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Dynamic Interactions Between Citizen Choice and Preferences and Public Policy Initiatives

A System Dynamics Model of Recycling Dynamics in a Typical Swiss Locality

The outcome of recycling initiatives depends on both citizens' policy compliance and on the development in the recycling markets. The task of localities is to find incentives to motivate citizens to participate in recycling programs producing a high quality recycling material. However, different local policy initiatives in Switzerland and in New York State showed some undesired consequences. A System Dynamics model is proposed in order to analyze the undesired effects and to test further policies. The model design is based on a feedback theory about human behavior and public policy that stresses both the importance of contextual and personal factors. Hidden attitudinal stocks in the system create adaptation delays, leading to unexpected system behavior. A plausible personal structure is suggested that represents the overall propensity to separate waste. First policy runs show that a combination of interventions altering personal and contextual factors is superior to single focused strategies.

Key words: System dynamics, feedback systems, citizen choice and preferences, human behavior, propensity, public policy analysis, solid waste management, computer-aided decision making

Introduction

The role of local authorities in public policy initiatives

Local authorities are often in charge of implementing national policies. The success of a national policy depends on a farsighted development of local strategies to motivate citizens to comply with public policy initiatives, such as recycling programs[1]. However, the outcome of local public policy initiatives depends not only on the compliance of the citizens but also on market forces. Therefore the present paper suggests a System Dynamics model for municipal solid waste management (the SWM-model) that addresses both long-term feedback effects of market forces and dynamics of citizen's choice and preferences that affect the outcome of local and national policies.

[1] For a theory-based discussion of the role of local authorities see Oates, 1990.

The long-term feedback perspective should help to recognize and analyze important loops causing desired and undesired outcomes of national and local solid waste policy (see Richardson and Pugh 1981).

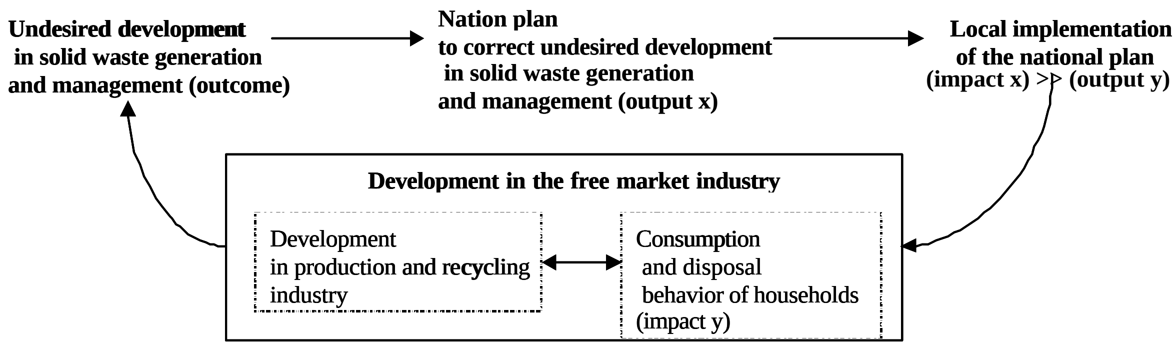

Figure 1: Long-term feedback effect of national and local municipal solid waste management policies

Background of the research: The Swiss Priority Program „Environment"

In 1992 the Swiss National Science Foundation launched a broad program to promote the research on relevant topics for a sustainable development, the Swiss Priority Program "Environment" (SPPE[2]). 500 researchers in 200 projects were underway to analyze and understand complex systems in order to find solutions to prevailing environmental and development problems. Especially interesting for the proposed work are the new insights about environmentally significant behavior of individuals or social groups and policy building[3], such as in-depth knowledge about hurdles and keys to promote environmentally sound behavior (see Gessner 1996, Gessner and Bruppacher 1999, Kaufmann-Hayoz and Gutscher 2001).

Households as consumers have an important influence on the success or failure of specific products and the development of whole industries. Their lifestyles determine what kind of technologies, materials, and resources will be used. Therefore at the local level households are important players towards a global sustainable development. However, many studies about environmentally relevant behavior show that even environmental concerned consumers face many obstacles when trying to adopt a environmentally sound lifestyle. Therefore, local interventions that help to overcome those obstacles can be crucial. For policymakers it is important to have a heuristic that helps to understand the processes and

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[2] http://www.snf.ch/SPP_Umwelt/overview.html

[3] Particularly the **Integrated Project** "Strategies and instruments for sustainable development: Bases and evaluation of applications, with special regard to the municipality level (Nr. 5001-48826) with several subprojects, (1997 –2000) and earlier on the Module 4 "Environmental awareness and activity (1992-1996).

factors that influence citizens' choice and preferences as well as the dynamics that alter the state of the social system. Subsequently it can help to find the right intervention points.

A first synthesis of findings that emerged from the intensive research about human behavior and environmental policy instruments has resulted in a simple feedback theory about human behavior and public policy (see Kaufmann-Hayoz and Gutscher 2001a, Kaufmann-Hayoz, Bättig et al. 2001).
Figure 2 represents the basic assumption about human action as a result of an interaction between the internal structure of the actor, (including personal factors) and the external structure (representing contextual factors in the cultural, socio-economic, institutional, and physical framework). The external structures offer options but also constrain human behavior. It is a result of a multistage decision process in political/administrative, technological and economic domains. "All actors have only limited possibilities to alter their own framework of actions, because they are determined by other actors' decisions. However, collective actions or social practices stabilize and reproduce the mutual framework conditions, or, alternatively, they contribute to their change. Over time there is a 'co-evolution' of individual and collective patterns of behavior and its framework" (Kaufmann-Hayoz and Gutscher 2001a:24). This feedback view is in line with the control theory proposed by Powers' major work, 'Behavior: The Control of Perception' (Powers 1973 1990). He emphasizes that individuals not only behave as they do because of the stimuli they perceive but also that how individuals behave affects what they perceive.

Figure 2: A simple feedback theory about human behavior and public policy
(Kaufmann-Hayoz et al. 2001:82)

(see end of paper)

Based on the feedback theory, Kaufmann-Hayoz et al. (2001) conclude that policy makers either can alter the internal or the external structure in order to induce behavior change. Different types of policy instruments such as "command and control instruments", "economic instruments", "service and infrastructure instruments" and "collaborative agreements" can alter the external structure. Policy types such as "communication and diffusion instruments" and also "collaborative agreements" can modify the individual's internal structure. A coherent explanation of the different types of policy instruments is given in (Kaufmann-Hayoz, Bättig et al. 2001).

One aim of the present work is to operationalize this broad theory in the SWM-model in order to gain a better understanding about the dynamics of contextual and personal factors and possible intervention points. The model should help to gain insights into dynamic interactions between citizen choice and preferences and public policy initiatives. The focus is on intended and unintended effects of different local recycling initiatives that result in policy resistance.

This paper contains three main parts, which are the model conceptualization, the SWM-model description, and the model behavior. Those are framed by an introductory chapter and by some thoughts about first insights and conclusions. Since the modeling process is still ongoing, only the first important model parts and preliminary policy experiments are described. However, the modeling project will be finished in the summer of 2003 and an updated version of the model as well as final insights will be presented at the conference.

Issue: Solid waste management in Switzerland

This study deals with local solid waste management policies in a typical Swiss locality. The overall purpose of the modeling project is to gain a better understanding of local solid waste management problems. However, such local problems seem also to be crucial for national policies, since they address national and global behavior trends (see Duggan 2002; OECD 2000 in Ludwig, Hellweg et al. 2003). The assessment of the actual situation in solid waste management made by 'the Swiss Agency for the Environment, Forest and Landscape', can be summarized as follows.

The overall achievement of the solid waste policy is a well-organized management of solid waste. But the whole production and recycling process still involves an inordinate consumption of energy and materials. The aim should be to create incentives for waste avoidance and recycling by levying charges for disposal services, and to promote the purchase of long-life products. Sustainable use of raw materials and the search for incentives that promote the necessary changes in behavior are likely to become the key issues for waste management. Waste mountains are a sign of inappropriate production methods and behavior (see SAEFL 2002).

A comparison between Switzerland and the USA shows that the solid waste management system in Switzerland is relatively advanced.

	Switzerland[4]	**USA**[5]
Amount of solid waste	1.2 kg/person/day 2.65 pounds/person/day	2 kg/person/day 4.5 pounds/person/day
Recycled	43%	30.1%
Incinerated	57%	14.7%
Land filled	0% (but 0.64Mio t. combusting ash)	55.3%

Table 1: Municipal Solid Waste management in Switzerland and USA (2000)

In Switzerland municipal authorities are responsible for solid waste management. The law[6] for solid waste management requires that the services be paid according to the polluter-pays-principle. Therefore, many municipalities levy charges per collected garbage-bag (garbage-bag charges). That means that the households are required to pay a charge per bag for burnable solid waste. Most other collecting-services for recyclable products (paper, cardboard, glass, ferrous metal - like tins, hazardous waste - like oil, batteries, pet[7]-plastic, aluminum, batteries, food scraps) are free of charge; respectively it is intended that the cost

[4] http://www.umwelt-schweiz.ch/buwal/eng/medien/umweltbericht/druck/index.html (Swiss Agency for the Environment, Forest and Landscape)

[5] www.epa.gov./epaoswer/non-hw/muncpl/facts.htm(US Environmental Protection Agency)

[6] Environment Protection Law amended 1997 by the Swiss national government

[7] polyethylenterephtalat

be covered by basic taxes or by some prepaid taxes. However, the households have to pay an extra price for the disposal of some recyclable material, (e.g. for metal, electrical and electronic equipment and appliances).

As a consequence of the introduction of the garbage-bag-charge-policy, the fraction of burnable waste decreased and the fraction of recyclable material increased. The cost for collecting the different streams of recyclable material increased as well. Thus the municipal budget for solid waste management is growing. There is also a need for monitoring the disposal behavior of citizens, which adds to the cost. Due to higher operative cost and bad recycling-market conditions the relative profit from delivering the separated material to recycling instead to incineration plants is decreasing. The households resist paying higher prices for solid waste management services. This is a critical problem (see Joos, Carabias et al. 2002). Disposal services are not perceived as a cost-effective public service and citizens still expect to get those services for free[8].

In order to disburden the municipality from the high cost for solid waste management and to promote recycling further, the national government discusses the initiation of prepaid disposal charges on more recyclable products. "Advance disposal[9] charges make it possible to apply the polluter-pays principle in financing the comprehensive network of take-back[10] points that is required for a high recovery rate, as well as transport and, finally, environmentally sound processing" (SAEFL 2000:115).
This statement describes the intended effect of the prepaid disposal policy. But there will probably be some unintended effects, as the prepaid disposal charges give different signals to the households and to the recycling sector. It may happen that the awareness of the prepaid price for disposal will decline, and people may put more recyclable material into the burnable garbage. A further side effect could be that the infrastructure for collecting the material could deteriorate. Since there are few incentives for retailers, they are not interested in promoting good collecting services.

[8] http://www.umwelt-schweiz.ch/buwal/de/medien/umwelt/2002_3/index.html (p35).
[9] Advance disposal charges are prepaid disposal charges: the disposal price will be included in the product-price.
[10] Take-back points are collecting points for recovered recycling material.

Separated Materials	1987-1991	1992	1993	1994-1997	1998-2001
Organic material	■	■	■	■	■
Paper	■	■	■	■	■
Glass	■	■	■	■	■
Metal	■	■	■	■	■
Aluminum	■	■	■		
Pet		■	■	■	■
Ferrous metal (tins)			■	■	■
Food scraps			■	■	■
Hazardous waste (oil)				■	■
Electronic waste					■
Number of recycling streams	**5**	**6**	**8**	**8**	**9**

Table 2: Recycling streams separately collected by Swiss municipal authorities

A short glance at recycling programs in some localities in New York State shows that they face similar problems. Duggan (2002) reported recently the actual situatio in the Times Union. Since there is not yet a strong market for recyclable materials, the cities have to pay someone to take the separated material for most collecting categories. Furthermore the operating expense for picking it up separately generates higher costs than if it would be dealt as normal "trash". Hence "recycling" can become economically questionable for the localities. The following two voices of local solid waste management experts point out two major problems they have to deal with. B. Chamberlain, Troy's solid waste management coordinator observes, "If the secondary markets don't improve, the prices to recycle certain material will go up, and once it passes what it costs to landfill it, it won't be economically beneficial" (cited in Duggan 2002). A further important aspect of recycling programs deals with the quality of the separated recyclable material. In the case of New York City they created a useless mixed material since they collected and compacted glass and plastic together, for which there is no demand. J. Enck, a policy advisor stated: "State law does not prescribe how you are supposed to do the collection. You can sabotage a recycling program if you wanted to" (cited in Duggan 2002).

