

Evaluating the sustainability of recycling packaging materials combining LCA and Fuzzy Set Theory

Event

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Project

On behalf of Swiss retailer interest group

- 25 years of experience in environmental consulting
- 30 specialists in the field of environmental science, chemistry, physics, toxicology, biology and economics
- LCA team of 8 members
- Our clients are from the private industry, public authorities and NGOs
- Advisory activity all over the world, but with focus on Switzerland and neighbouring countries.
- independent, neutral and objective
- Certification for ISO 9001:2000 Quality management standards

1. Introduction
2. Evaluating the different aspects
3. Fuzzy Sets
4. Modelling the recycling system
5. Results & conclusions

In Switzerland there are separate collection & recycling systems for different materials such as:

beverage cans, PET bottles, Glass bottles, Paper, etc.

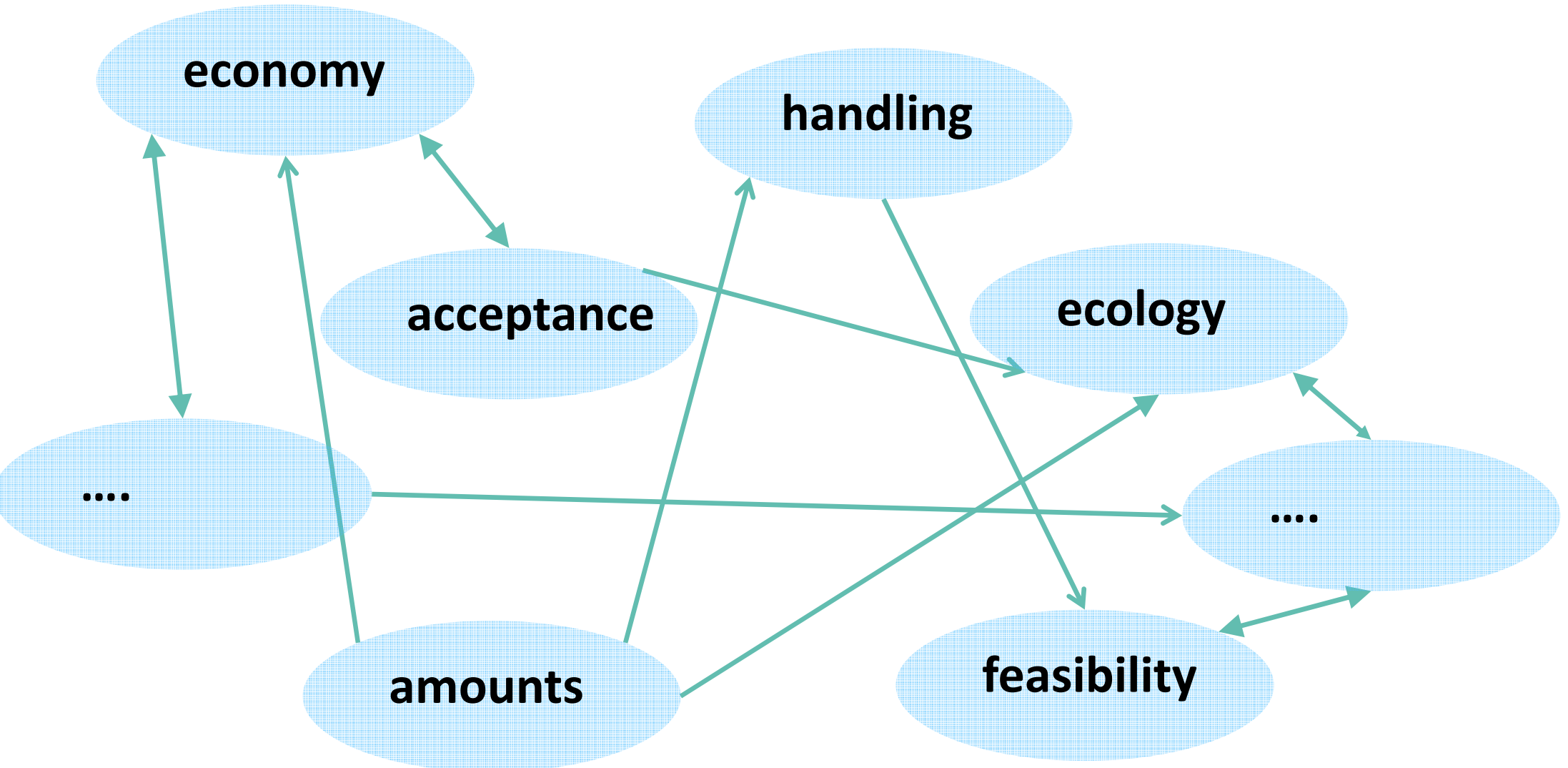
But there is a variety of other materials for which collecting and recycling is possible such as:

LPB, CD, PE bottles, plastic bags etc.

