Looking for Alternatives ?
Split-shots as an exemplary case

Lars Carlsen
Awareness Center

An alternatives assessment is:

- a process for identifying, comparing, and selecting safer alternatives to chemicals of concern.
- intended to facilitate an informed consideration of the advantages and disadvantages of alternatives to a chemical of concern.

NAS 2014a

An alternatives assessment is not:

- *a safety assessment*, where the primary goal is to ensure that exposure is below a prescribed standard,
- *a risk assessment*, where risk associated with a given level of exposure is calculated
- *a sustainability assessment*, that considers all aspects of a chemical's life cycle, including energy and material use.

NAS 2014a

Lars Carlsen
LC@AwarenessCenter.dk

Alternatives Assessment Framework

Step 1: Identify the Chemical of Concern.
Step 2: Scoping and Problem Formulation.
Step 3: Identify Potential Alternatives.
Step 4. Refer Cases with Limited or No Alternatives to Research and Development.
Step 5. Assess Physicochemical Properties.
Step 6. Assess Human Health and Ecological Hazards, and Assess Comparative Exposure.
Step 7. Integration of Information on Safer Alternatives.
Step 8. Life Cycle Thinking.
Step 9. Optional Assessments: Additional Life Cycle Assessment,
Step 10. Identify Acceptable Assessments and Refer Cases With No Alternatives to Research and Development.
Step 11. Compare or Rank Alternatives.
Step 12. Implement Alternatives.
Step 13. Research or De Novo Design of Safer Alternatives.

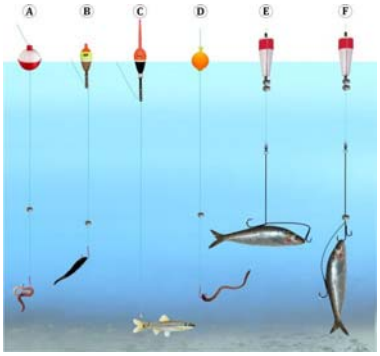
NAS 2014a

Alternatives Assessment Framework

Step 1: Identify the Chemical of Concern.
Step 2: Scoping and Problem Formulation.
Step 3: Identify Potential Alternatives.
Step 4. Refer Cases with Limited or No Alternatives to Research and Development.
Step 5. Assess Physicochemical Properties.
Step 6. Assess Human Health and Ecological Hazards, and Assess Comparative Exposure.
Step 7. Integration of Information on Safer Alternatives.
Step 8. Life Cycle Thinking.
Step 9. Optional Assessments: Additional Life Cycle Assessment,
Step 10. Identify Acceptable Assessments and Refer Cases With No Alternatives to Research and Development.
Step 11. Compare or Rank Alternatives.
Step 12. Implement Alternatives.
Step 13. Research or De Novo Design of Safer Alternatives.

NAS 2014a

Lars Carlsen
LC@AwarenessCenter.dk



A little background - Why?

Nearly 2,500 metric tons of lead are used each year in the United States to produce fishing sinkers.

Many of these sinkers are lost during use.
One study found that anglers lost,
on average, one sinker
every six hours of fishing.

Lead sinkers are lethal to waterbirds,
such as loons and swans.
One study found that the most common cause of death in adult breeding loons was lead toxicity from ingested fishing sinkers.

TURI, 2006

Step 11. Compare or Rank Alternatives

Example of a Summary Matrix for Multiple Alternatives across Several Criteria in a Case Study based on the TURI Framework

The decision analysis methods used in MCDA are one way to integrate disparate information to rank or differentiate alternatives.

MCDA methods may be useful in some cases, they may be more complicated than required for many assessments

There are other ways to rank, compare, and select alternatives, including simple matrix methods

NAS 2014a

Step 11. Compare or Rank Alternatives

Example of a Summary Matrix for Multiple Alternatives across Several Criteria in a Case Study based on the TURI Framework

The decision analysis methods used in MCDA are one way to integrate disparate information to rank or differentiate alternatives.

MCDA methods may be useful in some cases, they may be more complicated than required for many assessments

There are other ways to rank, compare, and select alternatives, including simple matrix methods

NAS 2014a

Assessment Criteria		Lead (Referenced)	Comparison Relative to Lead				
			Bismuth	Ceramic	Steel	Tin	Tungsten
Technical and Performance Criteria	Density	11.34 g/cm^3	-	-	-	-	+
	Hardness (desirable for "feel" and noise)	Soft Mohrs: 1.5	+	+	+	= (pure) + (alloy)	+
	Malleability (split-shot application)	Yes	-	-	-	=	[illegible]
	Low melting point (for home production)	622°F	+	-	-	[illegible]	-
	Corrosion resistant	Yes	=	=	[illegible]	=	=
Environmental Criteria	Highly toxic to waterfowl	Yes	+	?	+	+	+
	Toxic to aquatic species	Yes	+	[illegible]	+	+	+
	Primary drinking water standards (MCL Action Level)	15 µg/L	[illegible]	?	+ (iron)	+ (FL & MN)	?
Human Health Criteria	Carcinogenicity	EPA [illegible] 2B	+	+	+	+	+
	Developmental toxicity	Yes (Prop 65)	+	+	+	+	+
	Occupational exposure REL (8-hour TWA)	0.050 mg/m^3	?	+	+	+	+
Cost	Retail price	Low	-	-	-/=/+	-	-
	Availability of end product	Excellent	-	-	-	-	-