These developments in the real world set the stage for the proposed research. The SWM-model should help to address and analyze these observed problems.

Model conceptualization

Problem statement

The problem addressed by the System Dynamics model is represented in the following questions:

What local policies increase recycling, reduce the overall generation of solid waste, and help to establish / ensure a solid waste management system that fosters competitive recycling markets?

- How do you motivate the households to participate in solid waste reduction and separation?
- How do you recover recyclable material to produce competitive secondary raw material?
- How do you finance the recovering and disposal activities of local agents?

Reference modes and problem dynamics

In the following paragraph, some variables of interest and their historical dynamics from a typical Swiss locality over the last 14 years (1987 – 2001) will be presented. Subsequently, the question "What caused the given development?" (see Randers 1996) will be addressed. Chart 1 shows the development of the municipal budget for solid waste management. There is an increase in cost over time and in some periods there was a deficit. However, there was also an increase in the amount of solid waste during this time. Therefore, this chart gives us no information about the development of costs per kg.

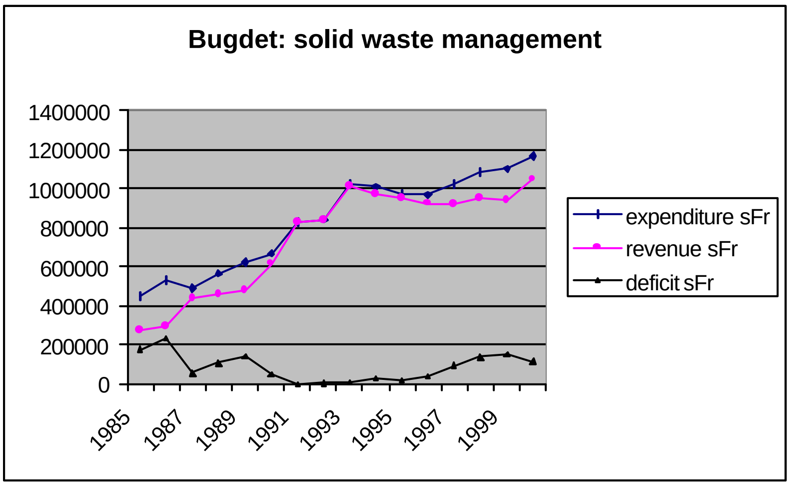


Chart 1: Municipal budget development for solid waste management

In order to slice the problem (see Saeed 1992) and to decompose the growth trend of solid waste generation, the budget of solid waste per capita and per kg is computed (see Chart 2).

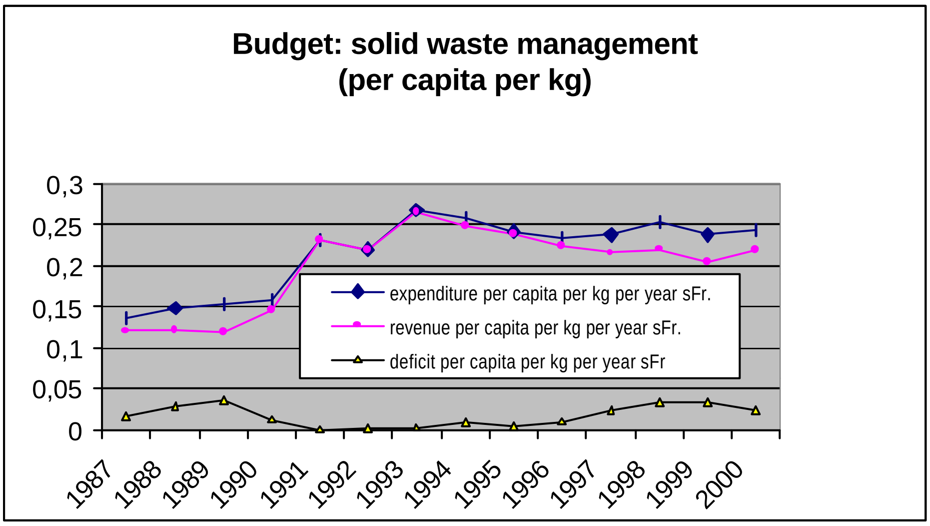


Chart 2: Budget development per capita per kg per year

According to Chart 2, there is an upward trend in the unit cost that peaks in 1994 followed by a slight drop, and then it seems to reach a plateau. However the revenue continues to fall. There are two periods with a higher deficit (1997 – 1992) and (1996-2001). As the deficit has grown, the local authorities increased the tax for solid waste management and the volume related trash bag charges (see Table 3).

Time period	**1973 - 1990**	**1991 - 1999**	**2000 - ???**
Taxes, per year, according to the size of the apartment / house	24 – 60 sFr.	50 – 110 sFr.	83 – 184 sFr.
Volume related trash-bag charges (35 liter)	None	0.9 sFr	1.80 sFr.

Table 3: Changes in taxes and trash-bag charges (Einwohnergemeinde X 1973 - 2000), (Einwohnergemeinde Xa 1973 - 2000)

Chart 3 illustrates the changes in the number of recycling streams. Between 1991-93 four additional recycling streams were offered to the citizens. From 1993 to 2001 only one additional recycling stream was introduced.

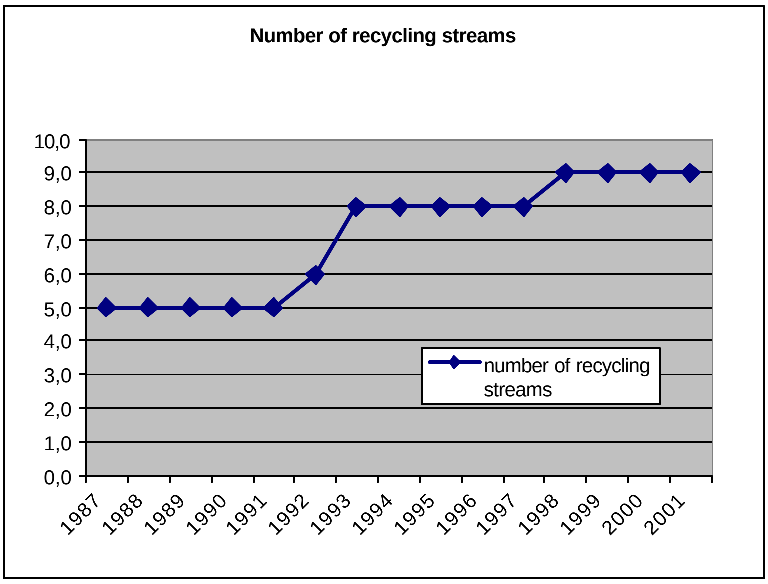


Chart 3: Development of number of recycling streams

Chart 4 portrays the change in the fraction of separated material and the material disposed for burning. The fraction separated for recycling increased from about 30% to 50%.

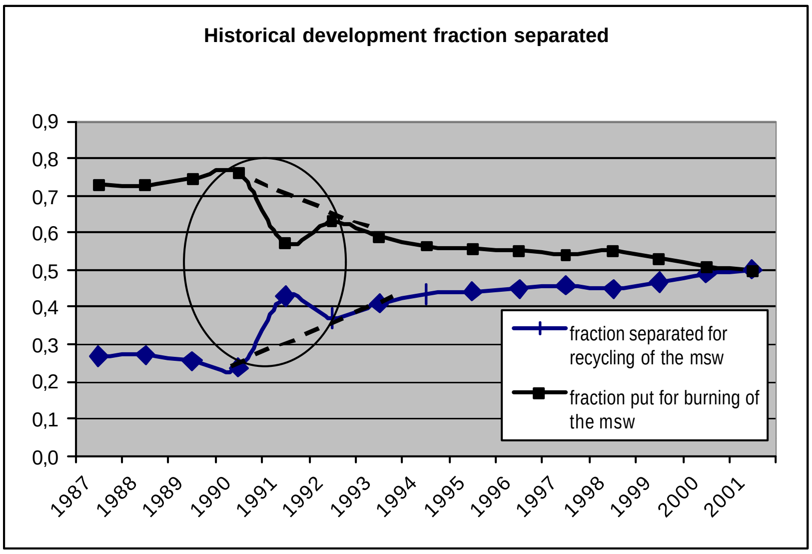


Chart 4: Historical development of fraction separated for recycling (GSA, Bauverwaltung Gemeinde X 1997)

Between 1990 and 1992 there was a transition phase with a short term dynamic in the fraction of separated waste and the fraction disposed for burning. These dynamics can be ascribed to the implementation of the trash bag charges in 1991. As the citizens learned that the disposal cost would increase, they started to clear out useless material. In 1991 the price incentives had a strong effect on the disposal behavior of the citizens. They probably over invested in separation activities since they tried to avoid disposal cost (over reaction).

However, the SWM-model will not address these short-term effects. Nonetheless, it is interesting to see that the 100% increase in the trash bag charges had nearly no behavioral effect in year 2000. A reason for this phenomenon could be that the monetary incentive given in 1991 was high enough to activate the potential capacity of citizens to separate given a constant amount of recyclable material. Sterns concept of limiting conditions would explain this effect on the individual level with diminishing returns of interventions. If the financial incentives demonstrate a clear personal benefit a further increase may be far less effective than other interventions (providing more opportunities, giving better information or other incentives) see (Stern 1999).

To explain the long-term dynamics of the reference modes the following dynamic hypothesis is postulated.

Since the performance of citizens' separation behavior was low, the localities gave price incentives in form of a garbage bag charge. The intended effect was to promote the separation behavior. As a consequence the fraction of separated waste increased and the relative amount of solid waste for burning decreased. The unintended effect was that not only the relative amount of waste disposed for burning decreased. But also the revenue generated from the trash bag charges declined. Therefore, the budget deficit started to increase. A further increase in the price for burnable material had nearly no additional effect on the separation behavior, since the number of recycling streams was held nearly constant. The citizens had no real legal option to avoid higher costs for disposing the burnable material. As an unintended consequence, the quality of the separated material decreased. Citizens started to put burnable material in the recycling streams. However, this effect was only observed and could not be exactly quantified.
The following causal loop diagram shows the postulated main feedback loops that are responsible for the dynamics of the variables of interest. The balancing feedback loop "limiting propensity from time cost" refers to the citizens ' behavior (Figure 3) and the other "deficits limits investments" refers to the authorities (Figure 4).
The balancing feedback loop "limiting propensity from time cost" postulates that a high propensity to separate would foster (with a delay) the development of further recycling streams. This link represents the theory that a high discipline in separation behavior of citizens would increase the purity of the separated recycling material. As a consequence, the recycled material would become competitive, fostering the development of recycling capacity, and new recycling streams. As the number of recycling streams increases, the time

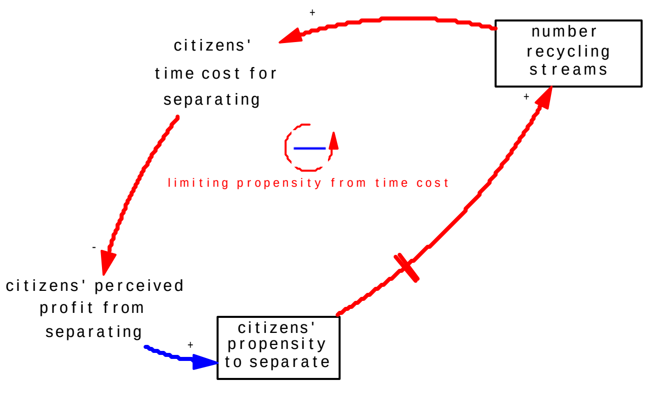


Figure 3: time cost limiting propensity to separate

cost to separate increases. This results in both a lower perceived profit and propensity.