Which collecting and recycling system would be successful on the long run?

Which system would be sustainable?

Evaluating the sustainability of recycling systems



LCA was used for the environmental dimension

We conducted different LCA studies on existing recycling systems. Based on these experiences, possible systems were analysed by:

- Using available data and estimations for the foreground data
- Using Ecoinvent for the background data
- For open loop recycling, applying allocation by substitution taking into account the economic value
- Evaluating different impacts and methods
- Choosing ecological scarcity for single score

For the economic dimension, the costs for the different systems were estimated based on data from existing recycling systems and expert judgements.

For other aspects such as

Acceptance
Feasibility
Handling
Potential contamination
...

there are mostly no available quantitative data but expert estimations given in linguistic statements

Dependencies and valuation

There exist expert statements
Sometimes these are contradictory

So we had to look for a method which is able to

- **deal with quantitative and qualitative data and**
- **handle different judgements**

We used the Fuzzy Set Theory as an extension of the classical set theory



To become a mathematical theory extending the existing theories, it is necessary that all rules and function are given and valid.

In the borderline with the crisp set theory the results of both must be the same.

Both requests are met by the FST.

Technical people normally like to have exact figures



The more digits after the comma, the better the result!

Real life is different. We generally use linguistic terms, which are not well defined

“Do you see the **tall, old** man **near** the corner?”

What means tall, old, near

Is it a man with a body size of 180cm?

If yes, is a man with a height of 179.9cm small?

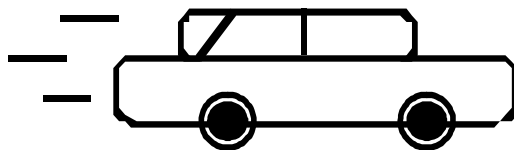
Is that negative or a limitation?

No it is efficient !!!



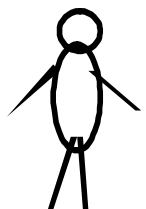
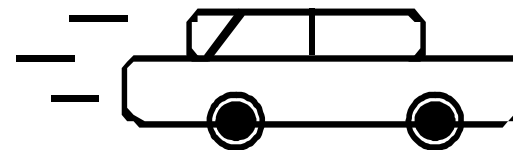
Exact world

A white Mercedes 450 SL with black wheels, silver stripes at the side is approaching you with a velocity of 51,234 km / h



