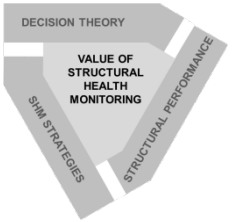
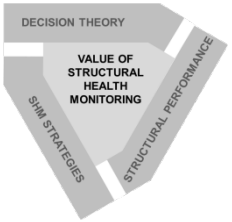


Smart Structures for Smart Maintenance

Lessons learned from ongoing monitor initiatives

W.M.G. Courage, A.J. Bigaj-van Vliet, W.H.A. Peelen & G.T. Luiten (TNO)
R. Drieman (Fugro GeoServices)
The Netherlands



Introduction

SBRCURnet:

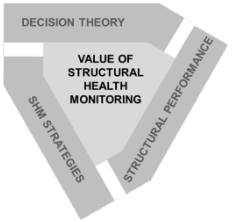
Dutch association with partners from building industry

Initiating research topics, stimulate innovations, develop guidelines, disseminate knowledge

Committee 1992: study with respect to:

How can monitoring be applied and promoted in construction and maintenance

With participation of TNO, Delft University, governmental parties, municipalities, building and consulting industry



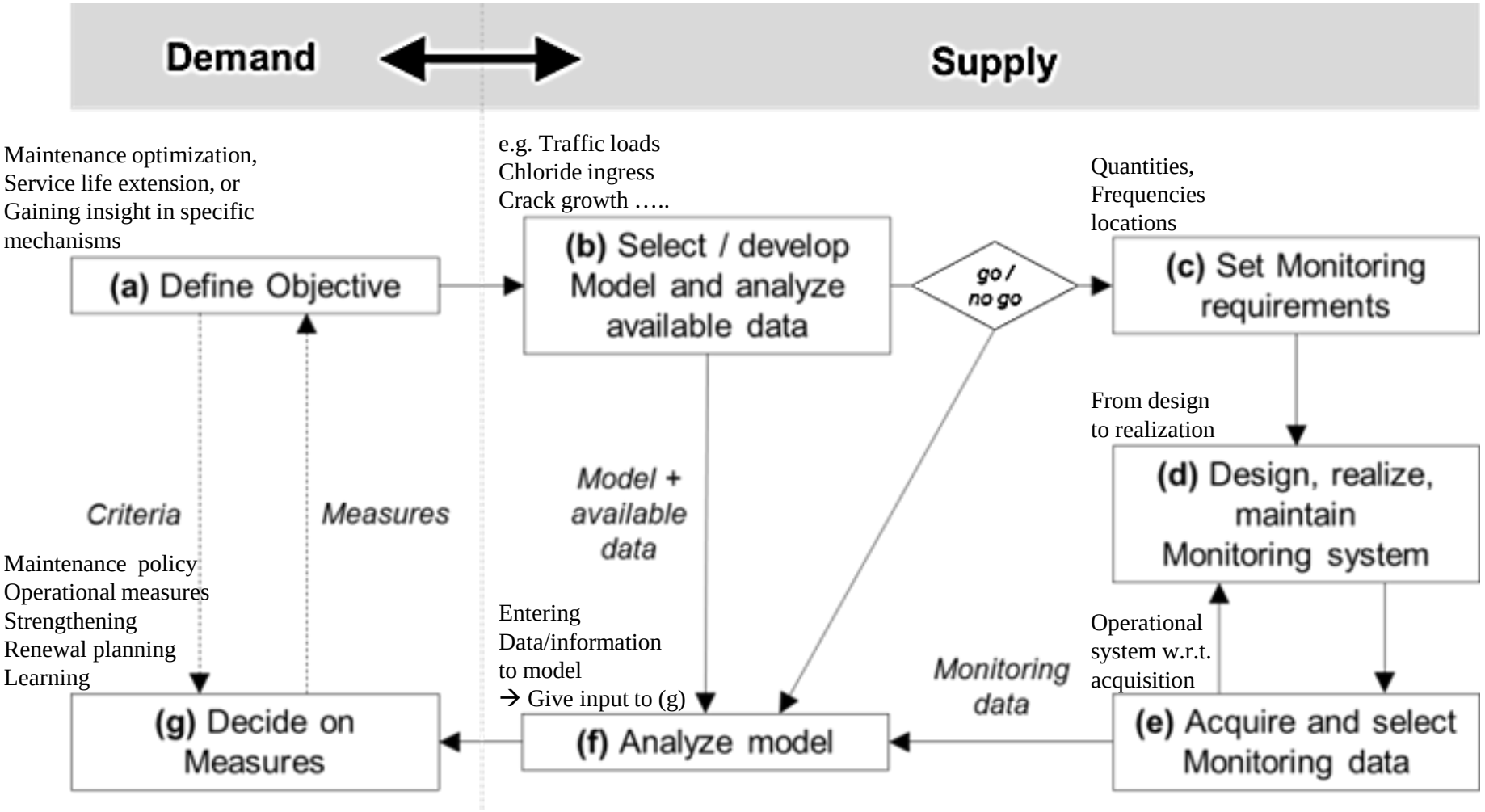
Scheme

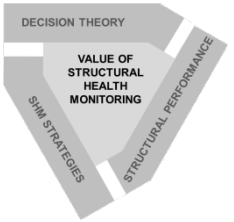
Evaluate ongoing monitoring projects:

success / no success, opportunities / threats, and, and ……
why ?
lessons learned?

How to evaluate?

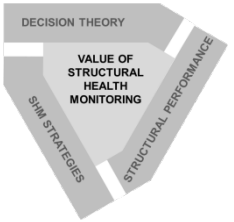
Scheme


Demand
Supply
Maintenance optimization,
Service life extension, or
Gaining insight in specific
mechanisms
e.g. Traffic loads
Chloride ingress
Crack growth …..
Quantities,
Frequencies
locations
(a) Define Objective
(b) Select / develop Model and analyze available data
go / no go
(c) Set Monitoring requirements
From design
to realization
(d) Design, realize, maintain Monitoring system
Criteria
Measures
Model + available data
Maintenance policy
Operational measures
Strengthening
Renewal planning
Learning
Entering
Data/information
to model
→ Give input to (g)
Monitoring data
Operational
system w.r.t.
acquisition
(g) Decide on Measures
(f) Analyze model
(e) Acquire and select Monitoring data



Scheme

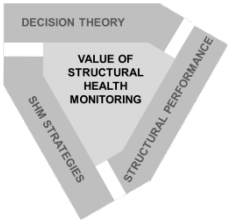
- **Interests/needs (owner/user objective)** – including reflection on the higher-level (societal/economic).