(citizens' choice)

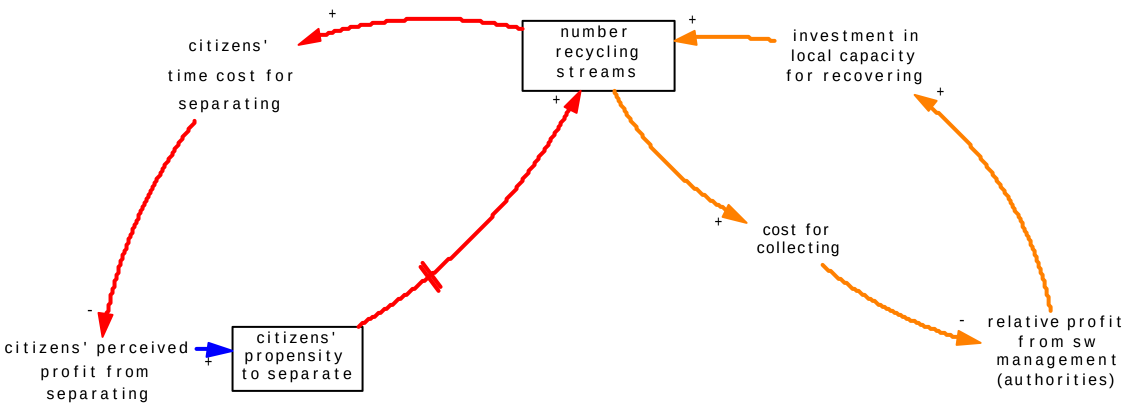


Figure 4: Deficits limits investment
(choice of the authorities)

The balancing feedback loop "deficit limits investment" describes the economic concerns of the localities. As long as the price for disposing the separated material is lower than for burnable material, there is a relative profit in the local recycling program. As the number of recycling streams increases, the operating cost elevates for collecting the various separated materials. Therefore, the relative profit from the recycling program decreases and the willingness to invest in local capacity decreases as well.

These two balancing loops indicate that there will be an upper limit in the number of recycling streams, due to limited local capacities.

Figure 5 captures the pricing structure in Swiss localities that creates a reinforcing feedback loop "propensity to separate increases deficit". This loop describes the unintended effect of a growing deficit between the revenue and expenditure for swm-services in the period from 1996 – 2000, (see also Chart 2). The price incentives given by the trash bag charges increased the propensity to separate. As a consequence, the amount of material disposed for burning decreased relative to the amount of separated material, resulting in lower revenue from burnable material. Therefore, not only the relative but also the overall profit decreases (respectively the deficit increases). Consequently, the authorities raised the price for burnable waste in year 2000. This reinforcing loop indicates that this pricing structure will not ensure a sound solid waste management system.

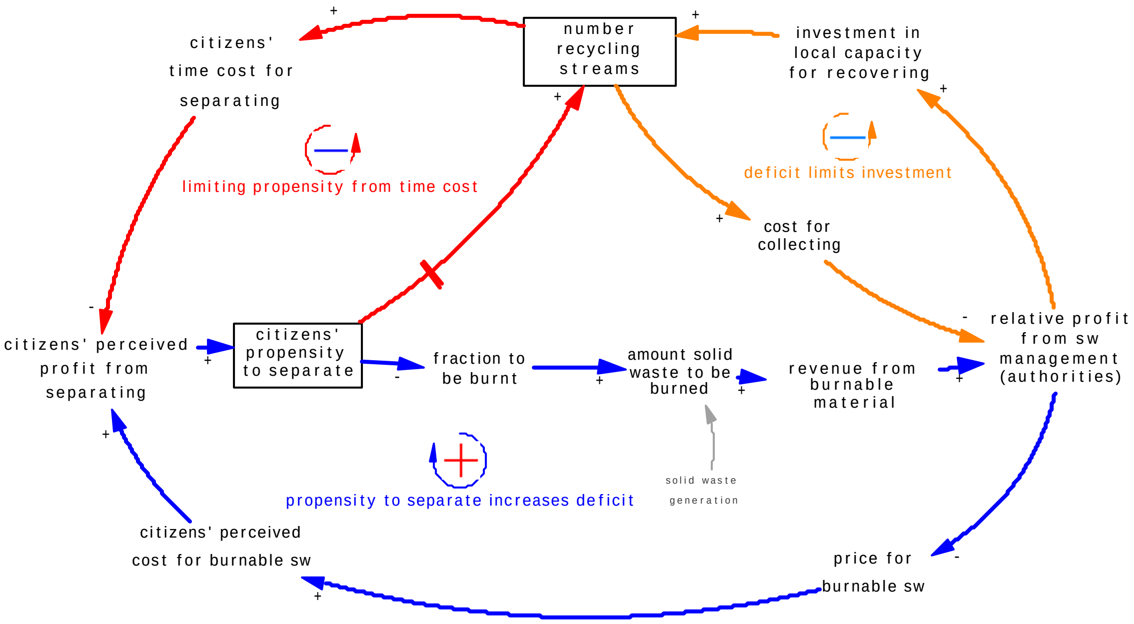


Figure 5: propensity to separate increases deficit

The next two reinforcing loops “policy resistance” (Figure 6) explain, how a further unintended effect sabotages the local recycling program. Due to price incentives the citizens perceive a high profit from separating (see the lower feedback loop) and their propensity to separate increases. Since only a limited fraction of solid waste is recyclable, the citizens are tempted to put burnable material into the recycling streams in order to avoid disposal costs. Therefore, the impurity in the separated material increases. As a consequence, the recycling industry is not going to accept these materials or will charge higher prices. This increases the operating cost of the localities and decreases the relative profit and also the willingness to invest in local capacity for separating. Therefore the number of recycling streams could decrease. Given a high propensity to separate, citizens continue to put burnable waste into the recycling streams.

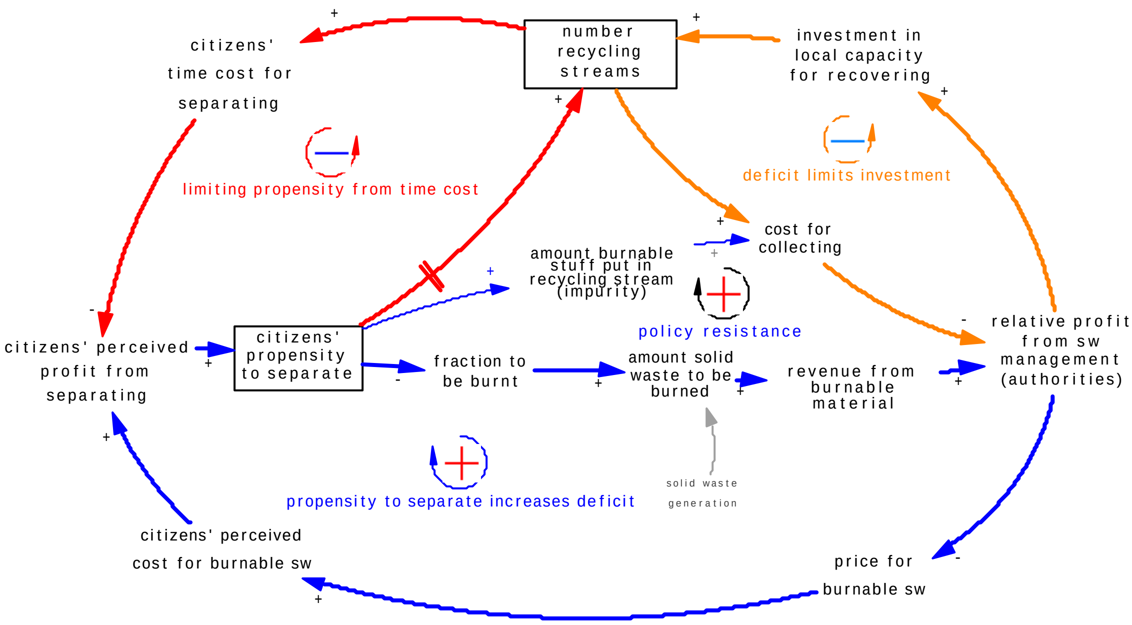


Figure 6: policy resistance

The outline of the problem and the dynamic hypothesis give evidence that the number of recycling streams is an important stock at the local level. The following causal loop diagram (Figure 7) gives a reason, why the number of recycling streams is also a critical factor for development of recycling markets.

A higher number of recycling streams decrease the cost for recycling, since the recycling industry gets a better quality of collected material. Hence it has to invest less in sorting processes. Lower production cost of secondary raw material increases the profit and reduces the relative price of recycled raw material. Therefore the demand for recycled raw material will increase. Furthermore the supply and the variety of recyclable material in products will increase. As a result of a successful recycling market, not only the willingness to invest in higher capacity increases but also the readiness of new recycling technologies to enter the recycling-market increases. Therefore the number of recycling streams grows. If the citizens will separate the recyclable material according to the different recycling streams, the recycling industry will face lower recycling cost. In this scenario the reinforcing feedback loop will foster a growth in the recycling market. Otherwise, higher processing cost from impure recycling material will shut down the recycling market. These scenarios will be analyzed in the model.
Results of some pilot-experiments and studies about expanded recycling initiatives for plastic in different Swiss localities give empirical evidence of the stated dynamic hypothesis (BUWAL 2001).

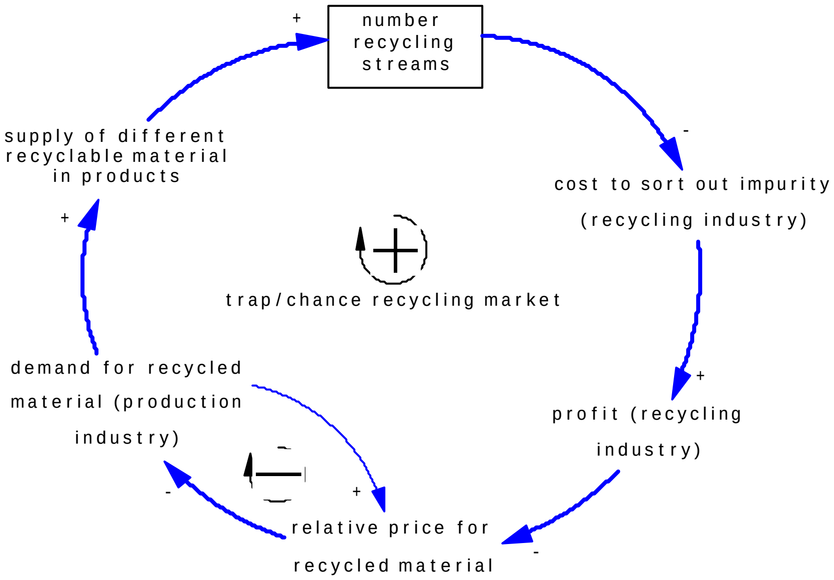


Figure 7: Chance for the recycling market

Effects of prepaid disposal charges

With the swm-model not only the given development will be addressed, but also the effect of further policy-strategies, such as prepaid taxes. The model will be designed to give insights to the question: what are the likely effects of other strategies such as prepaid disposal charges on a growing number of products?

Prepaid disposal charges have an important feature. For the consumer this is a hidden price. Therefore, the collecting service system will have a feedback structure of non-price mediated resource allocation (see Sterman 2000).

A higher service quality in the collecting centers stimulates the propensity to separate. Citizens will bring back a higher amount of different recyclable material.

A higher amount of collected recyclable material erodes the service quality as the crowding increases. This dynamic represents the balancing feedback loop "limit of recyclable growth". This means that the service quality will limit the amount of collected recyclable material. The second balancing feedback loop, "limit of resources", shows that a higher service request increases the need for adequate services. The increased adequacy of service will demand a better infrastructure, which would elevate the cost. As a consequence, the availability of service resources will be diminished, resulting in lower service quality.

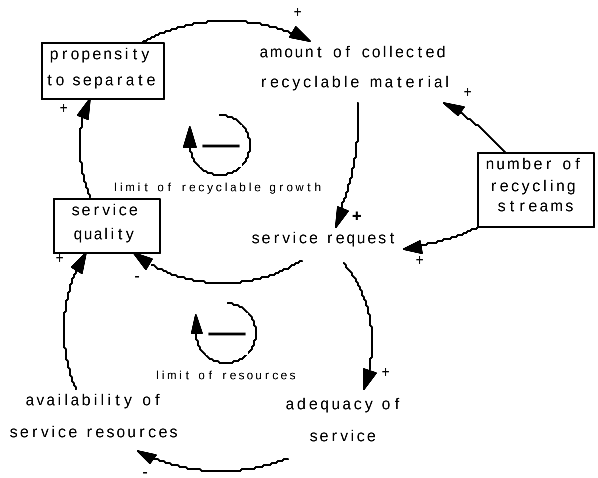


Figure 8: Feedback structure of the non-price mediated resource allocation system (adapted from Sterman 2000:172)

The two balancing loops indicate that a prepaid disposal charge can foster the separation behavior of citizens only to a certain limit. Once the propensity to separate tends to decrease, the fraction separated for recycling will stay constant on a certain equilibrium level, even when the number of recycling streams will increase.