Real world

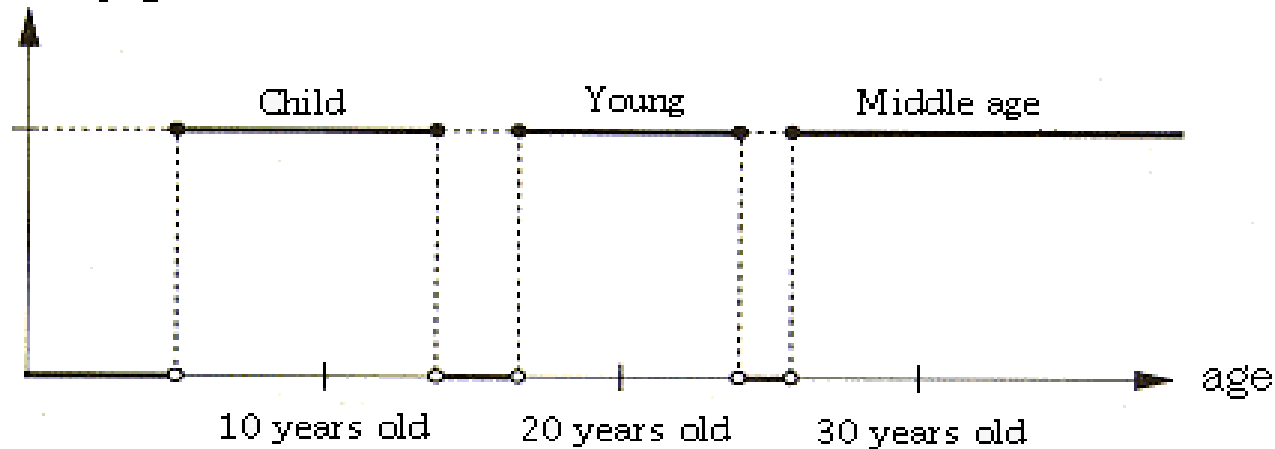
Attention a car



How to express linguistic uncertainty?

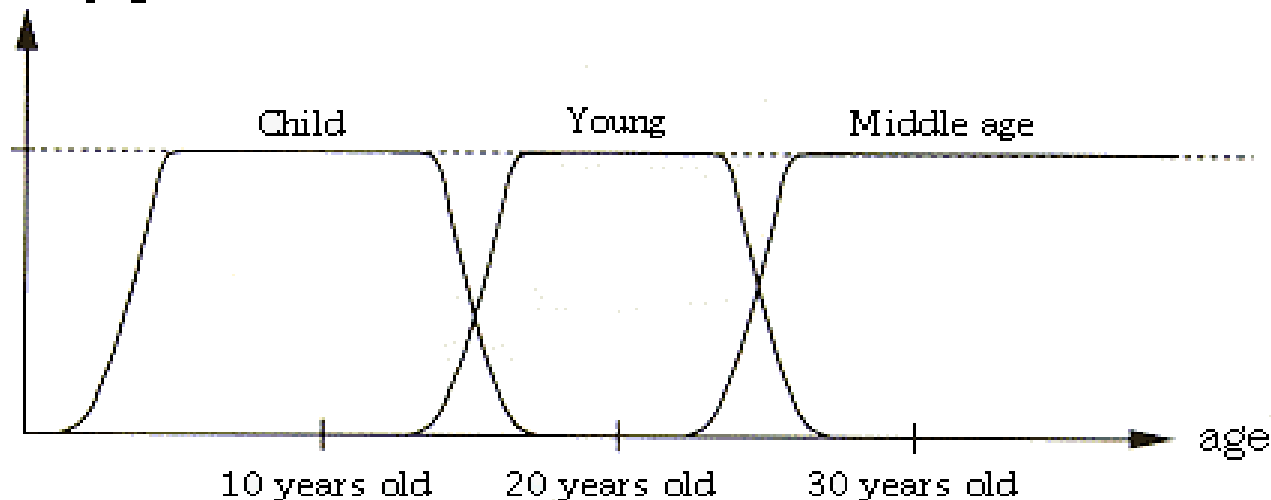


Membership grade



In the classical set theory there are crisp boundaries between the different sets. An element is a member of a set or it is not.

Membership grade



In the fuzzy set theory an element can be a member of a set to a certain grade.

b) Classification of "child", "young" and "middle age" by fuzzy method

How to express relations?



With linguistic rules such as:

"When the acceptance of a recycling system is high, the communicability is good and the system is convenient"

then

"The collection quotes are high"

