VALUE-OF-INFORMATION AND VALUE-OF-CONTROL IN OIL SPILL RISK MANAGEMENT

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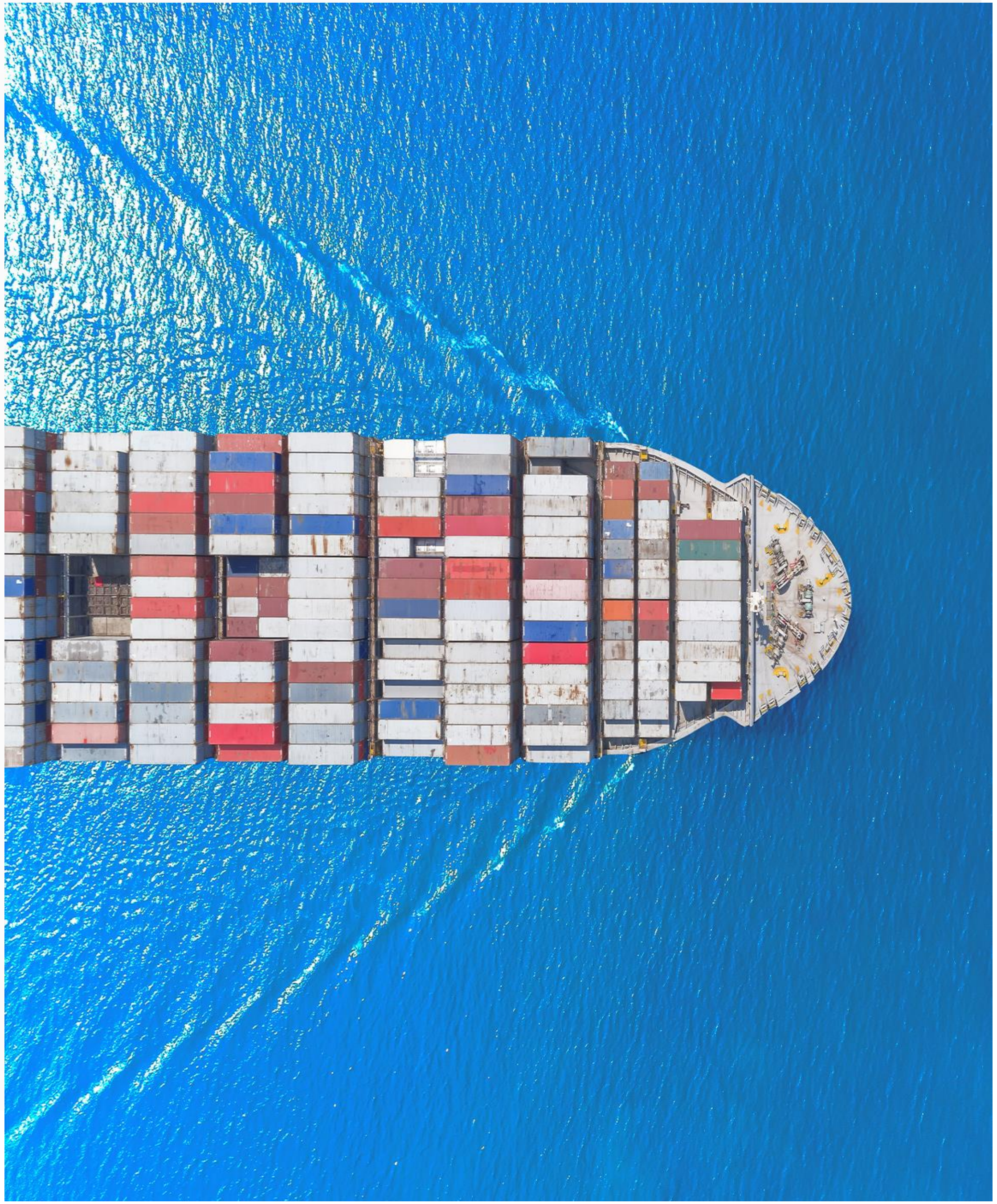
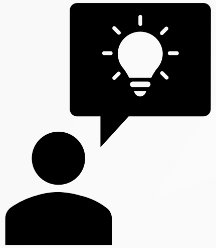
AGENDA