Note: + Better = Similar - Worse ? Unknown

Let's bring Partial Ordering into play

NAS 2014b; TURI 2006

Lars Carlsen
LC@AwarenessCenter.dk

The data matrix (non-conservative approach)

Criteria	Pb	Bi	cer	ste	Sn	W
dens	0	-1	-1	-1	-1	1
hard	0	1	1	1	0	1
mall	0	-1	-1	-1	0	-1
lowm	0	1	-1	-1	1	-1
corr	0	0	0	-1	0	0
hito	0	1	0	1	1	1
toaq	0	1	0	1	1	1
dwst	0	0	0	1	1	0
carc	0	1	1	1	1	1
devt	0	1	1	1	1	1
ocex	0	0	1	1	1	1
repr	0	-1	-1	0	-1	-1
avail	0	-1	-1	-1	-1	-1

1: better, -1: worse, 0: equal, note '?' substituted by 0, i.e. regarded equal

Applying all criteria

Getting virtually no information

The criteria

TPCr (Technical and Performance)
- dens
- hard
- mall
- lowm
- corr

EnCr (Environmental)
- hito
- toaq
- dwst

HHCr (Human Health)
- carc
- devt
- ocex

Cost
- repr
- avail

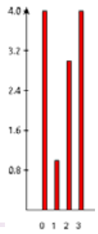
Lars Carlsen
LC@AwarenessCenter.dk

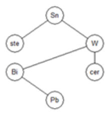
The data matrix compressed
(non-conservative approach)

Criteria	TPCr	EnCr	HHCr	Cost
Pb	0	0	0	0
Bi	0	2	2	-2
cer	-2	0	3	-2
ste	-3	3	3	-1
Sn	0	3	3	-2
W	0	2	3	-2

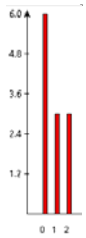
The Results (non-conservative approach)

```
Pb:   3.5
Bi:   2.1
cer:  2.1
ste:  3.5
Sn:   5.6
W:    4.2
```





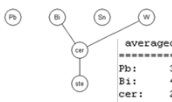
```
Pb:   1.6
Bi:   3.2
cer:  2.4
ste:  3.0
Sn:   6.0
W:    4.8
```



0: TPCr
1: HHCr
2: EnCr
3: Cost

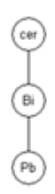
The Results (non-conservative approach)

TPCr



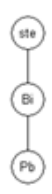
```
averaged ranks
================
Pb:   3.5
Bi:   4.9
cer:  2.8
ste:  1.4
Sn:   3.5
W:    4.9
```

HHCr



```
averaged ranks
================
Pb:   1.0
Bi:   2.0
cer:  3.0
ste:  3.0
Sn:   3.0
W:    3.0
```

EnCr



```
averaged ranks
================
Pb:   1.0
Bi:   2.0
cer:  1.0
ste:  3.0
Sn:   3.0
W:    2.0
```

Cost

```
averaged ranks
================
Pb:   3.0
Bi:   1.0
cer:  1.0
ste:  2.0
Sn:   1.0
W:    1.0
```


Lars Carlsen
LC@AwarenessCenter.dk

The data matrix (conservative approach)

Criteria	Pb	Bi	cer	ste	Sn	W
dens	0	-1	-1	-1	-1	1
hard	0	1	1	1	0	1
mall	0	-1	-1	-1	0	-1
lowm	0	1	-1	-1	1	-1
corr	0	0	-1	-1	0	0
hito	0	1	-1	1	1	1
toaq	0	1	-1	1	1	1
dwst	0	-1	-1	1	1	-1
carc	0	1	1	1	1	1
devt	0	1	1	1	1	1
ocex	0	-1	1	1	1	1
repr	0	-1	-1	0	-1	-1
avail	0	-1	-1	-1	-1	-1

1: better, -1: worse, 0: equal, note '?' substituted by -1, i.e. regarded worse

Applying all criteria

Again: very little information

The criteria

TPCr (Technical and Performance)
- dens
- hard
- mall
- lowm
- corr

EnCr (Environmental)
- hito
- toaq
- dwst

HHCr (Human Health)
- carc
- devt
- ocex

Cost
- repr
- avail

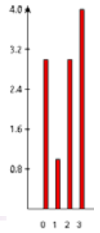
Lars Carlsen
LC@AwarenessCenter.dk

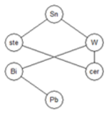
The data matrix compressed
(conservative approach)

Criteria	TPCr	EnCr	HHCr	Cost
Pb	0	0	0	0
Bi	0	1	1	-2
cer	-3	-3	3	-2
ste	-3	3	3	-1
Sn	0	3	3	-2
W	0	1	3	-2