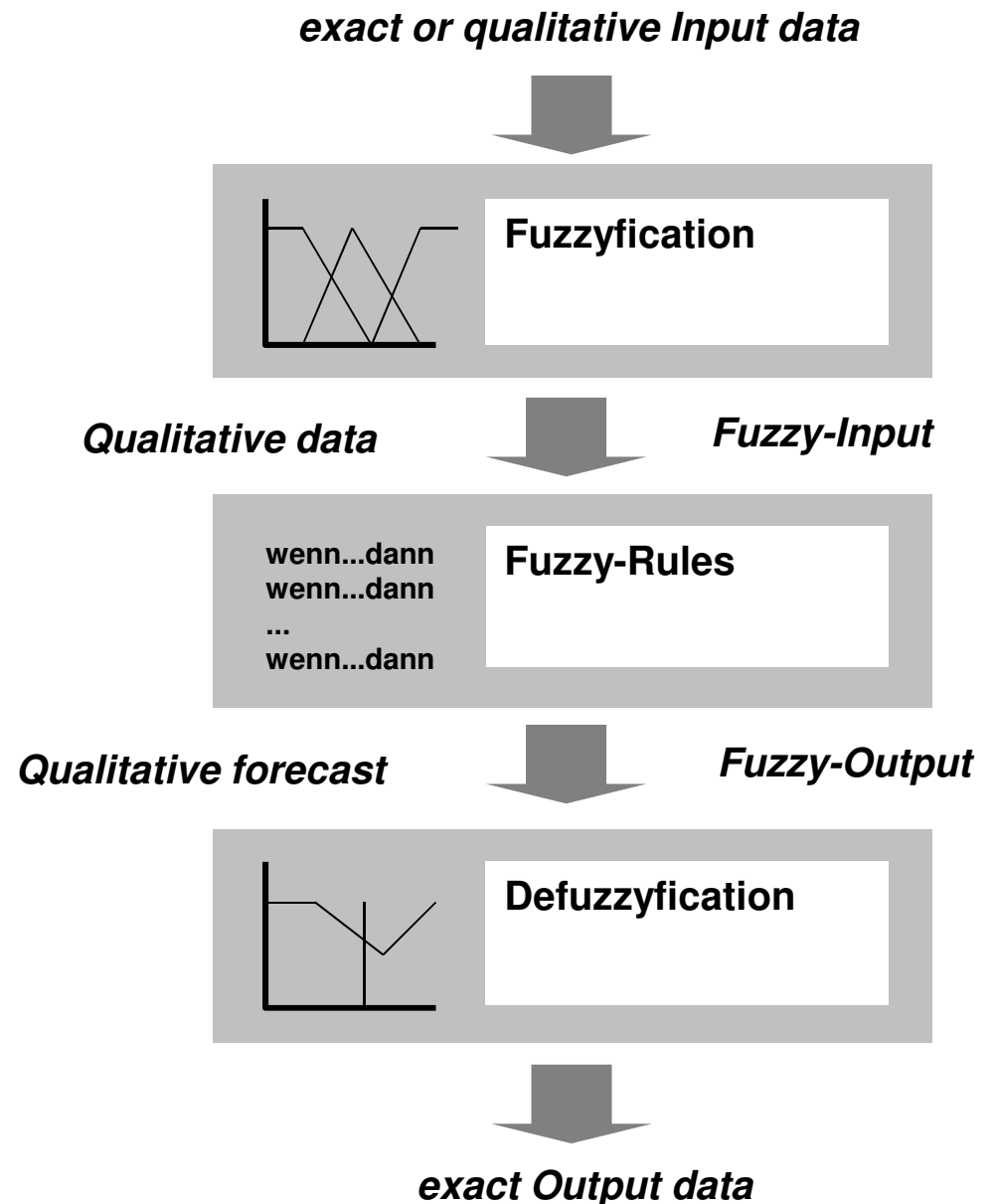
Major steps of a rule-based application



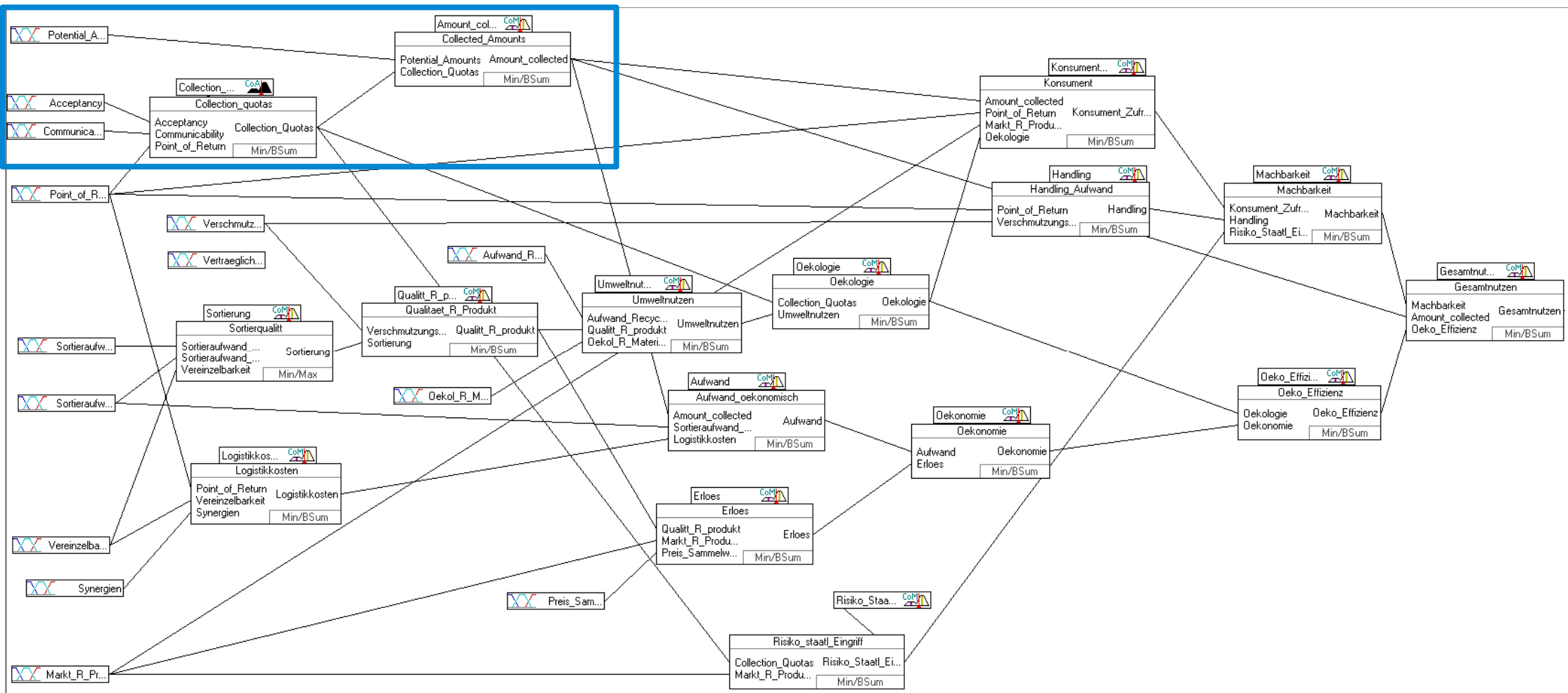
System description with linguistic rules and linguistic variables