- Introduction
- Methods
- Analysis results
- Discussion points
- Future possibilities



INTRODUCTION



- **Research** helps us to choose the most beneficial actions
  - Without knowledge it is hard to form adviced policies – more uncertainty, economical losses…

- **Policies** help us to reach the most desired state of the system
  - Knowledge alone does not result as changes, we need actions too
  - Without policy implementation, no change in the state of the system

The connection between science and policies; information and control; knowing and doing…

INTRODUCTION

- Policy makers need to decide on resource allocation between policy implementation and research
- However, only a few published papers looking at the relationship between control and information
- E.g., paper by Fenwick et al. (2008) on implementation of new technology in the medical field
    - A lot of research on cost-effective health care technologies, but the implementation uncertainty of said technologies is not considered in the analyses

RESEARCH QUESTIONS

1. What is the relationship between VoI and VoC?

2. What implications the results can offer on optimal resource allocation for oil spill risk management?

METHODS: BAYESIAN NETWORKS AND INFLUENCE DIAGRAMS

Bayesian Networks

Causal probabilistic networks, uncertainty nodes and arcs describing the causal relationships between them

Information about the variables and their relationships from different sources: data, experts, simulations…

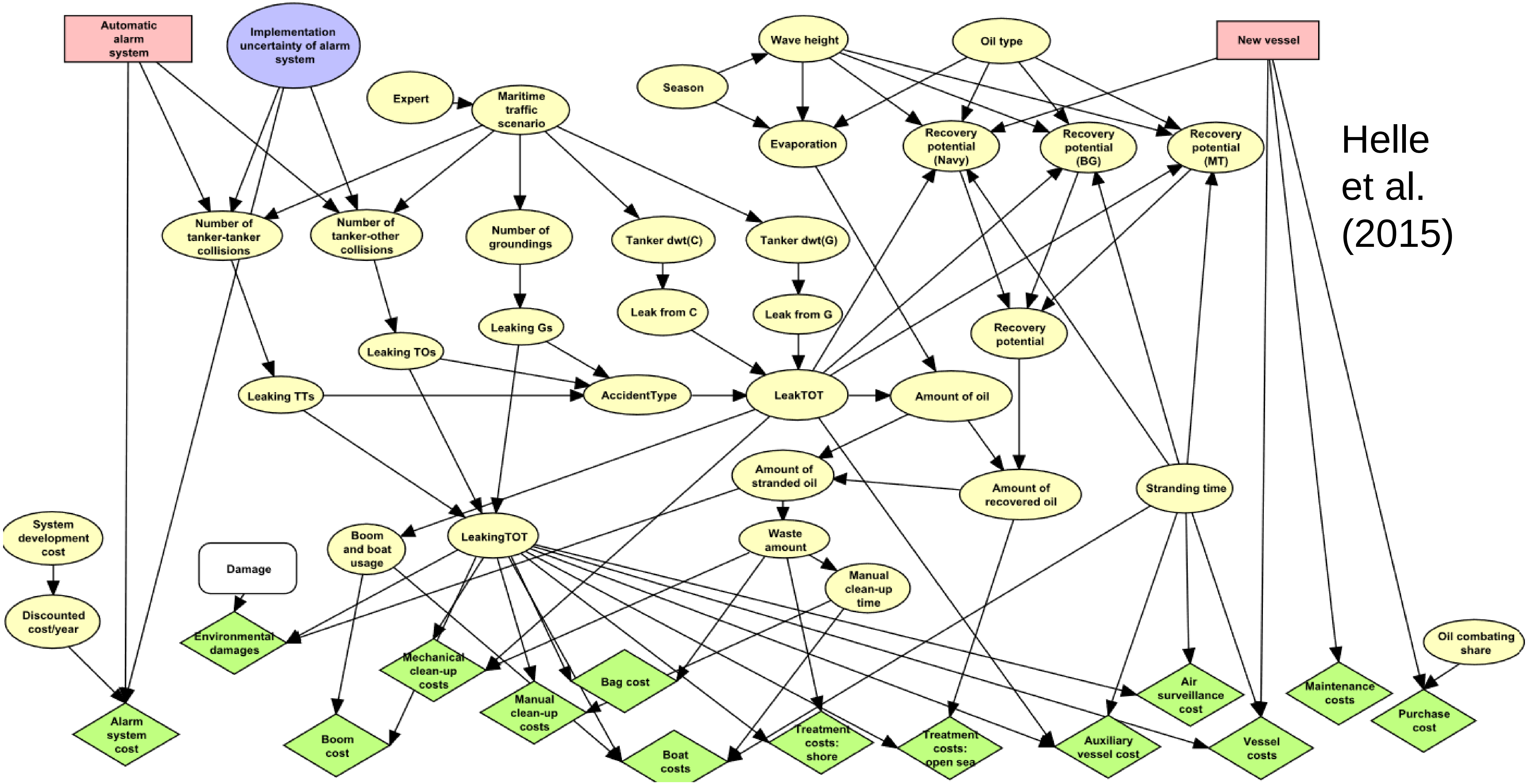
Influence Diagrams

Additional nodes for decisions and utilities

How decisions influence the system by changing probability distributions of outcomes and overall benefit defined by utility function

THE MODEL BY HELLE ET AL. (2015)

- A published Bayesian decision model
- Cost-benefit analysis of two oil management policies
  - Automatic Alarm System AAS = a preventive pre- spill policy measure
    - Decreases the probability of tanker-collision accidents
  - New combatting Vessel NV = a post- spill policy measure
    - Decreases the probability of oil reaching the shoreline (increasing environmental- and cleaning costs)



Helle et al. (2015)

METHODS: VALUE OF INFORMATION

- If we could observe the true state, i.e., have no uncertainty, of a certain variable prior to making a decision, how much would be gained from this observation?

- Decision without the additional knowledge: Expected Maximum Value (EMV)
- Knowledge clearing all uncertainty prior the decision is made:

