 per service unit: €57,88 in 2012; €55,87 in 2013 and €53,92 in 2014
 - **Safety:** No specific threshold defined in RP1
- RP2 aims to achieve a full coverage of ANS provisions (gate-to-gate scope including target setting in all KPA)
 - great challenges for ANSP ahead!
 - need to reflect processes!

Capacity

EU-wide + National / FAB level

Average en route ATFM delay per flight

maximum of 0,5 minutes per flight in 2014

Cost efficiency

EU-wide + National / FAB level

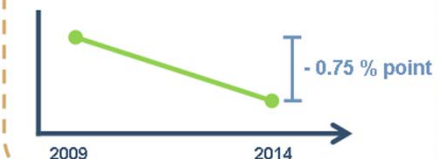
Average EU-wide determined unit rate for en route ANS



Environment

EU-wide + Network Manager level

Horizontal en-route flight efficiency

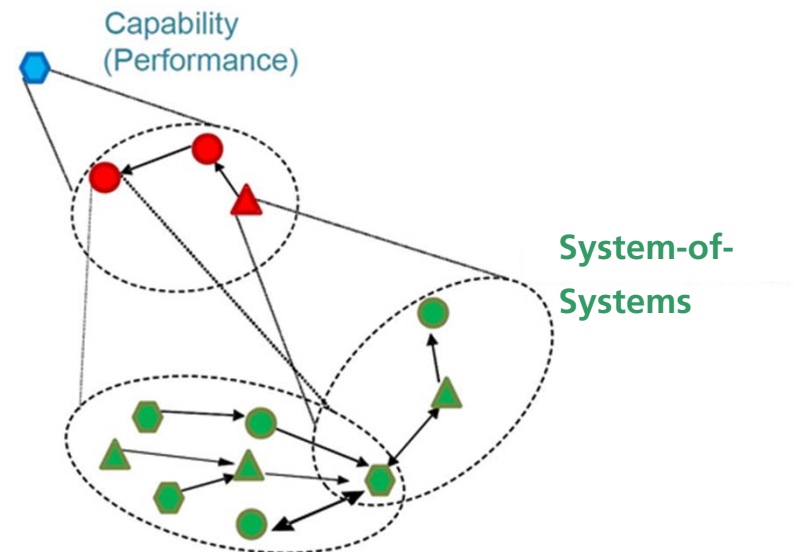


EUROCONTROL, SES Performance Scheme Reference Period 1



Research question

What interdependencies exist in the system of air navigation service provider and how can these ones be modelled, analyzed and assessed?

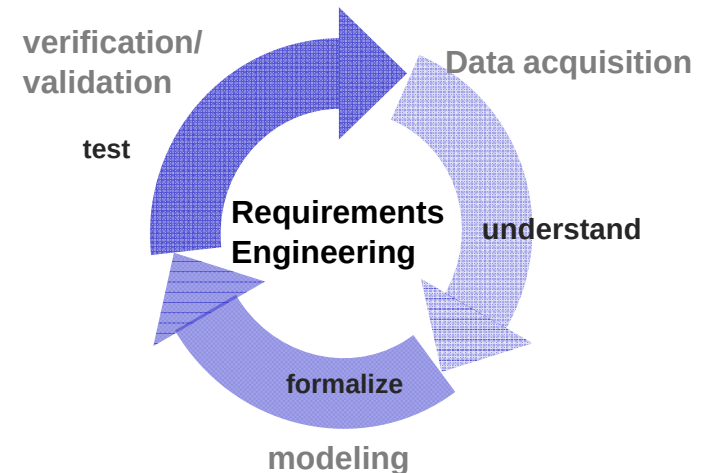


Hahn, S.Y. and DeLaurentis, D.A., "Development Interdependency Modeling for System-of-Systems (SoS) using Bayesian Networks: SoS Management Strategy Planning", 2013