Qualitative modelling rules are defined as logic conclusions if ... then

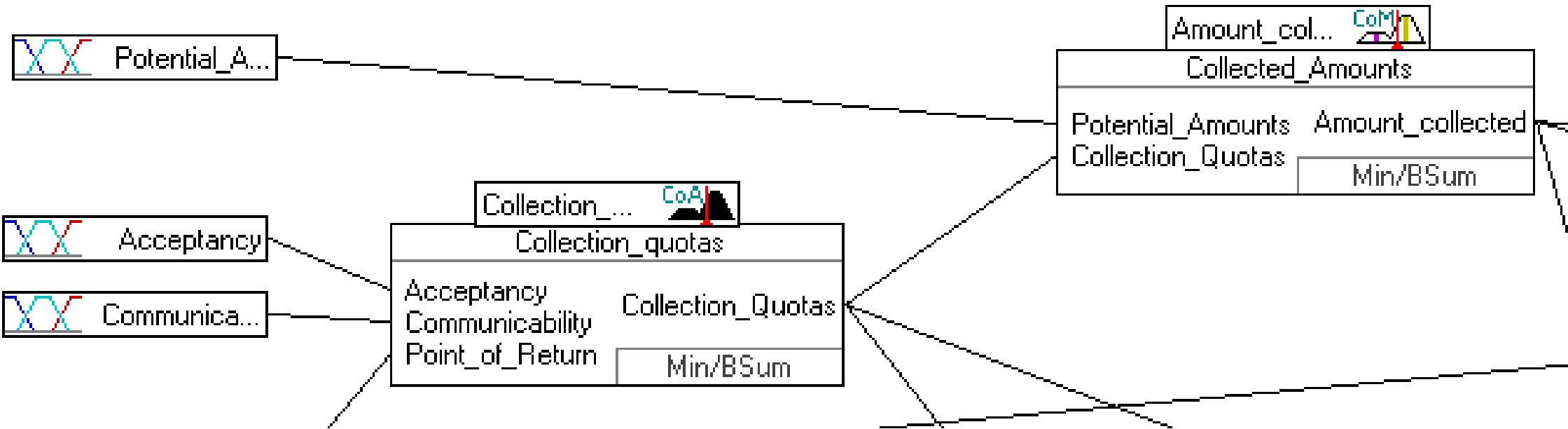
Transformation of the qualitative data into quantitative data, if needed.