- **Opportunities and threats** – efficiencies/successes found enabling upscaling SHM?
  factors may hindering large scale application of SHM?
- **Time horizon** – e.g. temporary, indefinitely?)
- **Cost-benefit** – qualitative and quantitative incl. (initial) single costs/benefits versus upscaling,
- **Data management** – readiness of organisation to deal with data management; coupling to existing information
- **Technology Readiness Level (TRL)** –to what extent the system is technically ready for repeated or organization-wide application



Results

Objective: maintenance optimization

Project	Objective	Status	Success?
Light intensity, Maas Tunnel, Rotterdam	Optimize cleaning frequency	On hold; system designed (c) but no decision on project taken yet	Seems possible and feasible, but not yet executed
Joint, viaduct highway A73, Venlo	Optimize maintenance frequency with early warning system	Go/no-go decision pending (b) / system tested in lab (d)	System works satisfactorily in lab conditions
Identification of objects of National Road Authority, Eastern part of The Netherlands	Optimize inspection process by better identification of objects with RFID chips	System installed (d)	Identification with RFID chips works satisfactorily; actual use still has to start
Chloride penetration in concrete, feasibility study	Assess non-destructively the structural health of corroded reinforced concrete structure	Feasibility study until preliminary system design (d)	Right sensors do not (yet) exist
Joint distance, viaduct 24 Oktoberplein, Utrecht	Guarantee safety of bridge without (expensive) physical repair measure	Running, no (physical) measure needed until today (f) / (g)	Yes, with the monitoring system repair measures could be avoided, without increasing the safety risks