Chart 5 represents the hypothesized reference mode that takes into account the underlying balancing feedback structure explained in Figure 8.

Due to the balancing feedback loops the fraction separated for recycling will reach an equilibrium position while the maximal acceptable number of recycling streams for citizens will be reached. Due to information delays in the market system the number of recycling streams will increase further resulting in an overshoot in the number of recycling streams.

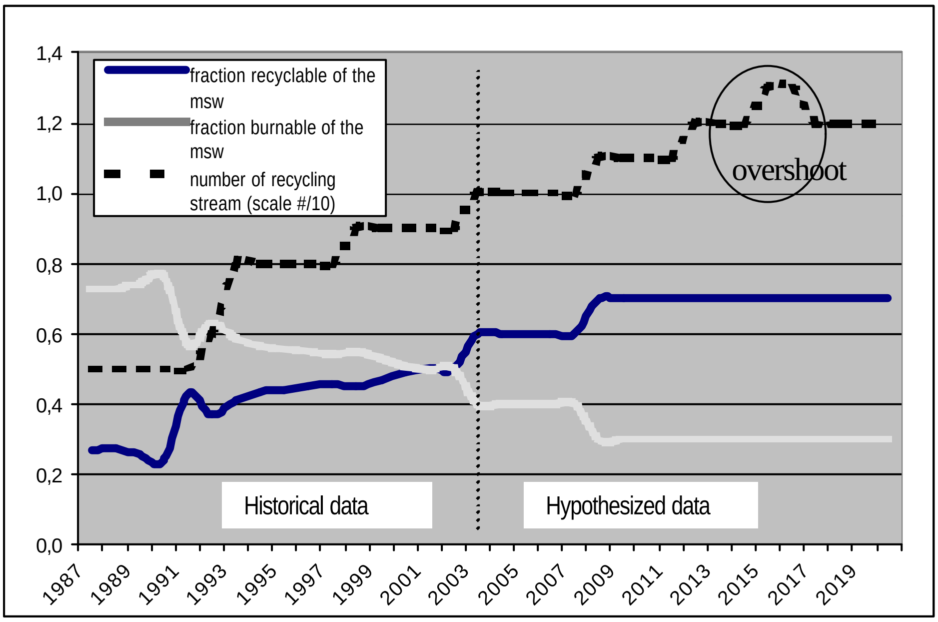


Chart 5: Hypothesized development of fraction separated for recycling and number of recycling streams

For the time frame of this study a steady increase in the overall amount of waste (including both burnable and recyclable waste) is hypothesized, which could be even exponential. This assumption reflects the observation that solid waste generation is highly correlated with economic growth[11]. The scenario of economic growth shows the externally driven behavior pattern. This component of the behavior pattern is modeled in a smaller subsystem that can be switched off. Subsequently, the discussed developments in the SWM-model can be analyzed either with or without economic growth – scenarios. This helps to partition the messy problem in the solid waste management into macro-economically driven developments and into policy-incentive driven developments (see Saeed 1992 in Richardson 1996). One additional challenge of this work would be, to analyze if the macro-economically driven development could be influenced by local policy interventions. Under which condition could a growing green consumerism result in solid waste avoiding behavior (see also Joos, Carabias et al. 2002)[12]?

[11] http://www.umwelt-schweiz.ch/buwal/eng/medien/umweltbericht/druck/index.html (Swiss Agency for the Environment, Forest and Landscape)

[12] http://www.IP-Waste.unibe.ch/public/Abschlussband/inhaltsverzeichnis.html

Purpose of modeling

The model is designed to create a computer based learning environment or a micro world for local policymakers to play with their knowledge of the solid waste system and to debate policy and strategy change (see Morecroft 1988). It can be used ase a communication tool to enhance a debate between the different agents about organizational structures in the area of solid waste management (see Schwaninger 1997). Finally it adds to the scientific discussion about long term dynamics between citizen choice and preferences and public policy initiatives.

To be more concrete, the following objectives should be met:
Firstly, the model help to discover the underlying causes of changes in the fraction separated and the quality of the separated material.
Secondly, the model is designed to uncover and clarify possible side effects of changes in the price structure and of prepaid disposal charges.
Lastly, the model helps local authorities dealing with mandates from the federal government and implementing sound solid waste management policies.

The overall model structure

In order to analyze long-term effects of different local policy intervention a time horizon from 1987 to 2020 was chosen. For the time period 1987 to 2001 there is data available (see reference modes) revealing historical patterns of behavior. The time span of two decades from 2002 to 2020 allows experimenting with further policy options and strategies and analyzing their behavioral impact. The sectors in the model are seen from a specific distance in order to see the internal structure, social pressures, market forces, and important decision points. A balance between a microscopic view that is too psychological and a telescopic view that captures an economic perspective that is too aggregated is aimed for (see Forrester 1961, Richardson 1991). Therefore in the model the different recyclable materials will be aggregated to one flow. However, the model is designed to focus on the number of different recycling streams and the effects of a change in the number.

The solid waste model includes the following sectors (see Figure 9):
The main sector is the local separation sector that is disaggregated in the following sub sectors: the household waste separation sector, the household decision sector and the local solid waste management sector. These sectors include endogenously operating dynamics deemed important to address the solid waste management problems and to conduct policy analysis.
The household waste separation sector includes:

- The different flows and qualities of the burnable and recyclable waste that result from separation activities of different groups of citizens.
- The initial amounts of different waste qualities, and recyclable and burnable material will be given exogenously but will be modified by behavioral effects.

- The habits of different groups of people to dispose their waste and factors that lead to changes in habits (i.e. changes in relative prices and the number of recycling streams).

The household decision sector will describe:

- What factors influence the decision of people to become willing / unwilling to separate the recyclable material?
- What influences the willingness to spend time or money on waste separation activities?

The local policy sector / solid waste management sector includes:

- The development of municipal budget for solid waste management under different policy options.
- Capacity building processes and the effect of a backlog of separated waste.

Furthermore basic structures of the recycling sector, the supply sector and the incineration sector are designed in a higher aggregation representing the development of recycling markets. In these sectors capacities, prices and changes in number of recycling streams will be computed. This information will be transmitted into the local separation sector.

Some aggregated information about the impact on the environment of incineration and recycling activities and of the exploitation of raw material from the supply sector will feed in the household decision sector. The income per capita and the population are given exogenously. Some time delays due to unavailable and delayed information will occur at different decision points such as in capacity adjustment processes influencing the system behavior (see Chung 1992).

Figure 9: Overall model structure

(see end of paper)

Possible local policy options

For forecasting, different policy strategies will be designed that are characterized by specific "bundles" of parameter values.

"Business as usual policy"

The "business as usual policy" represents the actual policy and is simulated in the base run. This scenario forecasts the development of the amount of waste and the solid waste management budget in the municipality without new interventions. This scenario constitutes the base run. The prices and the number of recycling streams will be held constant after 2000.

"Environmentally ignorant policy"

In this strategy, the main goal is to minimize the disposal cost. No special incentives for households are given. The specific parameters are: hidden prices for recycling services, lower service quality resulting in higher time costs for separating, constant or fewer number of recycling streams, lower garbage bag prices, lower budget for solid waste management.

"Separating policy"

The "separating policy" aims to offer convenient (time saving) collecting services for households resulting in a higher budget for solid waste management. A high number of recycling streams is offered in order to collect a high quality of recyclable material. There is probably a trade off between minimizing the time for separation behavior and enlarging the number of collecting streams.

"Waste avoidance policy"

In this strategy, the local authorities aim to show the real cost for collecting services and they would spend more money into educational programs. This strategy implies the following parameter changes: higher budget for solid waste management, more investment in local service capacity, a transparent price structure (no taxes), prices for collecting separated material. Probably this strategy would show a "first worse before better" behavior.

The Solid Waste Management – model

This section firstly describes existing model parts in depth and secondly gives an overview of model parts that are still under construction. Since the concept of propensity – the propensity of citizens to separate - seems to be crucial for the success of recycling programs, it will be modeled explicitly. Therefore a special weight is put on the formulation of the decision process guiding citizens' behavior to separate.

In the feedback theory about human behavior and public policy (Kaufmann-Hayoz, Bättig et al. 2001), contextual and personal factors in a decision making process are emphasized. Therefore in the SWM-model, interactions between contextual and personal factors will be addressed. Hidden attitudinal stocks in the system can create adaptation delays leading to unexpected system behavior and unintended consequences. Elements of the attitudinal structure will be represented in the household decision and the household separation sector.

Designing propensity to separate: The household decision sector

Citizens' disposal behavior is seen as a routine behavior and not as a planned behavior. In Forrester's term this would be called an informal policy. "… But most guiding policies are informal, although fully as influential. Informal policy results from habit, conformity, social pressure, ingrained concepts of goals, awareness of power centers within the organization, and personal interest" (Forrester 1994:58).

This assumption suggests that people decide once whether to separate or not. Once they have made this decision, they set a new routine, resulting in new separating habits (see also Dahlstrand and Biel 1997). This implies that there are two main groups of citizens: a group of people "willing to separate" and a group of people "not willing to separate". However, in each population we can distinguish sub groups that are transients (see Figure 10):

- In the group "people willing to separate" there are some inexperienced people – they will show a lower separation performance than the experienced ones. But as they learn to separate they will move into the stock "experienced people". The "time to learn" determines how long this takes.
- In the group "people not willing to separate" there are experienced people that got disappointed from separation consequences. The "experienced people not willing to separate" will move into the stock "inexperienced people not willing to separate" as they will forget, they are changing their separation behavior and set up a simpler routine behavior. The "time to forget" calculates when these people will move on.

Figure 10: Changes in citizen's willingness to separate
(see end of paper)

The flow between the two groups of people "willing to separate" and "not willing to separate" is an important decision point in the system. Therefore, its decision rule determining the rate has to be precisely determined (Forrester 1961, 1994, Sterman 2000). The goal would be to formulate the decision rules with sufficient accuracy in order to gain insight into how people respond to different circumstances, pressures and policy interventions. Following Forrester (1994) the aim is not to mimic a process of planned behavior. He suggests a process of seeing governing policies rather than individual decisions.

The decision to separate is influenced by the social norm to separate, the time cost of separating, and real cost for separating. The decision to become unwilling is influenced by alternative cost such as time cost and real cost for burning and the social norm for burning. In a further advanced version of the model, factors such as "perceived policy effectiveness" and "knowledge" will be included in the decision function. The information about the decision cues (e.g. time cost, real cost, later on the perceived policy effectivness) comes from other model sectors. In the following part some psychological assumptions are described.

Some psychological assumptions
The decision rule applied is based on some psychologically grounded assumptions (Latané 1981, Cialdini, Reno et al. 1990, Hopper and Carl-Niesen 1991, Reno, Cialdini et al. 1993, Mosler 2000, Mosler, Gutscher et al. 1996, Black, Stern et al. 1985). In the following paragraph they will be made explicit and explained.

Social norm
The perceived social norm for separating is a function of the fraction of people "willing to separate". An increasing fraction of people "willing to separate" in the municipality, will generate a stronger norm to separate, resulting in a higher number of people "willing to separate". In the decision function this idea is represented in a non-linear function (see Chart 6). Given the obvious "disposal - or environmental problems" it is reasonable to assume that a small "normal" fraction of people will become willing to separate even when they perceive no or only a minimal social norm to do so.