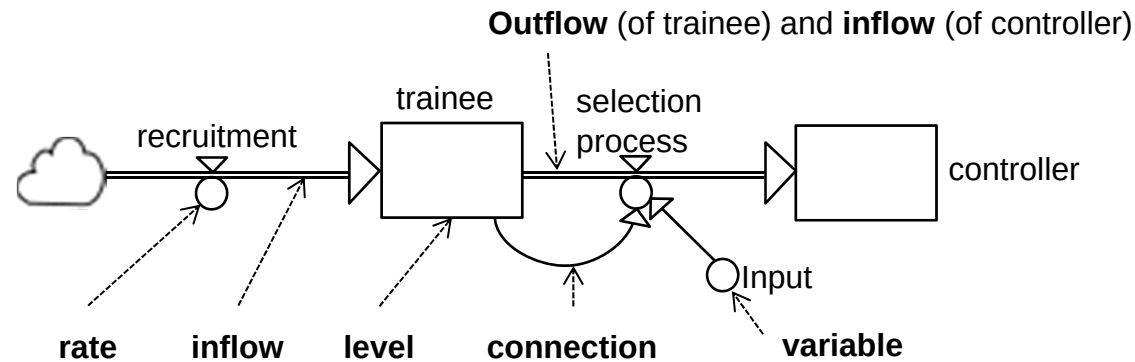


Requirements engineering

- Identify, analyze and evaluate the interactions between the relevant parts of an ANSP in terms of capacity and overall (economic) performance with regard to their impact on the system's behavior
- Develop a dynamic model that considers tight couplings among parameters and actions leading to rather counterintuitive effects
- Validate the model's results in order to add value to the decision process



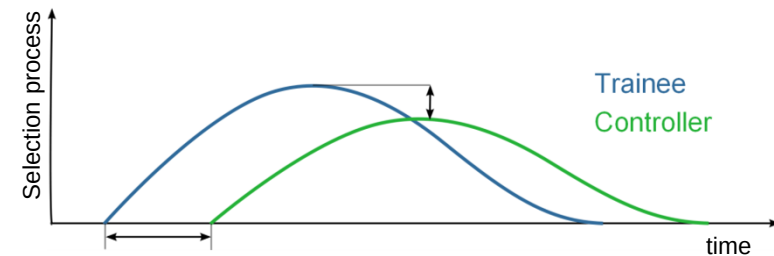
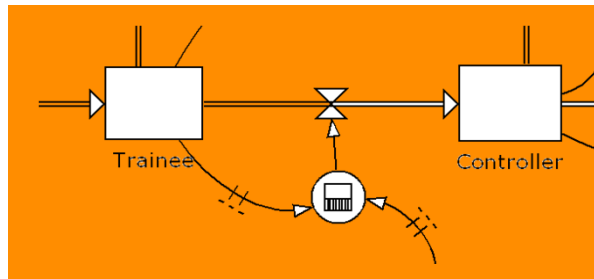
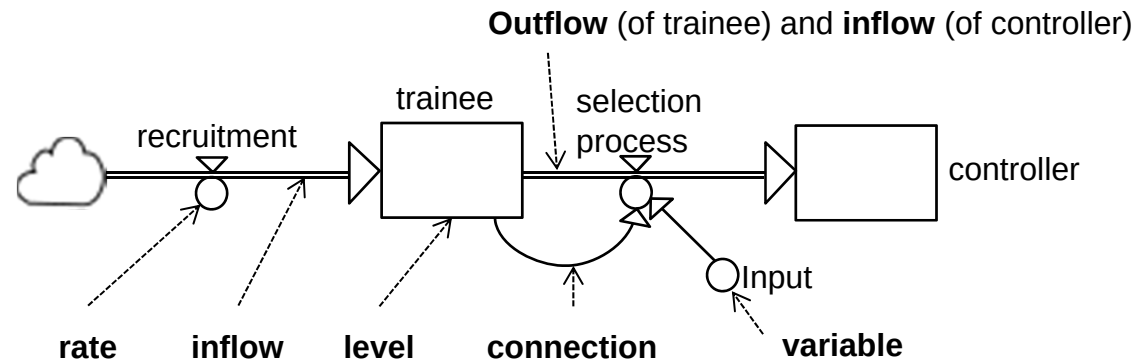
Choice of method



- System Dynamics (SD) approach created by J.W. Forrester at the MIT in mid-1950s
- SD models deal with the interactions of objects in time-dependent and complex systems
- Span of applications grew to include social sciences and economics
- Models are defined by
 - levels (stocks)
 - inflows/outflows (rates)
 - variables/constants
 - connections