  Expected Value of Perfect Information (EVPI)

- Value of Perfect Information = EVPI – EMV

  i.e., the difference between expected values under perfect certainty and uncertainty

METHODS: VALUE OF CONTROL

- Uncertainty in the outcome of a policy, i.e., the annual number of collisions after the implementation of an alarm system
- From previous research we can tell, that VoI decreases when controllability increases (Fenwick et al. 2008; Helle et al., 2015)
    - What happens to VoI when controllability is assumed to be worse than data and expectations suggest?
- Obtain controllability over the outcome of implementing AAS, introduce different uncertainty levels (0-10) and test the effect of increased uncertainty in VoI analysis results

The results of VoI analysis related to the decision on the new vessel (€).

State of AAS	No	Yes
Leaking TOT	539 000	526 000
Amount of oil	398 000	387 000
Leak TOT	347 000	335 000
Leaking Gs	272 000	271 000
Leaking TOs	261 000	250 000
Boom and boat usage	188 000	173 000
Leak from G	149 000	148 000
Marginal damage	131 000	124 000
Wave height	90 000	87 000
Leak from C	88 000	81 000
Leaking TTs	45 000	43 000
Number of TTs	27 000	25 000
Number of TOs	22 000	20 000
Number of Gs	1000	1000

Helle et al. (2015)

METHODS: VALUE OF CONTROL

Two approaches for creating noise, i.e., uncertainty, between the decision variable and the expected numbers of annual collision accidents:

1st approach: Proportional co- variation

- Deducting a probability mass from the most wanted outcome (zero accidents), and distributing it to rest of the outcomes (1 to 6 accidents) based on their proportional size

$$\sigma_{proportional}(\theta_k, x) = \begin{cases} x & if\ k = 0 \\ \frac{1-x}{1-\theta_0} * \theta_k & otherwise \end{cases}$$

Renooij (2014)

METHODS: VALUE OF CONTROL

2nd Approach: Order- Preserving uniform co- variation

- Deducting a probability mass from the most wanted outcome (0), and distributing it to rest of the outcomes (1-6) so that the initial order of the parameters is kept until the distribution reaches uniform distribution x^T

$$\sigma_{order-preserving}(\theta_k, x) = \begin{cases} x & if\ k = 0 \\ \frac{\theta_k - x^T}{x^T - \theta_0} * (x^T - x) + x^T & otherwise \end{cases}$$

Renooij (2014)

RESULTS FOR APPROACH 1: PROPORTIONAL CO-VARIATION, NV EXCLUDED

With proportional method, VoI increases only in uncertainty levels 9 and 10, indicating that the level of ”uncontrollability” can not be reached using this method.