The model developed to describe the overall benefit of a recycling system



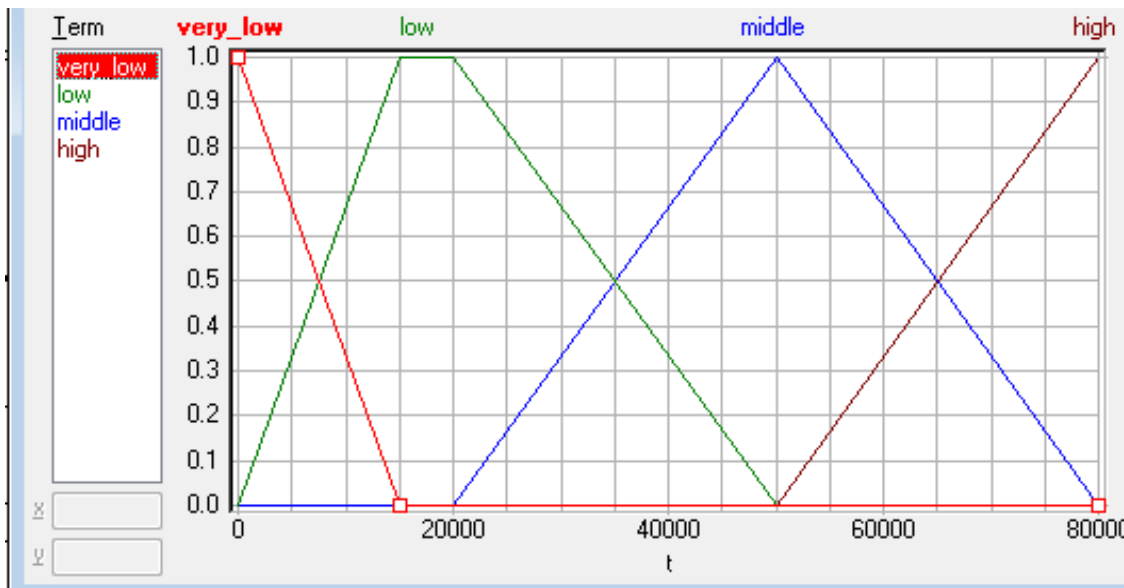
Collection quotas and collection amounts



As an example, the membership function of the collection amount and the rules to get these amounts