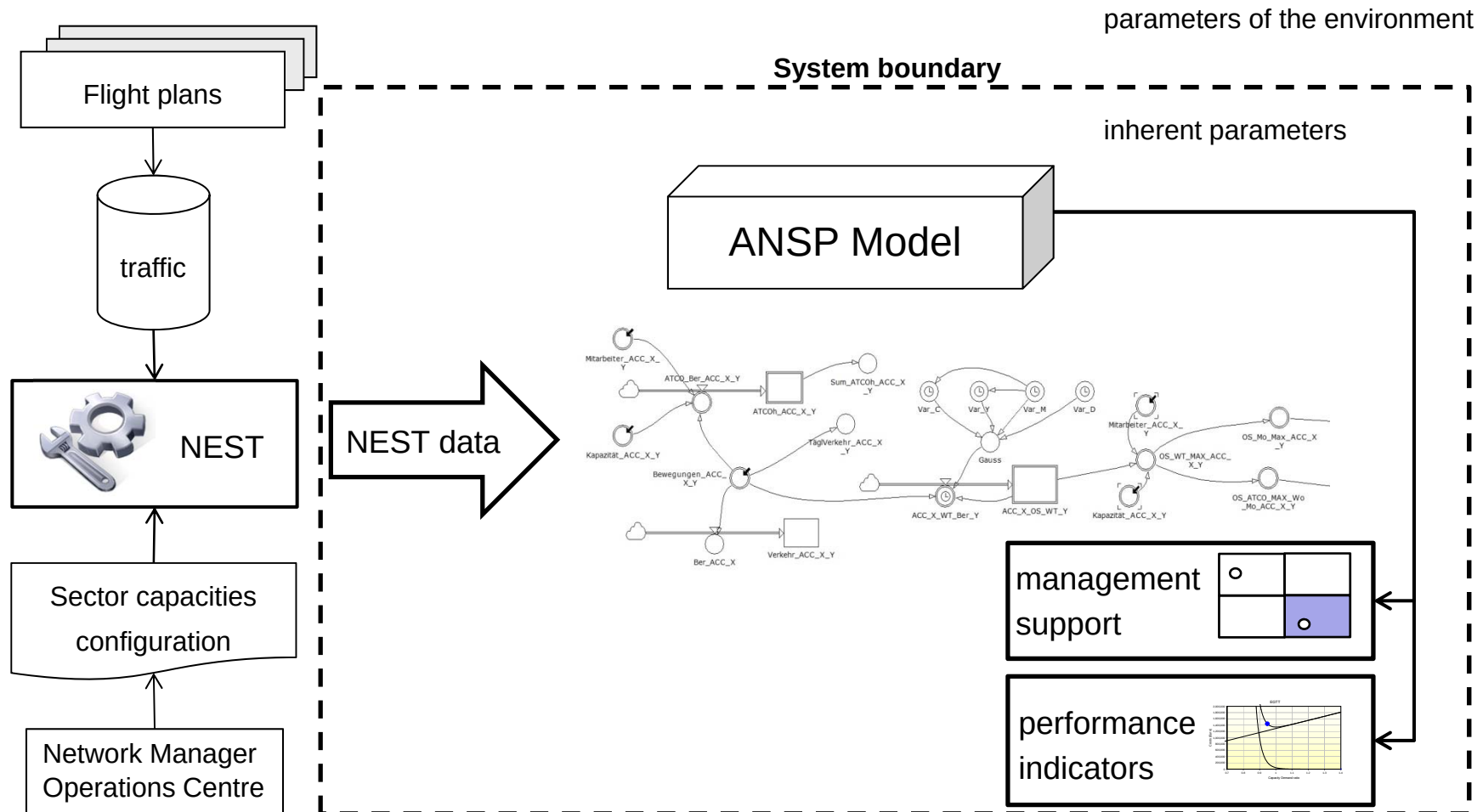
Choice of method



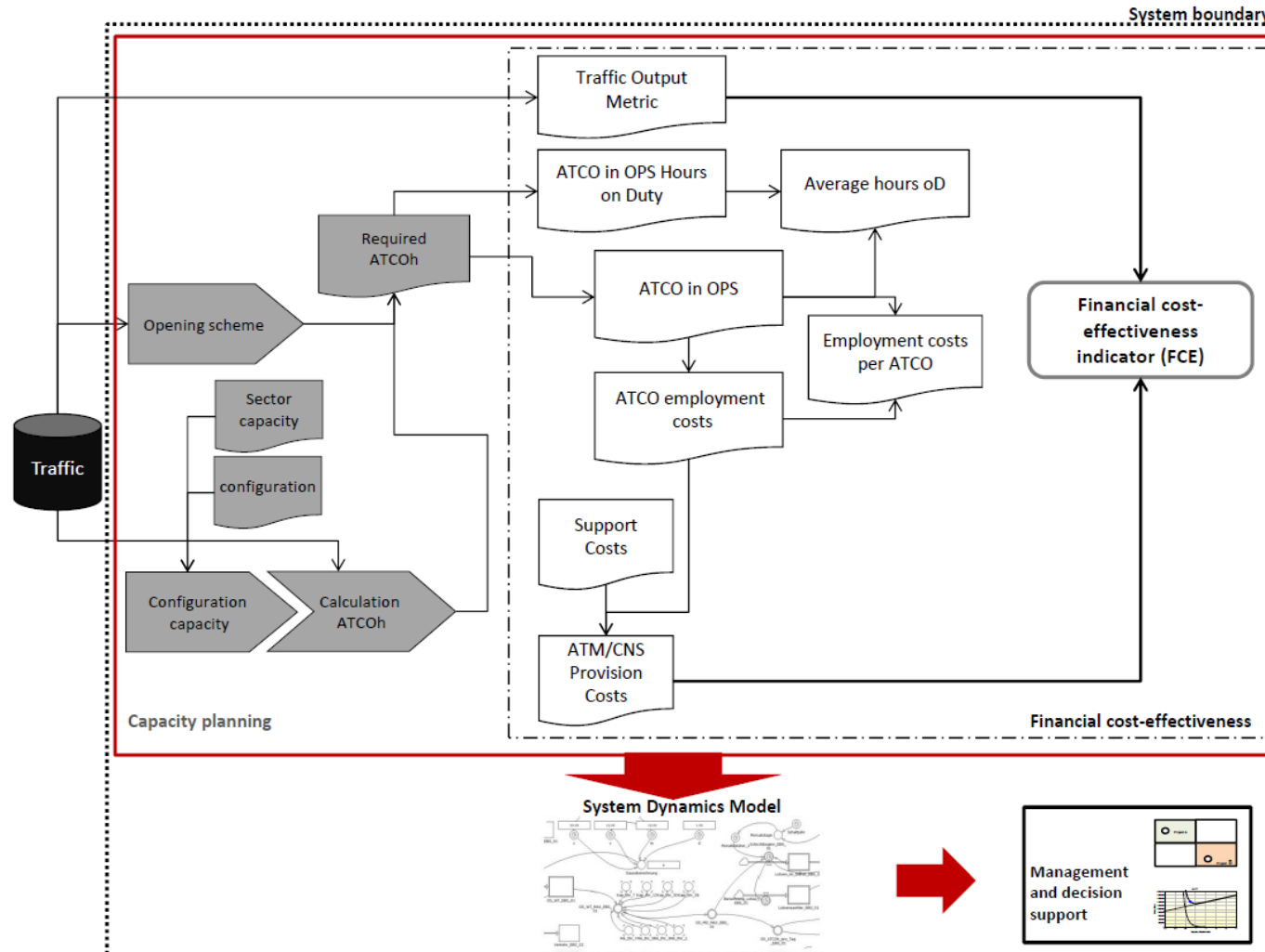
Dynamics of the overall system is determined by the stock and flow structure, delays, other mathematical functions and the principle of feedback loops (the information resulting from one action return and having an effect on future ones)



System environment



Modeling approach



Assessing interdependencies

basics / data

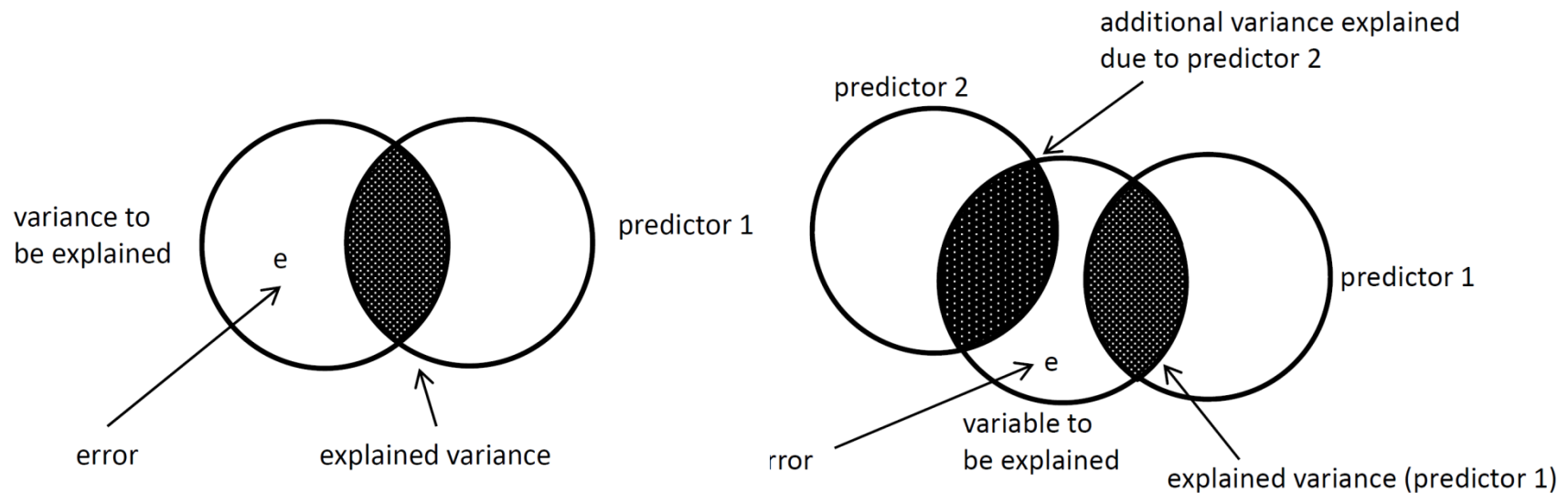
- Relevant variables:
 - Movements,
 - Air traffic controller hours (ATCOh) and
 - Delay
- Sample:
 - $n = 60$ values per variable covering 3 phases
 - phase before implementation (24 months = 24 values)
 - phase during implementation (12 months = 12 values)
 - phase after implementation (24 months = 24 values)
 - within the time period from 2009 – 2013
- Correlation between these variables? Any chance to approximate one variable by two others?