In highest levels of uncertainty, the VoI starts to increase.

NEW VESSEL: NOT IMPLEMENTED

Implementation uncertainty level	0	1	2	3	4	5	6	7	8	9	10
1.Marginal damage	0	0	0	0	0	0	0	0	0	**2 460**	**5 840**
2. Additional recovery (WTP)	0	0	0	0	0	0	0	0	0	**1 940**	**5 560**
3. Leak from C	0	0	0	0	0	0	0	0	0	0	**3 070**
4. Tanker dwt C	0	0	0	0	0	0	0	0	0	0	**568**
Sum of VoI	0	0	0	0	0	0	0	0	0	4400	15038
No. of variables	0	0	0	0	0	0	0	0	0	2	4

RESULTS FOR APPROACH 2: ORDER- PRESERVING UNIFORM CO- VARIATION, NV EXCLUDED

When only one policy decision is included, VoI increases all the way to the point of no controllability.

Using the order- preserving uniform method level of ”uncontrollability” can be reached.

NEW VESSEL: NOT IMPLEMENTED

Implementation uncertainty level	0	1	2	3	4	5	6	7	8	9	10
1.Marginal damage	0	0	**1 470**	**3 030**	**4 590**	**6 160**	**8 200**	**11 100**	**14 800**	**16 500**	0
2. Additional recovery (WTP)	0	0	**1 160**	**2 400**	**4 110**	**5 930**	**7 750**	**10 900**	**14 100**	**14 100**	0
3. Leak from C	0	0	0	0	**1 300**	**3 520**	**5 740**	**7 960**	**11 200**	**14 100**	0
4. Tanker dwt C	0	0	0	0	**0**	**1 073**	**3 560**	**6 030**	**8 840**	**12 600**	0
5. Number of accidents (WTP)	0	0	0	0	0	0	0	**1 050**	**3 840**	**8 020**	0
6. Discount cost/ year	0	0	0	0	0	0	0	0	0	**5 780**	0
7. System development cost	0	0	0	0	0	0	0	0	0	**5 780**	0
8. Additional efficiency (WTP)	0	0	0	0	0	0	0	0	0	**3 970**	0
9. Evaporation	0	0	0	0	0	0	0	0	0	**3 730**	0
10. Recovery efficiency (WTP)	0	0	0	0	0	0	0	0	0	**3 720**	0
11. Oil type	0	0	0	0	0	0	0	0	0	**1 730**	0
12. Season	0	0	0	0	0	0	0	0	0	**1 580**	0
13. Stranding time	0	0	0	0	0	0	0	0	0	**1 090**	0
14. Wave height	0	0	0	0	0	0	0	0	0	**963**	0
15. Improvement factor (WTP)	0	0	0	0	0	0	0	0	0	**384**	0
16. Maritime trafic scenario	0	0	0	0	0	0	0	0	0	**248**	0
17. WTP	0	0	0	0	0	0	0	0	0	**28**	0
Sum of VoI	0	0	2 630	5 430	10 000	16 683	25 250	37 040	52 780	94 323	0
No. of variables	0	0	2	2	3	4	4	5	5	17	0

RESULTS FOR APPROACH 1: PROPORTIONAL CO-VARIATION, BOTH POLICIES INCLUDED

As uncertainty increases from level 0 to level 3, additional research efforts are needed.

When uncertainty exceeds level 3 of uncertainty, at level 4 it is rather optimal to implement NV as well, and use less resources on obtaining new information.