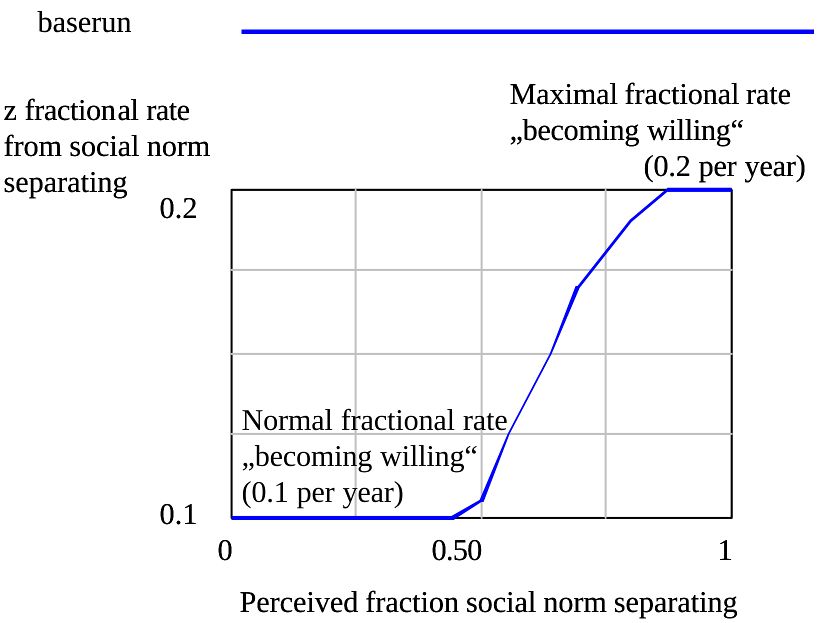


Chart 6: Fractional rate from social norm separating

The normal **fractional rate** "people becoming willing" is assumed to be 10% per year, resulting in a doubling time of 6.93 years[13] reflecting the maximal diffusion delay (ceteris paribus). The fractional rate will increase when nearly 50% of the population generates a social norm to separate. When nearly all the population is willing, a maximal fractional rate (0.2) will be reached. This value computes the minimal diffusion delay in the population (doupling time 3,5 years).
The s-shape of the relationship reflects the assumption that first people that are easy to convince will become willing and later on those that are harder to convince.

[13] Doubling time = ln(2)/fractional rate "becoming willing" (see Sterman, 2000:269)

Acceptable time to separate
The willingness to spend time for separating is a function of the perceived social norm to separate. It is assumed that people have a maximal acceptable time, they are willing to invest in separating activities. However, this time would be lower, if the social norm to separate is low. Chart 7 shows this relationship and discounts the maximal acceptable time (y-axis) when the social norm to separate goes down (x-axis).

Acceptable separating cost
The graph "acceptable separating time" is based on the same assumption as the concept of acceptable time. The maximal recycling cost that people are willing to pay, will be discounted, as the social norm to separate will decrease.

Effect of time cost separating
The graphical converter "z effect of time cost separating" computes the effect of the time cost on the diffusion process (see Chart 8). The effect of time cost is normalized; when "time spent for separating" = "acceptable time for separating"; the graphical function passes the reference point (1,1). If the time cost is very low the diffusion process will be accelerated to a maximal value of 1.5. If the required time spent for separating (TSS) is twice as high as the acceptable time for separating (ATS) the diffusion process will be stopped.

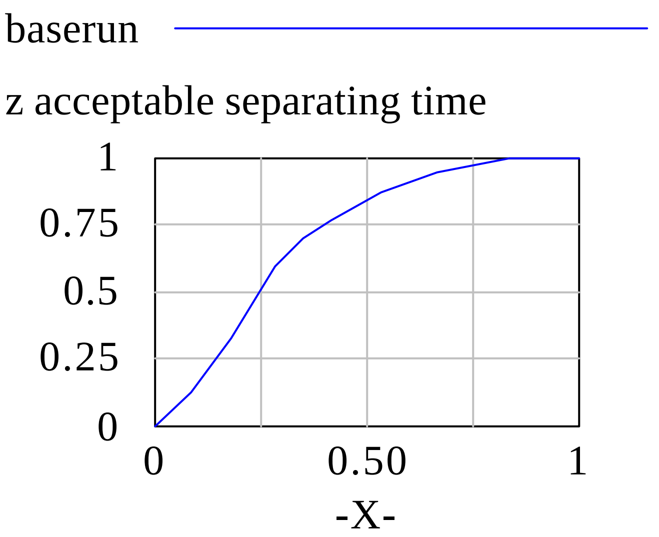


Chart 7: Acceptable time to separate
(X-axis: perceived social norm to separate, Y-axis: discount in percent of the maximal acceptable time)

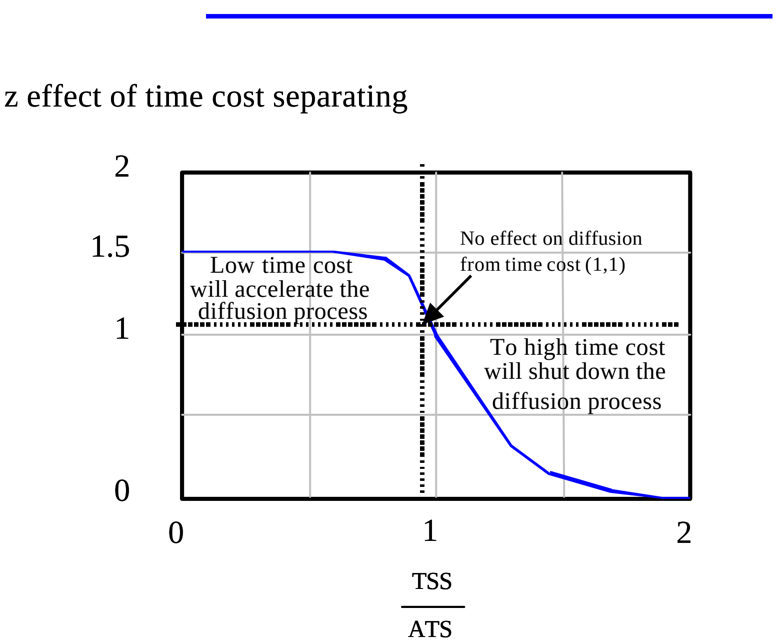


Chart 8: effect of time cost separating

Effect of separating cost
The graphical converter “z effect of separation cost” would calculate the effect of some prices for separating services in a similar way as the converter for “z effect of time cost separating” described above.

Decision rules
The “fractional rate becoming unwilling” is formulated in a similar way as the “fractional rate becoming willing”, but the alternative burning and time costs and a social norm to burn will determine the rate. A multiplicative formulation of the three decision rules “fractional rate from social norm”, “effect of time cost separating”, and “effect of separation cost” will be used since any extreme value in each of them can dominate the other effects as well as one effect can also reinforce another.
Fractional rate becoming willing = “fractional rate from social norm” * “effect of time cost separating” * “effect of separating cost”

However it is assumed that the two stocks “experienced people willing to separate” and “inexperienced people not willing to separate” will never get to zero. There will always be a fraction that will not change its behavior. This design would represent people with strong beliefs, people that just do not see any profit, or that are over occupied by separating.

The household waste separation sector

In the household waste separation sector, four different qualities of waste will be computed. The waste generated consists of recyclable material (A-waste) and non-recyclable material (B-waste). Therefore, the people have four different action choices to dispose the waste (see Figure 11).

A: The recyclable material can be appropriately separated (A1) or can be disposed for burning (A2).
B: The non-recyclable material can be disposed for burning (B1) or it can be inappropriately separated (B2) (generating impure and more expensive recycling material).
Figure 11 explains, how the different qualities of waste are computed.

Figure 11: Action choices for disposing the waste (wep: willing experienced people)
(see end of paper)

The per capita waste generation for all four groups is assumed to be the same over the years and will be held constant: 339 kg/person/year (based on real data 1987, Table 4).
The real data of the different waste qualities “waste put for incineration” and “waste separated” reflect an average system performance and a mixture of A1and B2, respectively A2 and B1 waste qualities.

Waste per capita	339,0 kg/person/year
Waste put for incineration	247,6 kg/person/year
Waste separated	91,3 kg/person/year

Table 4: real data 1987

However in the model it is assumed that the four different groups of people have different disposal habits, generating different amounts of the four waste qualities.

Chart 9 illustrates the assumed waste composition of the four groups of people. The compositions are calibrated, based on data of generated waste per capita in 1987.

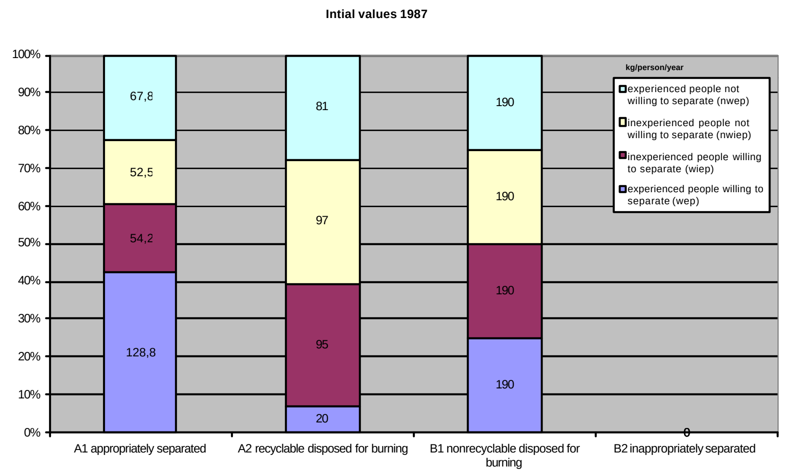


Chart 9: Waste composition of the four groups of people (Initial values assumed for 1987).

Given the disposal habits of the four groups, their contribution to four qualities can be shown. The "inexperienced people not willing to separate" start to produce 100% of the inappropriately separated waste (see Chart 10).

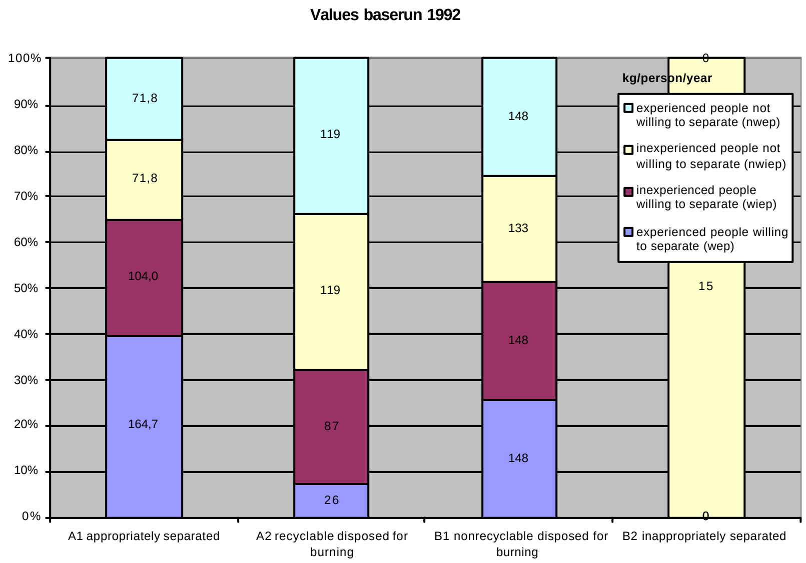


Chart 10: Contribution of the four groups to the different qualities of waste (model data 1992 baserun)

The different amounts of each group and quality are added together and the fraction separated can be computed (Table 5). The model is calibrated to the real data in 1987.

Model output 1987	**Initial amount of waste**
Total amount solid waste	3 628 M kg/year
Total amount disposed for burning	2 631 M kg/year
Total amount separated	997 M kg/year

Table 5: Model output 1987 calibrated to the real data 1987

As the people move from one group to the other the total amount of separated material will change. The disposal habits of the group "inexperienced people not willing to separate" are influenced by the relative price burning cost to separating cost. The separation habits of the "experienced people willing to separate" are influenced by changes in the number of recycling streams.

Local separation sector

In the following section an overview of the three main capacity building sectors will be given, including the local separation sector, the recycling sector and the production / supply sector. This model part is still under construction (see Figure 12).
In an abstract sense, the average propensity to separate can be seen as the capacity of the citizens to separate the recyclable material. This capacity and the local capacity to collect the separated waste will determine the flow "separating recyclable material by households". Three feedback loops will determine the rate "separating recyclable material by households". As the backlog "separated recyclable material in localities waiting to be recycled" increases both rates "capacity building for separating" and "separating recyclable by households" shut down. However an increasing demand of separated recyclable material promote the capacity building process. In all of the three different feedback processes there are both information and capacity adjustment delays, leading to an unstable system behavior and inefficiencies.

Recycling sector

The same underlying system-structure affects the rates of flow in the recycling sector. As the backlog "recycled raw material waiting to be turned into goods" increases, less material will be recycled and less recycling capacity will be built. However, an increase in demand for recycled material will increase the "capacity building for recycling". As a consequence of an increase in capacity building, the number of recycling streams will increase, too.

The Production and Supply Sector

In this sector again, the same system structure will be modeled. The backlog "recyclable material in goods waiting to be separated" will be computed by the average amount "recyclable disposed for burning" (A2-waste from the separation behavior sector). A higher demand of recyclable material in products by households increases the capacity for processing recycled material. The "actual amount recyclable material" computed in the household sector will measure the "demand of recyclable material in products by households".