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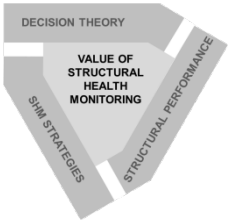
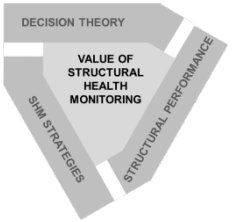


Results

Objective: service life extension

Project	Objective	Status	Success?
Moving abutments, Concordia bridge, Gorinchem	Gain insight in mechanisms for displacements of abutments to guarantee safe service of the bridge	Analyzing the fail mechanisms based on existing data proves more difficult than expected (b)	So far, the analysis did not result in conclusive answers. Added value of monitoring could not be established
Bridge joint, Martinus Nijhof bridge, Zaltbommel	Extend service life of joints safely by early warning system	Concluded (g)	Yes, maintenance delayed for one year without safety warning
Steel deck, Van Brienoord bridge, Rotterdam	Study feasibility of extending service life of steel bridge decks	Running (f), (g)	Yes, when combining measured data and models actual service life can be predicted
Alkali Silica reaction (ASR) deterioration, viaducts highway A59	Extend service life of affected concrete by assessing structural safety	Running (f), (g)	Although the fail mechanism is not yet understood completely, the consequences can be managed safely



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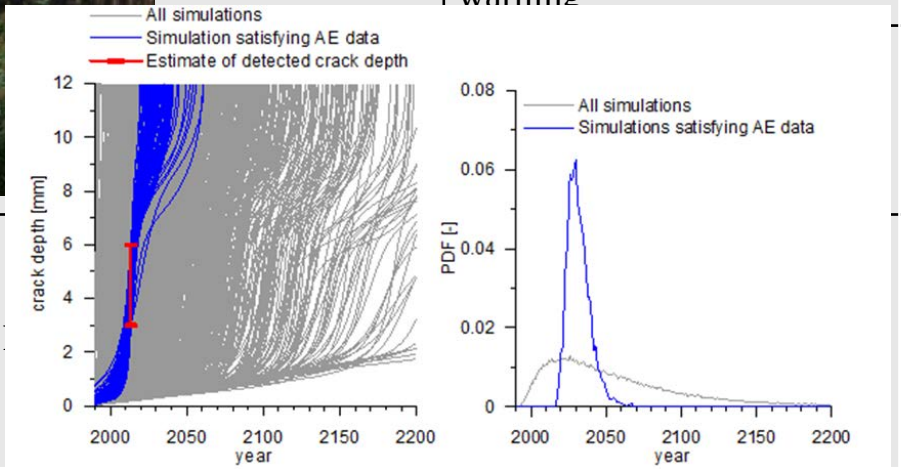
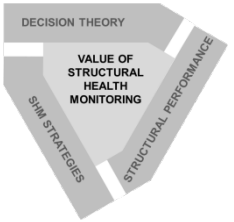
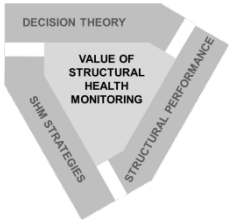