Optimal policies for both decision variables (1 = Optimal to implement, 0 = Optimal not to implement)											
Automatic Alarm System (AAS)	1	1	1	1	1	1	1	1	1	1	1
New Vessel (NV)	0	0	0	0	1	1	1	1	1	1	1
Implementation uncertainty level	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Leaking Gs	**271 000**	**320 000**	**370 000**	**419 000**	0	0	0	0	0	0	0
2. Leak from G	**148 000**	**171 000**	**204 000**	**262 000**	0	0	0	0	0	0	0
3. Marginal damage	**124 000**	**626 000**	**1 140 000**	**1 660 000**	**1 700 000**	**1 610 000**	**1 520 000**	**1 440 000**	**1 350 000**	**1 270 000**	**1 240 000**
4. Wave height	**86 700**	**199 000**	**311 000**	**423 000**	**47 100**	**9 600**	**9 630**	**9 660**	**9 690**	**9 720**	**9 730**
5. Leak from C	**80 800**	**480 000**	**966 000**	**1 490 000**	**1 520 000**	**1 430 000**	**1 350 000**	**1 270 000**	**1 200 000**	**1 150 000**	**1 130 000**
6. Number of groundings	**703**	**5 240**	**31 300**	**147 000**	0	0	0	0	0	0	0
7. Tanker dwt C	0	**250 000**	**770 000**	**1 310 000**	**1 330 000**	**1 240 000**	**1 160 000**	**1 100 000**	**1 010 000**	**938 000**	**896 000**
8. Tanker dwt G	0	**7 820**	**45 500**	**198 000**	0	0	0	0	0	0	0
9. Additional recovery (WTP)	0	**235 000**	**846 000**	**1 460 000**	**1 550 000**	**1 490 000**	**1 43 000**	**1 370 000**	**1 310 000**	**1 260 000**	**1 230 000**
10. Number of accidents (WTP)	0	**87 600**	**460 000**	**831 000**	**788 000**	**653 000**	**518 000**	**383 000**	**290 000**	**246 000**	**219 000**
11. Additional efficiency (WTP)	0	**17 200**	**176 000**	**447 000**	**298 000**	**99 400**	**12 800**	0	0	0	0
12. Stranding time	0	0	**97 900**	**415 000**	**425 000**	**287 000**	**152 000**	**64 300**	**6 930**	0	0
13. Oil type	0	0	**236 000**	**824 000**	**891 000**	**809 000**	**727 000**	**645 000**	**564 000**	**490 000**	**445 000**
14. Evaporation	0	0	**282 000**	**822 000**	**840 000**	**710 000**	**580 000**	**520 000**	**487 000**	**457 000**	**438 000**
15. Recovery efficiency (WTP)	0	0	**136 000**	**409 000**	**265 000**	**65 500**	0	0	0	0	0
16. Season	0	0	0	**218 000**	**76 000**	0	0	0	0	0	0
17. Improvement factor (WTP)	0	0	0	**80 000**	0	0	0	0	0	0	0
18. WTP	0	0	0	**15 600**	0	0	0	0	0	0	0
19. Maritime traffic scenario	0	0	0	**9 310**	**8 890**	0	0	0	0	0	0
Sum of VoI	711 203	2 398 860	6 071 700	11 439 910	9 738 990	8 403 500	6 029 430	6 801 960	6 227 620	5 820 720	5 607 730
No. of variables	6	11	15	19	13	11	9	9	9	8	8

RESULTS FOR APPROACH 2: ORDER- PRESERVING UNIFROM CO- VARIATION, BOTH POLICIES INCL.

Similar development of results as were in the last table:

Uniform co- variation presents more uncertainty faster compared to proportional one, thus VoI increases only to level 1
After this point, at level 2 NV is also optimal to implement, and less information is required.

At level 9, when AAS is not optimal to impement, need for information increases in the number of variables,
thus, it is more optimal not to use resoruces to implement AAS, but rather towards research.