Assessing interdependencies

Statistics

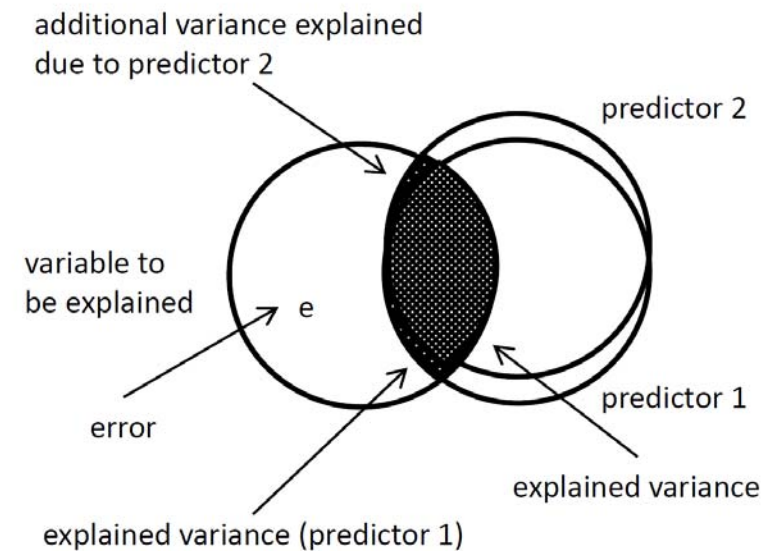
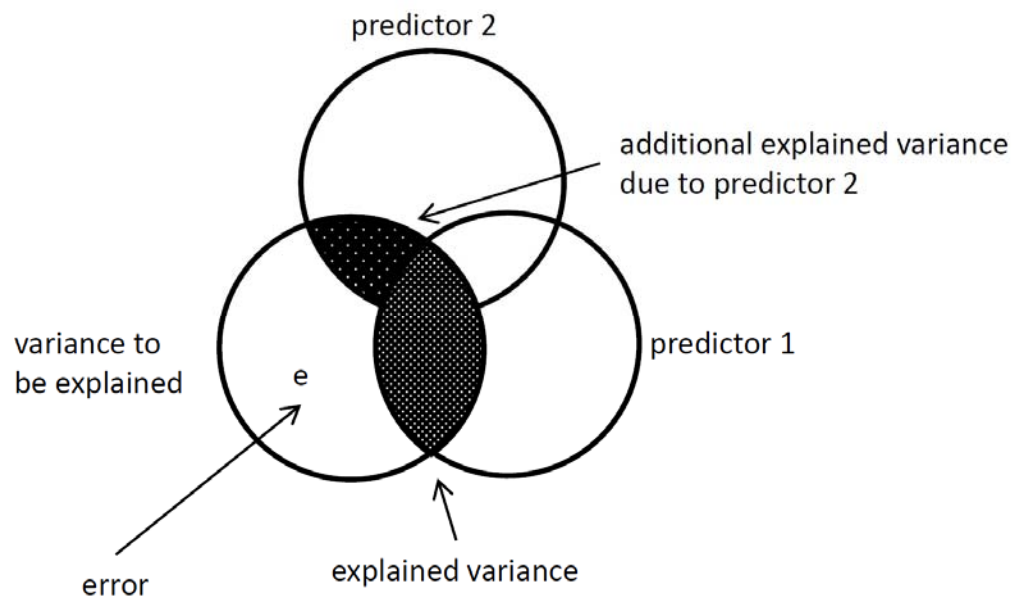
- Any chance to approximate one variable by two others?
- In mathematical terms, approximation of one variable by two others equals the explanation of its variance