Results

Objective: insight in the behaviour

Project	Objective	Status	Success?
Synthetic lock gates, Spiering sluice, Werkendam	Update regulations for structural analysis of synthetic structures under temperature loads	Running, data is being acquired, filtered and analyzed (e), (f)	System runs satisfactorily; until today, only limited temperature deviations measured
High strength concrete, 2nd Stichtse bridge, Blaricum	Gain insight in creep and shrinkage behavior of high strength concrete for better modelling	Running (f), (g)	Measurements are in compliance with the Model Code (2010)
Orthotropic steel elements, Galecoppen bridge, Utrecht	Determine additional load bearing capacity compared to regulations	Monitoring concluded (f); analysis in progress (g)	Data acquired successfully
Weight in Motion, highways, The Netherlands	Evaluate actual traffic loads, as regulated in Eurocode	Running (f)	Until today, the actual traffic loads are within the boundaries defined in the Eurocode



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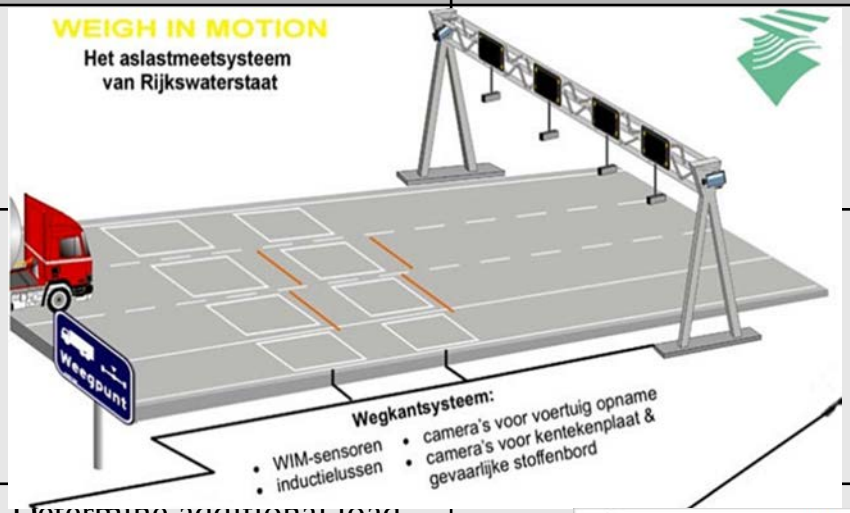
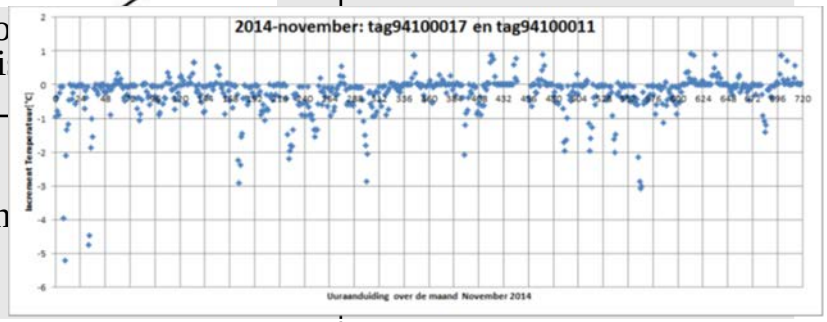
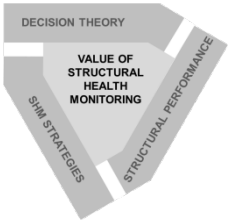






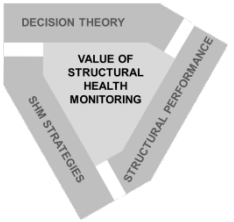
Conclusions

Flowchart

- guiding the appraisal
- facilitating monitor system design, balancing ***demand ←→ supply***
- facilitating comparison, feedback an communication w.r.t monitoring systems

Monitoring systems

- mostly off-the shell
- pilots by pioneers, research driven, sometimes business driven
- not (yet) always labelled as successful
- clear objectives and interaction with supply are a key for success



Conclusions

Application/upscaling

- resistance from practice
- problems not urgent enough
- problems too urgent
- who pays versus who profits
- pay now, profit much later

COST TU1402

- Structured approach, clear objectives, balanced demand and supply
- Quantification of Value of Information