Optimal policies for both decision variables (1 = Optimal to implement, 0 = Optimal not to implement)

Automatic Alarm System (AAS)	1	1	1	1	1	1	1	1	1	0	0
New Vessel (NV)	0	0	1	1	1	1	1	1	1	1	1
Implementation uncertainty level	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Leaking Gs	**271 000**	**412 000**	0	0	0	0	0	0	0	0	0
2. Leak from G	**148 000**	**250 000**	0	0	0	0	0	0	0	0	0
3. Marginal damage	**124 000**	**1 590 000**	**1 550 000**	**1 300 000**	**1 130 000**	**987 000**	**841 000**	**734 000**	**666 000**	**594 000**	**507 000**
4. Wave height	**86 700**	**407 000**	**9 620**	**9 710**	**9 790**	**9 870**	**9 950**	**10 000**	**10 100**	**10 900**	**10 300**
5. Leak from C	**80 800**	**1 410 000**	**1 370 000**	**1 170 000**	**1 020 000**	**876 000**	**823 000**	**778 000**	**735 000**	**689 000**	**629 000**
6. Number of groundings	**703**	**129 000**	0	0	0	0	0	0	0	0	0
7. Tanker dwt C	0	**1 240 000**	**1 180 000**	**962 000**	**761 000**	**699 000**	**639 000**	**579 000**	**520 000**	**459 000**	**385 000**
8. Additional recovery (WTP)	0	**1 370 000**	**1 450 000**	**1 280 000**	**1 110 000**	**947 000**	**802 000**	**720 000**	**637 000**	**549 000**	**450 000**
9. Number of accidents (WTP)	0	**780 000**	**556 000**	**262 000**	**121 000**	0	0	**1 430**	**4 520**	**7 070**	0
10. Evaporation	0	**747 000**	**616 000**	**467 000**	**372 000**	**276 000**	**180 000**	**84 100**	0	**3 490**	0
11. Oil type	0	**742 000**	**750 000**	**516 000**	**282 000**	**47 700**	0	0	0	**1 520**	0
12. Additonal efficiency (WTP)	0	**400 000**	**27 500**	0	0	0	0	0	3	**3 270**	0
13. Recovery efficiency (WTP)	0	**371 000**	0	0	0	0	0	0	0	**3 030**	0
14. Stranding time	0	**341 000**	**187 000**	**71**	0	0	0	0	0	**786**	0
15. Season	0	**181 000**	0	0	0	0	0	0	0	**1 070**	0
16. Tanker dwt G	0	**175 000**	0	0	0	0	0	0	0	0	0
17. Improvement factor (WTP)	0	**52 900**	0	0	0	0	0	0	0	0	0
18. WTP	0	**4 810**	0	0	0	0	0	0	0	0	0
19. Discount cost/ year	0	0	0	0	0	0	0	0	**308**	**5 100**	0
20.System development cost	0	0	0	0	0	0	0	0	**308**	**5100**	0
Sum of VoI	711 203	10 602 710	7 696 120	5 966 781	4 805 790	3 842 570	3 294 950	2 906 530	2 573 239	2 332 336	1 981 300
No. of variables	6	18	10	8	8	7	6	7	9	14	5

CONCLUSIONS

- Introducing data about the efficiency of a certain policy can be challenging, if no data exists before making the decision
  - Thus, testing the model with different uncertainty levels can be helpful for identifying the sensitivity of optimal decisions, as well as further research needs
- When only one policy option is available, additional uncertainty in the policy outcome increases the need for obtaining information about the system
- When both policy options are included, collecting information can only be optimal to a certain point – it can’t always support the objective outcome
  - ➢ At some point in the system, the optimal decision is to allocate funds to policy implementation

FOOD FOR THOUGHT – FUTURE POSSIBILITIES

- The effect of Russia’s actions to the effectiveness of current oil spill risk management policies
- Improving scientific cost-effectiveness through co-operation in the Baltic Sea
  - Including these additional benefits to models?
- Testing the presented methods in different types of influence diagrams
- Analysing the importance of information for certain variables/ variable groups for different states of ucnertainty
- A lot of talk about the relationship between research and policies, but how do the businesses fit in this equation?
  - Like discussed yesterday, businesses can contribute to research funding, as research has benefits to the businesses as well

THANK YOU! QUESTIONS?