Assessing interdependencies

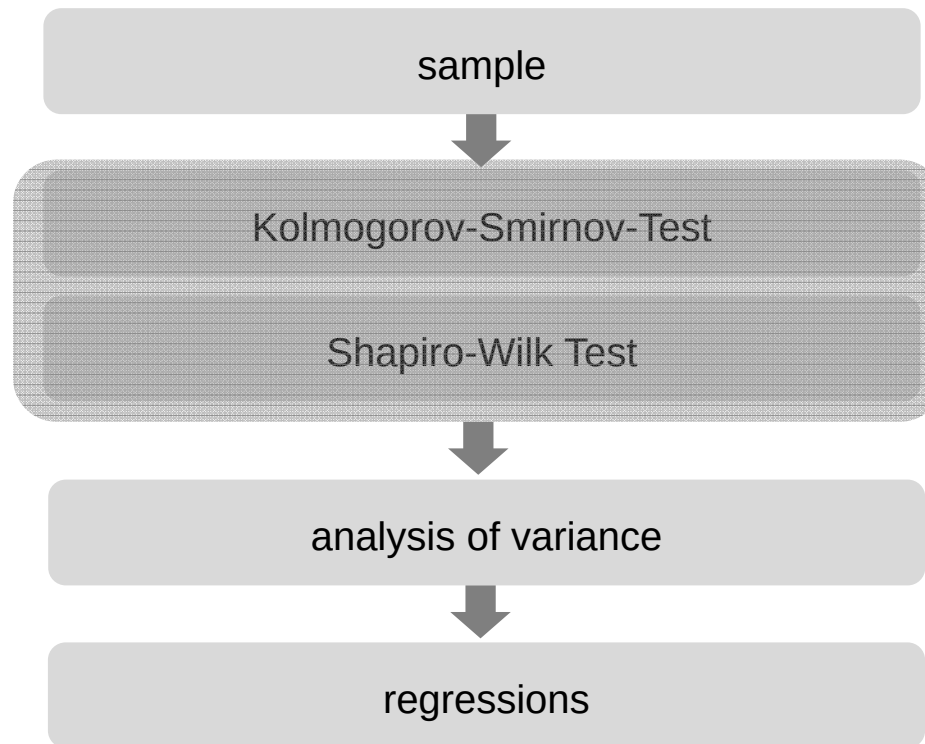
Statistics

- Semi partial correlation is used to assess the specific effect of each independent variable on the dependent variable.



Assessing interdependencies

Approach



K-S Test

	After Implementation		
	<i>Movements</i>	<i>ATCOh</i>	<i>Delay</i>
N (number)	24	24	24
Kolmogorov-Smirnov-Z	0,577	0,734	1,2
Asymptotic significance (2-tailed)	0,893	0,655	0,105