This overview of the model structure clarifies the hypothesized reinforcing feedback loop "trap/chance recycling market" presented in Figure 7. Furthermore, it explains the link of the "local separation sector" to "the recycling sector" and "supply sector" determining the development of recycling markets. Price signals and the perceptions of backlogs will adjust the capacitybuilding process in all three sectors. Different capacity development scenarios will be simulated. It is expected that delays lead to undesired effects such as over-investments in capacity building in the different sectors. Furthermore this structure should also help to understand the trade off between the maximal capacity to separate of citizens and the capacity development in the recycling sector.

Figure 12: Conceptual overview: Effects of Demand and Backlogs on capacity developments
(see end of paper)

Model behavior

First simulation runs show the dynamic of the model-structure representing the propensity to separate. The base run describes the model behavior with the actual policies in place: an increase in number of recycling streams and an increase in the price for a garbage bag in 1991 and 2000 – (In Graph 1 and 2 the historical data are adjusted to a three median smooth). The simulated fraction separated and burned closely tracks the smoothed real data (See Chart 11 A). There is a clear trend of growth in the fraction separated. Based on the historical growth trend the model data forecast a further increase in the fraction separated till it seeks equilibrium at 53%.

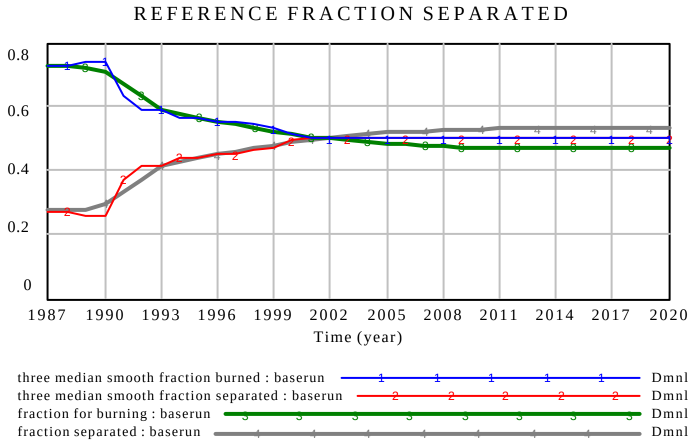


Chart 11A: Fraction burned and separated (Base run)
(Line 1 and 2 are three median smoothed real data)

The dynamics are created by the flow of people respectively by changes in the number of the four different groups of people willing / not willing to separate. Chart 11 B shows a clear increase in the number of "experienced people willing to separate" beginning in 1991, and a decrease in the number of "inexperienced people not willing to separate".

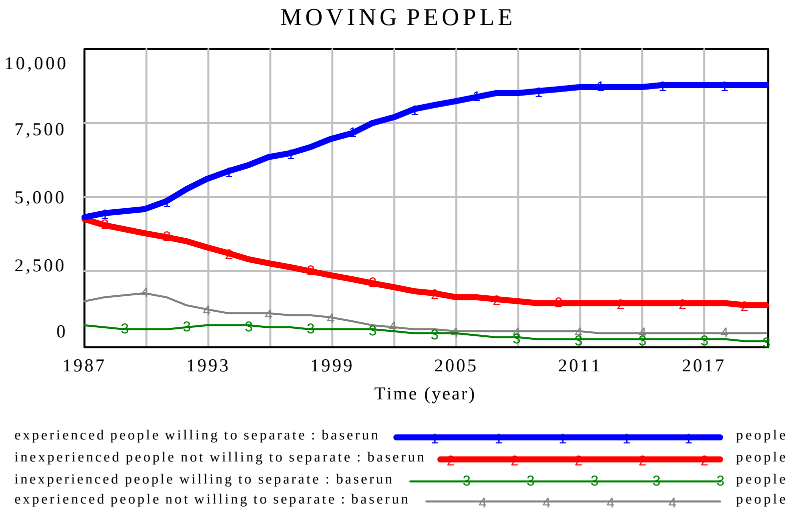


Chart 11 B: Number of the four groups willing / not willing to separate (Base run)

The outcome of the current policy is described in terms of “total amount appropriately separated” and “total amount inappropriately separated”. Chart 11 C illustrates an increasing trend in separated material. However, the price incentives lead to a sudden increase in the amount of inappropriately separated waste in 1991 and in 2000. But the decreasing trend in the number of “inexperienced people not willing to separate” reduces this amount over time to a equilibrium level. The gap between recyclable material and the appropriately separated material decreases, resulting in a smaller constant gap.

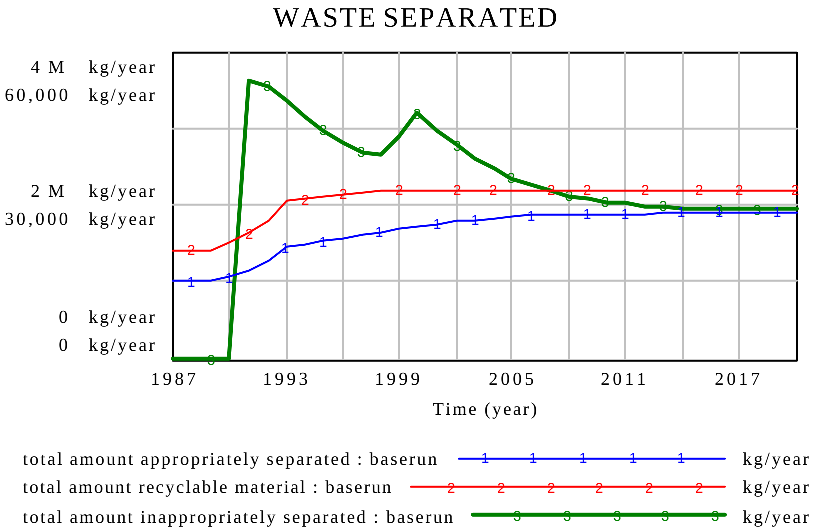


Chart 11 C: Total amount separated waste (Base run)

First policy tests

To gain further confidence in the model and to test its relevance, first policy tests were conducted. Since the base run explains the historical behavior pattern with the policy in place, the model can be used as a laboratory to address the question: What would have happened if other policies had been chosen? Three alternative policy experiments – a steady state policy, and two alternative separating policies - give some insightful answers:

“Steady state policy (do nothing)”

In this strategy, there are no price incentives (no garbage bag prices) and no changes in the number of recycling streams. Therefore, the amount of recyclable material in the waste does not change over time.

Charts12 A-C: portray the dynamics of the steady state policy: the fraction separated stays on a constant level. Over time only slightly more people become willing to separate. The total amount of separated waste stays nearly the same. Further more there is a remarkable gap between “total amount appropriately separated” and total amount recyclable material” indicating a low policy compliance (Chart 12C).
However this policy result is very sensitive to parameters changes. The model parameters operate near a tipping point – that means that different policy outcome would be possible depending on which loop dominates the diffusion process (people getting motivated or people getting disappointed).

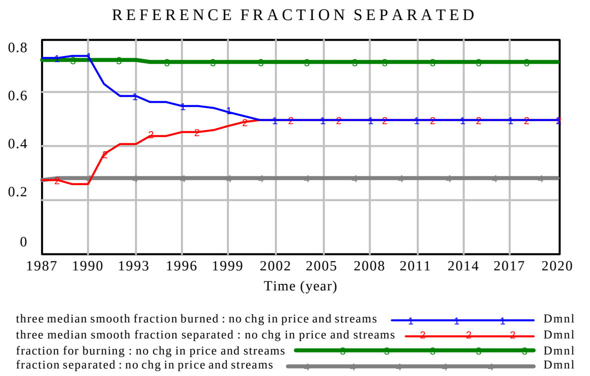
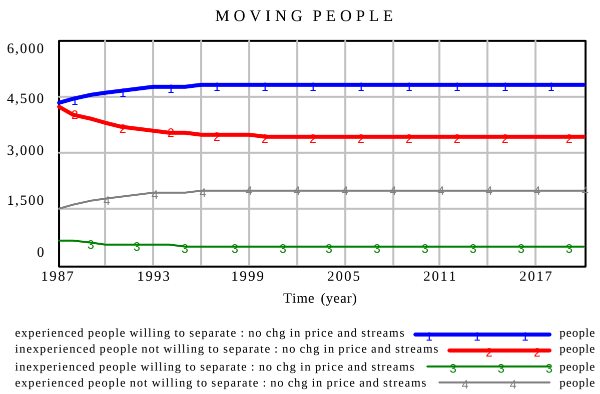


Chart 12 A: Fraction burned and separat ed (Steady state policy)



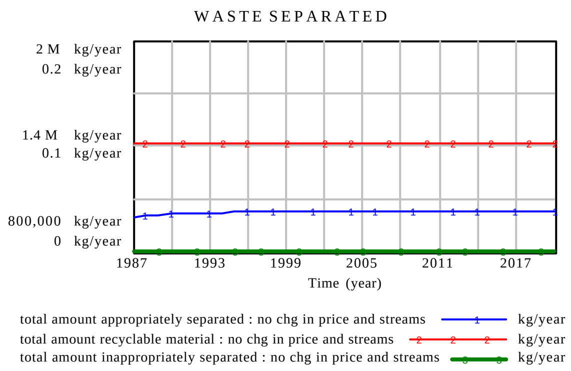
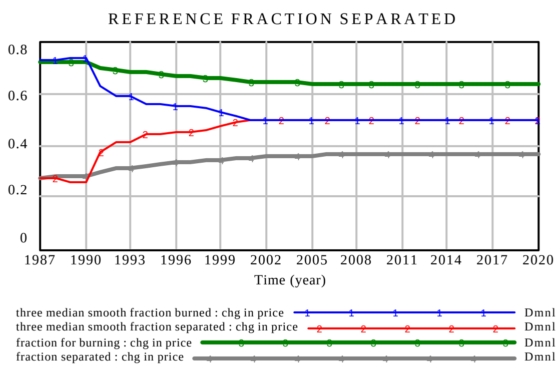


Chart 12 B-C: Impact and outcome of steady state policy“

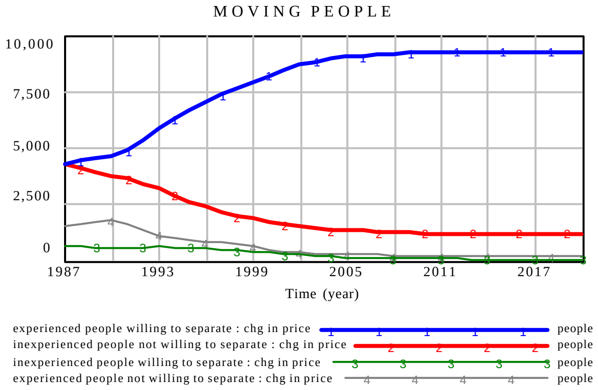
Giving price incentives”

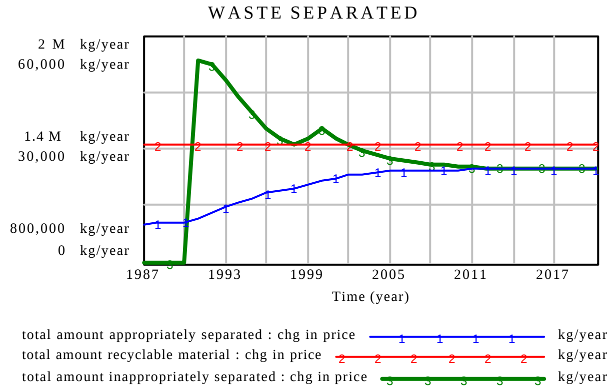
In this policy only price incentives to separate were given. Since 1991 the people have to pay a price per garbage bag. In 2000 the price increased by nearly 100%. The amount of recyclable material in the waste remains constant.
According to Charts 13 A-C, the policy increases the fraction separated slightly till it seeks equilibrium around 38%. Over time nearly all the people become willing to separate. The total amount separated finds equilibrium at a higher level. Due to the price incentives, the amount inappropriately separated peaks around 1991 and 2000 and decreases gradually to a low stable level.
Furthermore, the gap between the recyclable material and the appropriately separated material



decreases and then it becomes constant.