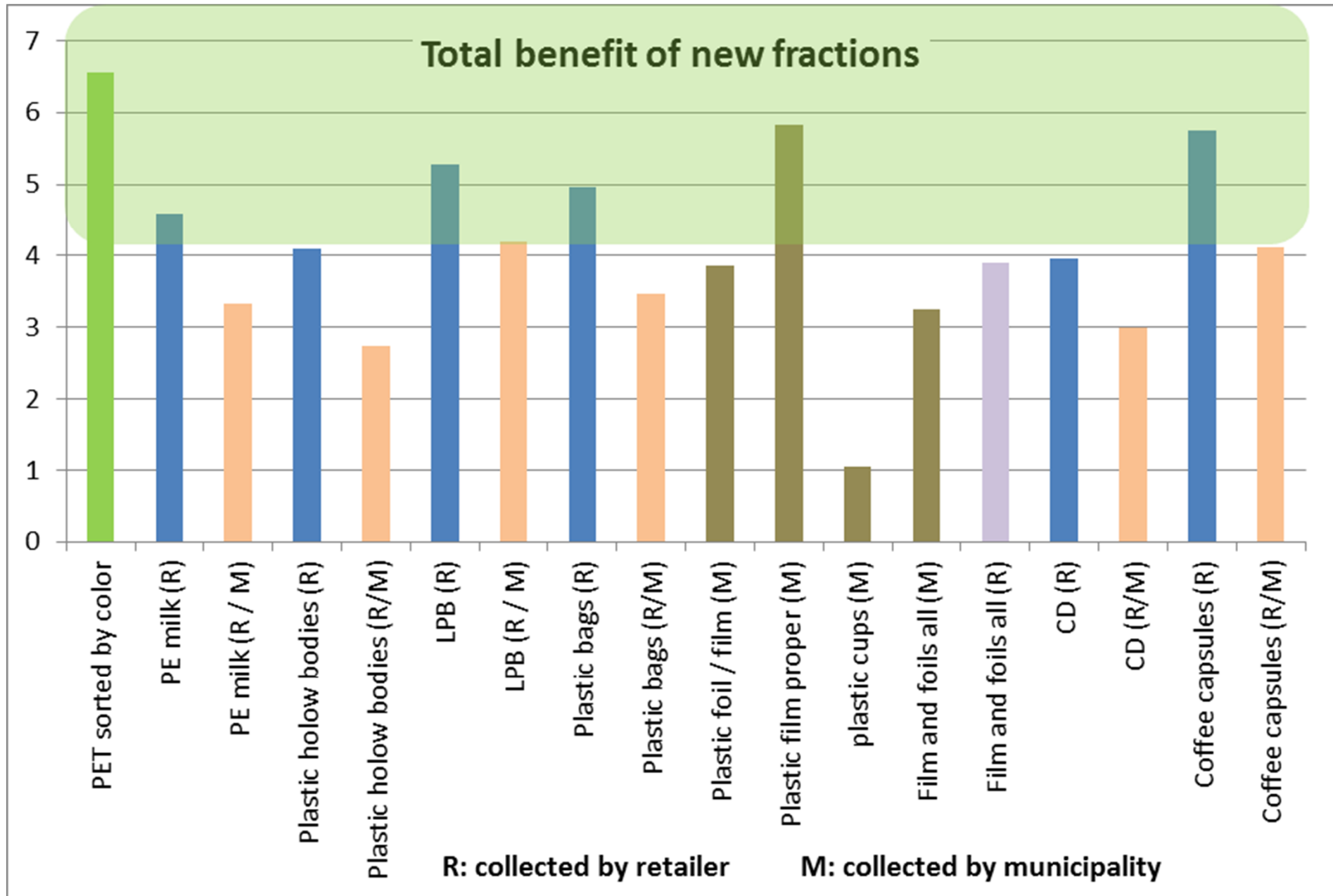
Membership function to link the linguistic terms "low – middle or high amounts" with the amounts in tons

Rules to define the relations between the potential amounts – collection quotas and the collected amounts



#	WENN	DANN		
	Potential_Amounts	Collection_Quotas	DoS	Amount_collected
1	very_low	low	1.00	very_low
2	very_low	middle	1.00	very_low
3	very_low	high	1.00	very_low
4	low	low	1.00	very_low
5	low	middle	1.00	low
6	low	high	1.00	low
7	middle	low	1.00	low
8	middle	middle	1.00	middle
9	middle	high	1.00	middle
10	high	low	1.00	middle
11	high	middle	1.00	middle
12	high	high	1.00	high
13				
14				

Total benefit of new fractions



Results and Conclusions for the clients

Good decision base for the retailers as well as for the municipalities and national administration to their policy for sustainable, future collection and recycling systems. Showing

- that the overall benefit can be very different
- the influence factors
- the point of return is crucial

Results and Conclusions

methodological

This approach is not only useful but very powerful for decision support of complex systems. The important advantages of this method are:

- representation of qualitative expert knowledge with linguistic terms
- bringing together quantitative and qualitative data and knowledge from different fields such as ecology, economy and societal as well as technical aspects - in a mathematically exact way
- non-linear relationships can be handled and FST makes the interpolation
- floating transitions which are typical for the environment can be handled
- Fuzzy logic can deal with more than one 'right' judgement, which is typical for human reasoning
- doing all this in a transparent way.

„All traditional logic habitually assumes that precise symbols are being employed. It is therefore not applicable to this terrestrial life, but only to an imagined celestial existence.”

Bertrand Russel

“When the complexity of a system increases, our capability decreases to make exact and significant statements on there behaviour. Above a certain complexity precision and relevance became two nearly excluding characteristics.”

Lotfi Zadeh

Thank you
for your attention!

Looking forward to your questions