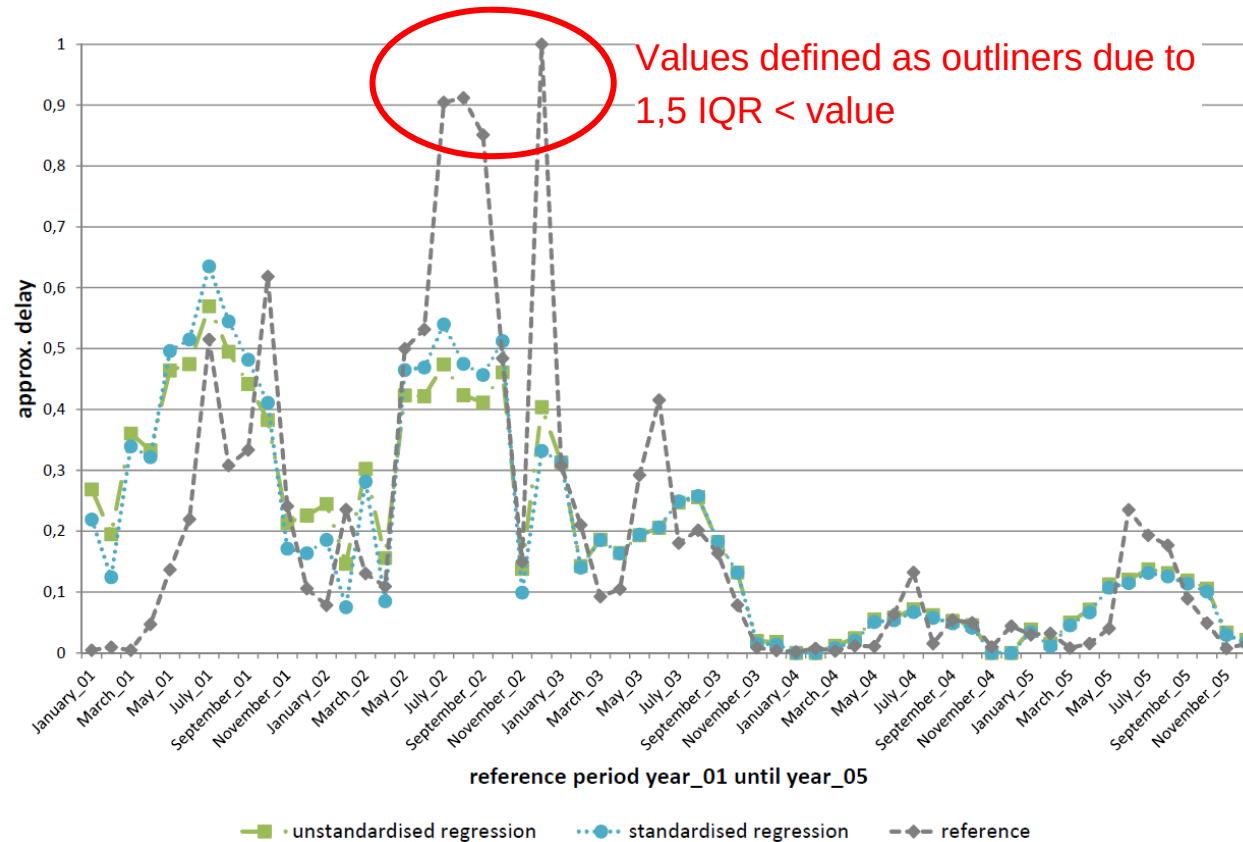
Shapiro-Wilk Test

	After Implementation		
	<i>Movements</i>	<i>ATCOh</i>	<i>Delay</i>
N (number)	24	24	24
W	0,948	0,941	0,748
Significance	0,246	0,174	0,000

threshold (alpha level) of 0,05 (5%) to decide whether a null hypothesis should be rejected or retained