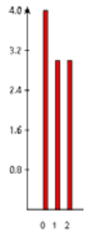
The Results (conservative approach)


```
Pb:     3.5
Bi:     2.0
cer:    1.667
ste:    4.333
Sn:     5.5
W:      4.0
```






```
Pb:     1.556
Bi:     3.111
cer:    1.778
ste:    3.889
Sn:     6.0
W:      4.667
```



0: TPCr
1: HHCr
2: EnCr
3: Cost

The Results (conservative approach)

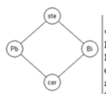
TPCr


```
averaged ranks
================
Pb:     3.0
Bi:     3.75
cer:    1.5
ste:    1.5
Sn:     3.0
W:      3.75
```

HHCr


```
averaged ranks
================
Pb:     1.5
Bi:     1.5
cer:    3.0
ste:    3.0
Sn:     3.0
W:      3.0
```

EnCr




```
averaged ranks
================
Pb:     2.5
Bi:     2.5
cer:    1.0
ste:    4.0
Sn:     4.0
W:      2.5
```

Cost

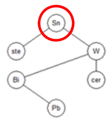

```
averaged ranks
================
Pb:     3.0
Bi:     1.0
cer:    1.0
ste:    2.0
Sn:     1.0
W:      1.0
```


Lars Carlsen
LC@AwarenessCenter.dk

How sure are we on the ranking?

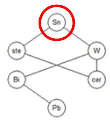
Three indicators

non-conservative approach



```
Pb:     1.6
Bi:     3.2
cer:    2.4
ste:    3.0
Sn:     6.0
W:      4.8
```

conservative approach

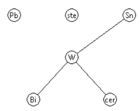


```
Pb:     1.556
Bi:     3.111
cer:    1.778
ste:    3.889
Sn:     6.0
W:      4.667
```

Indicators:
TPCr
HHcr
EnCr

How sure are we on the ranking?

(non-conservative approach; 4 indicators)

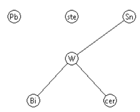


Bubley-Dyer

	1	2	3	4	5	6
Pb:	0.158	0.146	0.161	0.173	0.182	0.18
Bi:	0.356	0.371	0.198	0.075	0.0	0.0
cer:	0.335	0.348	0.251	0.066	0.0	0.0
ste:	0.151	0.135	0.162	0.182	0.197	0.173
Sn:	0.0	0.0	0.0	0.068	0.285	0.647
W:	0.0	0.0	0.228	0.436	0.336	0.0

How sure are we on the ranking?

(non-conservative approach; 4 indicators)



Bubley-Dyer

	1	2	3	4	5	6
Pb:	0.158	0.146	0.161	0.173	0.182	0.18
ste:	0.151	0.135	0.162	0.182	0.197	0.173
Sn:	0.0	0.0	0.0	0.068	0.285	0.647
W:	0.0	0.0	0.228	0.436	0.336	0.0

LPOMext

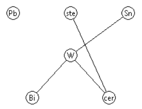
Sn > Pb: 0.8
Sn > ste: 0.8
W > Pb: 0.6
W > ste: 0.6

Lars Carlsen
LC@AwarenessCenter.dk

How sure are we on the ranking?

(conservative approach; 4 indicators)

Bubley-Dyer

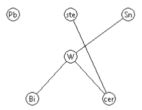


	1	2	3	4	5	6
Pb:	0.176	0.14	0.165	0.164	0.188	0.167
Bi:	0.328	0.421	0.21	0.041	0.0	0.0
cer:	0.496	0.376	0.128	0.0	0.0	0.0
ste:	0.0	0.063	0.175	0.293	0.254	0.215
Sn:	0.0	0.0	0.0	0.077	0.305	0.617
W:	0.0	0.0	0.322	0.425	0.253	0.0

How sure are we on the ranking?

(conservative approach; 4 indicators)

Bubley-Dyer



	1	2	3	4	5	6
Pb:	0.176	0.14	0.165	0.164	0.188	0.167
ste:	0.0	0.063	0.175	0.293	0.254	0.215
Sn:	0.0	0.0	0.0	0.077	0.305	0.617
W:	0.0	0.0	0.322	0.425	0.253	0.0

LPOMext

ste > W:	0.571
Sn > Pb:	0.8
Sn > ste:	0.667
W > Pb:	0.6

Step 11. Compare or Rank Alternatives

Example of a Summary Matrix for Multiple Alternatives across Several Criteria in a Case Study based on the TURI Framework

The decision analysis methods used in MCDA are one way to integrate disparate information to rank or differentiate alternatives.

MCDA methods may be useful in some cases, they may be more complicated than required for many assessments

There are other ways to rank, compare, and select alternatives, including simple matrix methods

NAS 2014a

Lars Carlsen
LC@AwarenessCenter.dk

The Conclusions

Partial order methodology is useful in the search for alternatives.

Partial order methodology is not specifically complicated
and may facilitate assessments

Initially only the very basics of partial ordering is used

Further approaches give further insights

The present study finds Sn (tin) as the optimal alternative

If cost is disregarded a somewhat more clear-cut picture develops

Lars Carlsen
LC@AwarenessCenter.dk