Chart 13 A: Fraction burned and separated (Giving price incentives)



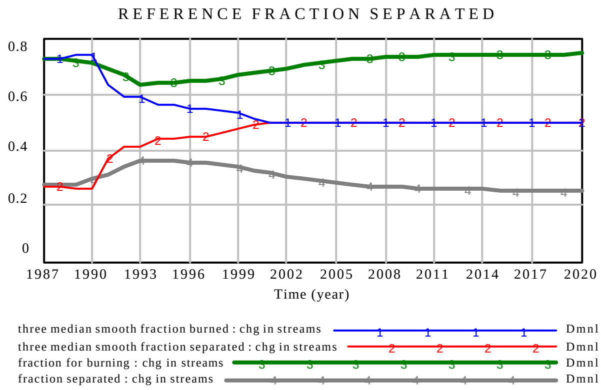


Charts 13 B-C: Impact and outcome of giving price incentives

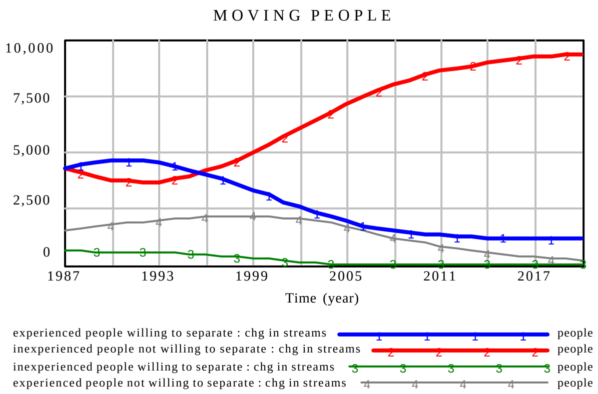
"Growing number of recycling streams"

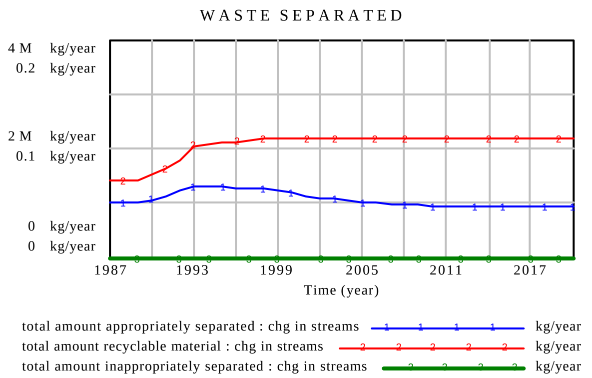
A growing number of recycling streams both creates more recycling opportunities and also increases the amount of recyclable material.

Charts 14 A-C illustrate a slight increase in the fraction recycled between 1987 and 1993. And after 1993 the fraction starts to decrease due to a sharp increase in people becoming unwilling to separate. The amount appropriately recycled falls below its initial value and the amount inappropriately recycled will increase as the number of people unwilling to separate increases. The compliance gap increases. Here again, the model parameters operate near the tipping point. A higher maximal acceptable time for recycling, could lead to an opposite policy outcome.



Charts 14 A: Fraction burned and separated (Increasing number of recycling streams)





Charts 14 B-C Impact and outcome of growing number of recycling streams

Policy lessons learnt

The overview of the policy-experiments (see Table 4) shows that the combinations of price policy and offering more recycling streams gives the best outcome concerning the fraction separated. However, this policy results also in two unintended consequences. On the one hand the price structure (garbage bag charge) leads to a deficit in the solid waste management budget. This deficit is a result of an internal feedback structure that is explained in the dynamic hypothesis (Figure 5), but not yet captured in this model version. Furthermore, once a price incentive is shown to create a clear gain for citizens to separate, a further increase in the price does not show any remarkable effect on the fraction separated. Moreover, it even worsen the quality of the separated material. Citizens not willing to separate might try to avoid the disposal cost by putting un-recyclable material in the recycling streams. However, this effect will be attenuated since more people will become willing to separate.

A further insight from simulating alternative policy options is related to the question: Which cues do we use to observe the policy performance? A glimpse on the fraction separated of the three alternative policies could tell us that there is only a small difference (the fraction separated stays relatively low in all three alternative policy-experiments , between 23-38%). But the simulation runs of the models highlight that there are important differences in the impact and outcome of each policy. Only the experiment "burning gets expensive" will show a robust policy impact getting people motivated to participate in recycling programs and improving the outcome. Conversely, due to the tipping point the two experiments "do nothing", and "more tasks" can either motivate / disappoint or overwhelm the citizens, resulting either in a worse outcome (with less material appropriately separated) or in a slightly better outcome (see Table 4).

Policies / **Results**	**Combination** Price, streams	**Do nothing** No prices, no chg streams **(Tipping point!)**	**Burning get expensive** Price	**More tasks** More streams **(Tipping point!)**
Reference mode	Frac separated ↗↗	Frac separated →↘ →↗	Frac separated ↗	Frac separated →↘ →↗
Impact Citizens	Citizens get motivated ☺	Citizens get disappointed ☹ ☺	Citizens get motivated ☺	Citizens are overwhelmed ☹ ☺
Outcome Amount and quality	Amount app. separated ↗↗ Quality ↘ (and deficit & resistance)	Amount app. separated ↘↗ Quality ↗	Amount app. separated ↗ Quality ↘ (and resistance)	Amount app. separated ↘↗ Quality ↘↗

Table 4: Overview policy tests

Playing with the model shows us that the outcome of an increase in the number of recycling streams depends on the number of people willing to separate. If there is already a certain social norm to separate in a community, the effect of an increase in the number of recycling streams will increase the amount of separated material. Conversely, in a community with a low social norm to separate, an increase in the number of recycling streams can overwhelm the people, resulting in even less appropriately separated material. The effect of an increase in the number of recycling streams depends not only on the social norm to separate, but also on the overall willingness to invest time in separation. The upper limit indicates a maximal capacity to separate. This interpretation of the observed tipping point in the model behavior suggest that in the long run a successful separation-strategy has to be sensitive to the number of recycling streams that are offered. The important information is the potential capacity of the citizens to separate but also the potential capacity to separate in the recycling sector. The latter will depend on the market development and the former on the social norm to separate and the maximal willingness to invest time in separation activities. These insights are in line with findings of an entropy-theoretical discussion of waste management (Ulli-Beer 2000) but also with some insights from computer based simulations of theories about environmental behavior (Mosler, Gutscher et al. 1996).

In sum the model gives evidence of the superiority of a mixed strategy, motivating citizens to participate and offering adequate opportunities. While only trying to motivate citizens, contextual factures could constrain their intention to separate. Similarly, if the focus is only on improving contextual factors, personal factors (such as a low willingness to spend time on separating) could inhibit the success of the policy initiative. However, the side effects of an extrinsic motivation (giving price incentives that results in higher impurity) can be harmful for the overall recycling initiative. A high impurity can become a trap for the recycling market. Therefore the challenge for local authorities would be to find policy strategies that helps to build up an intrinsic motivation to separate.

A further observation is that in all policies, there remains a gap between the amount of the possible recyclable material and the amount appropriately separated. The width of the gap can be interpreted as the compliance to separate. It depends not only on the number of people willing to separate and on other factors such as learning processes, changes in habits, and the design of the products but also on the indolence of people. The simulation runs illustrate that there will never be a 100% separation-compliance.
The insights about a maximal separation-compliance and a maximal separation capacity gives evidence that structural elements will constrain the overall possible propensity to separate at the local level.

Conclusions

This modeling project is strongly guided by a feedback perspective on human behavior and policy. This perspective influences the model design in two ways.
Firstly, it helps to focus on "hidden" personal factors in a system. The theory emphasizes the existence of such factors, and helps to reflect on the nature of those concepts. It gives an idea how they affect the system and helps to design them in the model. Disposal habits of a group of people can be measured in the amount of appropriately separated material. An overall propensity to

separate is determined by different behavioral habits of groups of people. Observed changes in the propensity to separate indicate changes in behavioral habits of people, leading to a differently structured society with new social norms. Furthermore, this line of thinking sharpens the focus on processes, explaining

- how contextual factors and personal factors interact with each other and
- how they influence the decision points and
- how and where they affect the state of the system.

Likewise, the System Dynamics modeling approach underscores this thinking discipline by focusing on the "physics of the systems". Conversely the decision rules in the model are only based on available information about the state of the systems, representing the theory that that the rate of change can only be controlled by perceived cues.

Secondly, the feedback theory about human behavior and public policy also guides the search for possible intervention points in the system. With the picture in mind that interventions can affect both personal and contextual factors, different intervention strategies can be designed. Policy interventions aiming to motivate citizens to participate in separation activities, will be different from policy interventions that aim to improve separation habits of inexperienced but willing people. While the theory illustrates different intervention points the System Dynamics model helps to differentiate those and also gives an understanding about the dynamics and effectiveness of interventions.
To conclude, complementary insights can be gained in the process of applying the theory in a System Dynamic model.

However, these are only first conclusions. The model has to be developed further and has to endure and pass different tests of logical coherence, and structural and behavioral correspondence. To become useful for the local decision makers, they have to gain confidence in the model; the structure and the behavior must make sense to them. Furthermore the model must be found useful to address the problems at hand. In order to address these requirements, further workshops with experts in the area of solid waste management will be arranged. A first feedback from the gatekeeper and representatives of the model audience[14] was very encouraging. It was related to the relevance of the problem statement and the model assumptions.

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[14] For an explanation of different roles in group model building see (Richardson and Andersen 1995)

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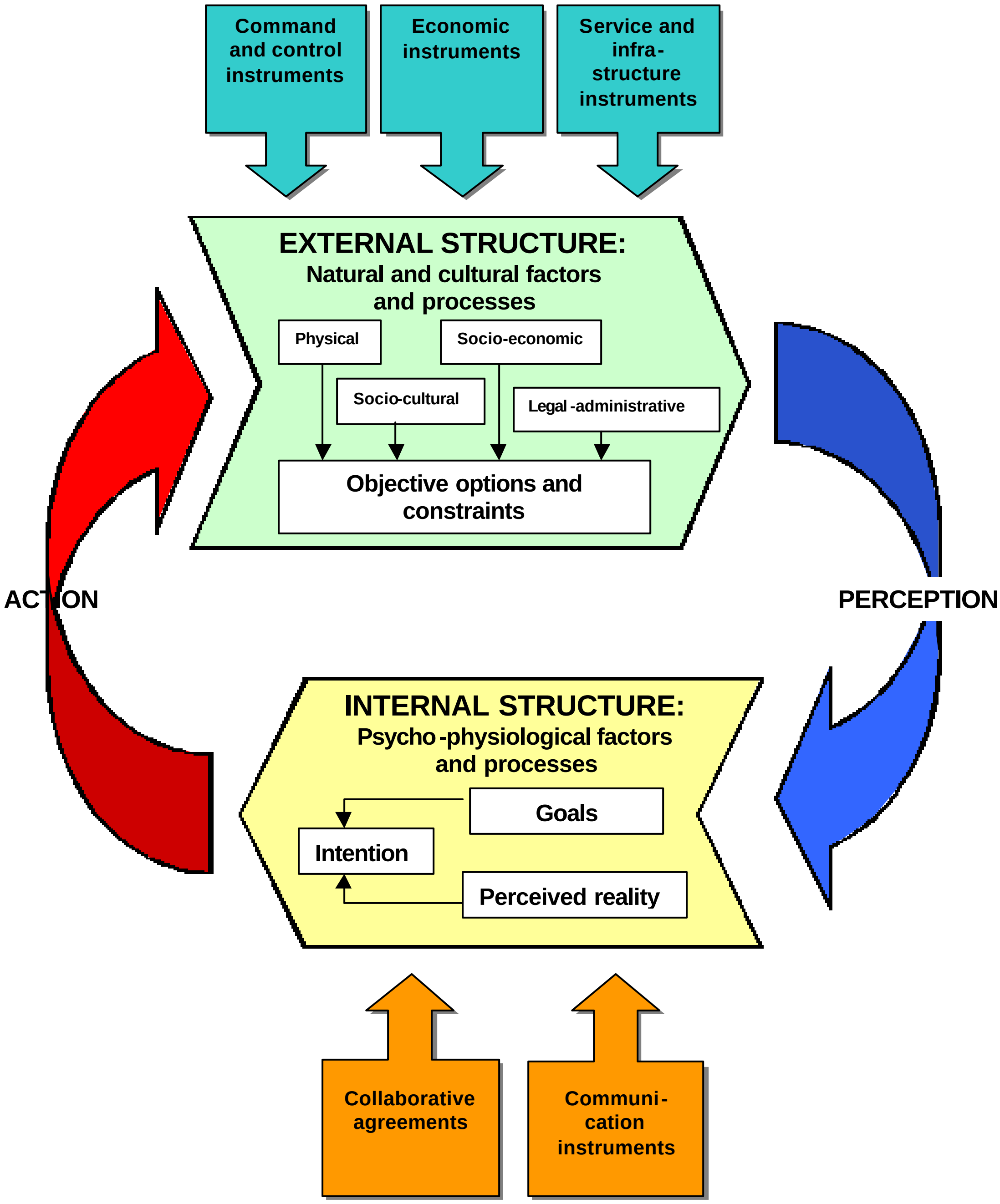