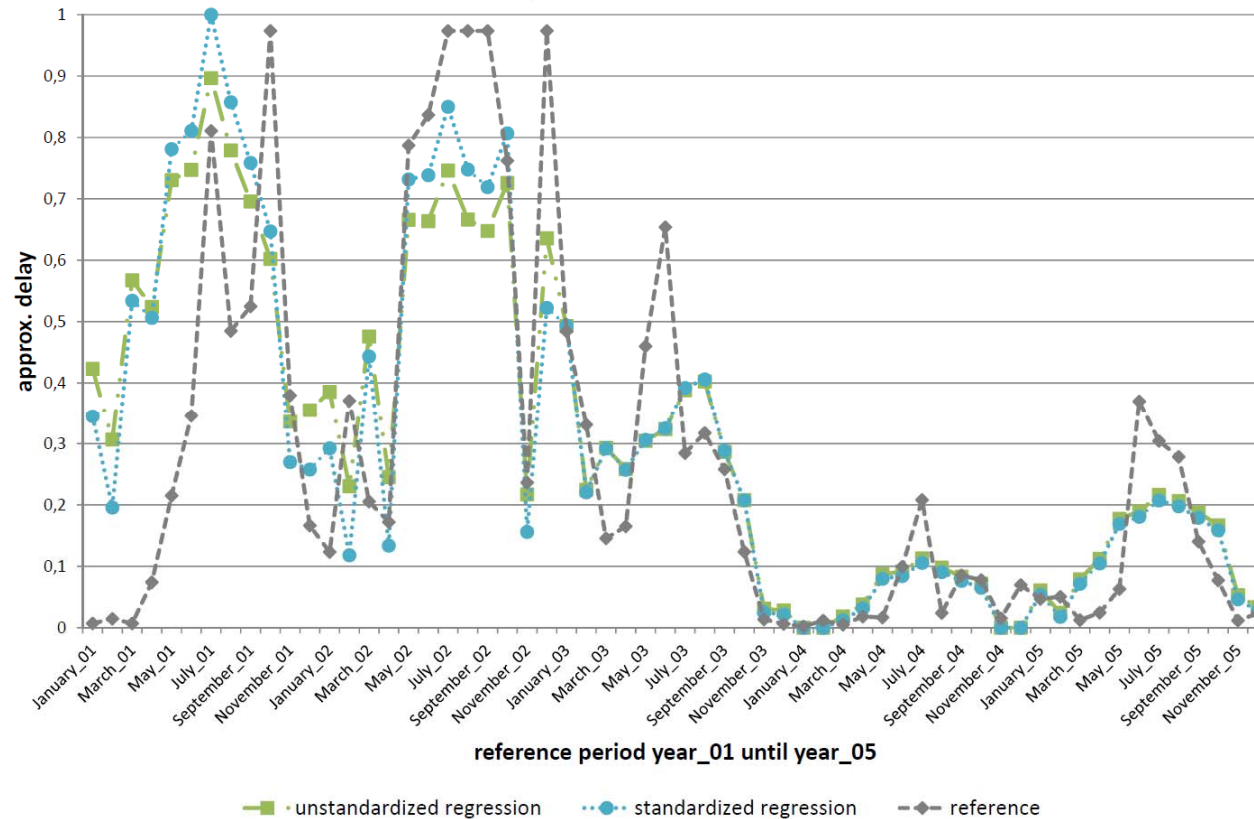
Results



- Standardized regression offers better reproduction of the delay development than unstandardized regression ($r = 0,55$ compared to $r = 0,53$)



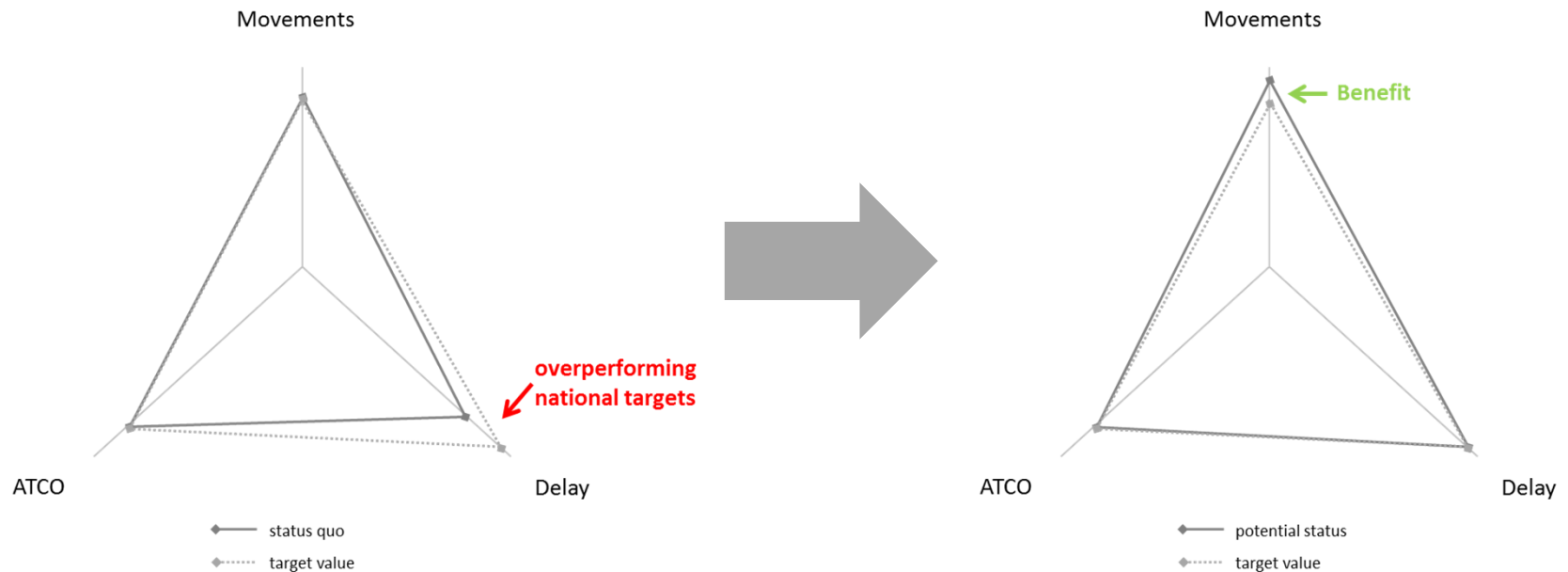
Results



- Correlation coefficients can be increased up to $r = 0,8$ by substituting the defined outliers



Application to future performance measurement



- Assessing interdependencies between relevant parameters increases the understanding of the system's behavior
- Generic approach allows the model's adaption to several national ANSP



Conclusions

- Systematically developed approach towards the performance evaluation of an ANSP focusing on capacity and economic related aspects
- Applying System Dynamics to the issues of an ANSP for microeconomic analysis is a first of its kind approach
- The use of the generic approach allows the adaptation to the analyses of different ANSP
- Focused on the interactions between relevant parts of an complex system



Thank you for your time!

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