Figure 2: A simple feedback theory about human behavior and public policy (Kaufmann-Hayoz et al, 2001:82)

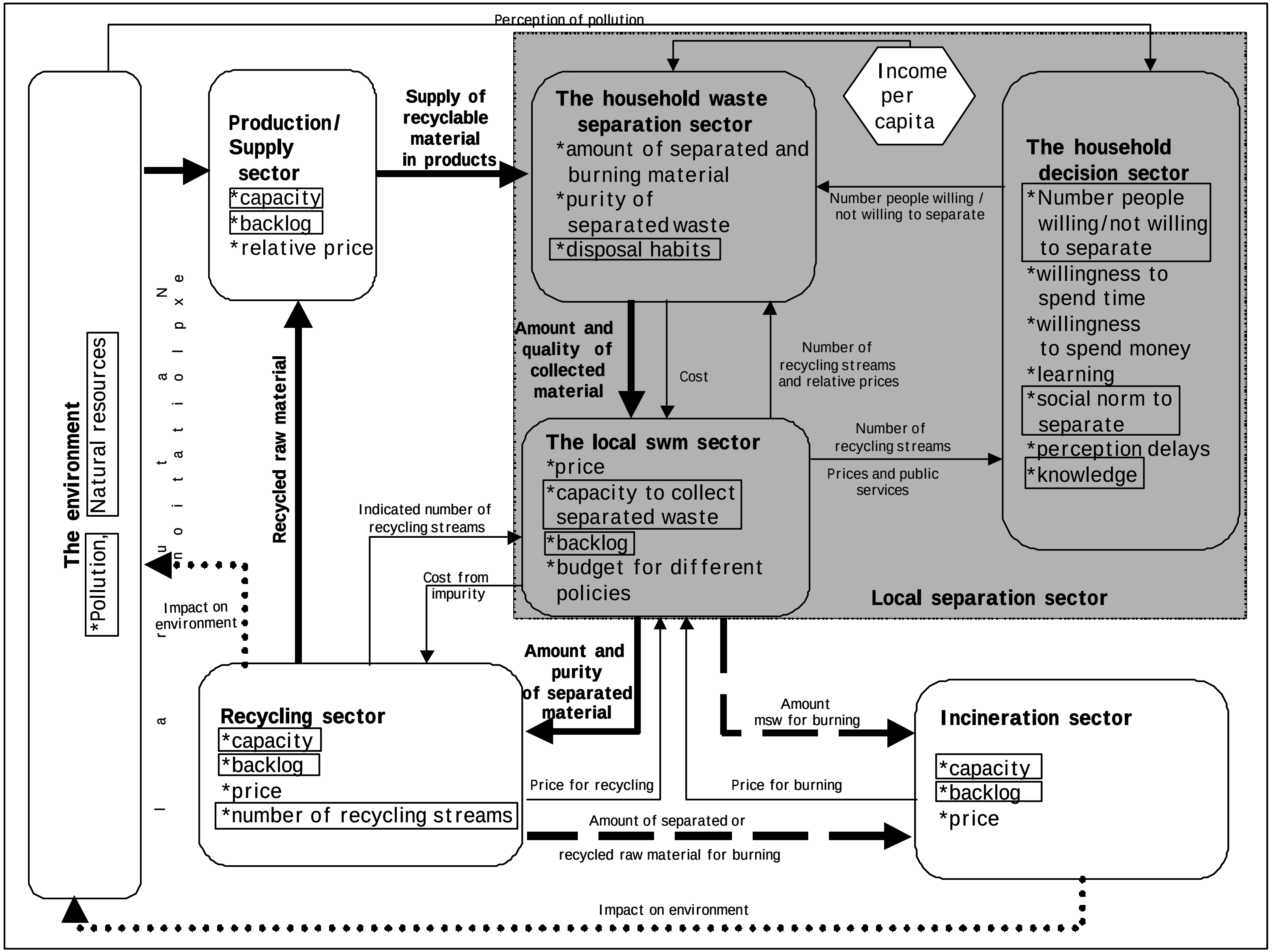

Figure 9: Overall model structure

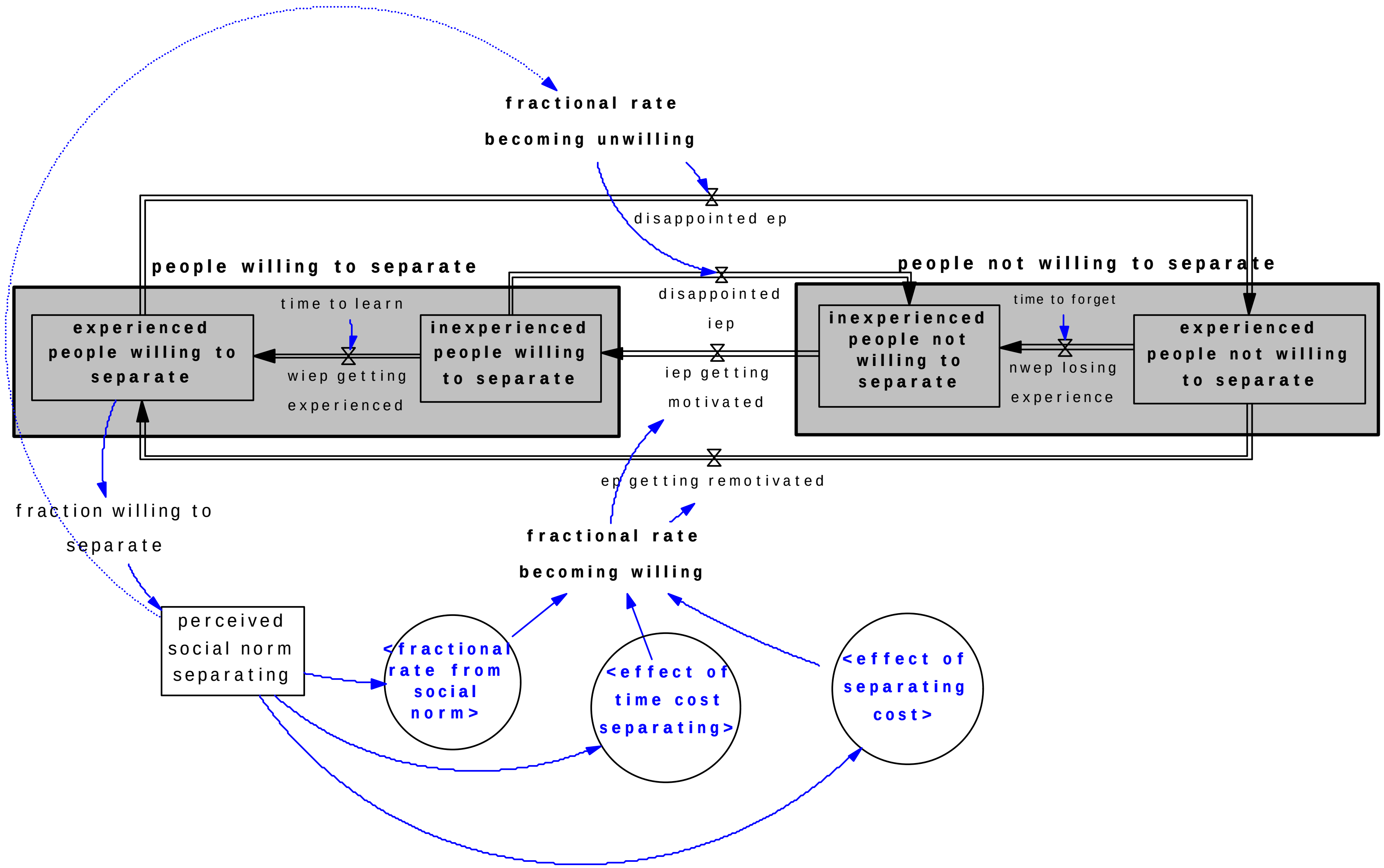

Figure 10: Changes in citizen's willingness to separate
(ep: experienced people, iep: inexperienced people, wiep: willing inexperienced people, nwep: not willing experienced people)

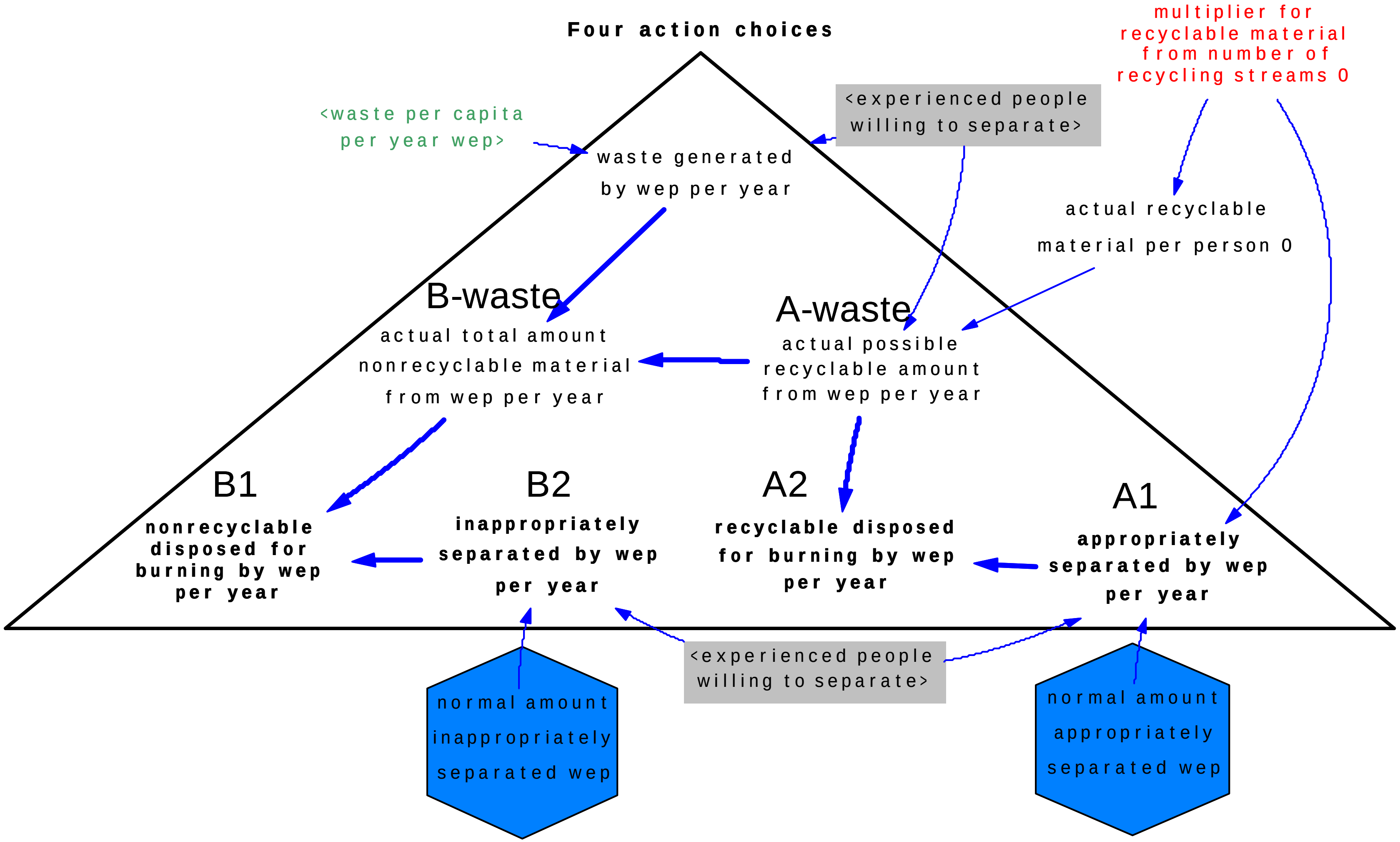

Figure 11: Action choices for disposing the waste (wep: willing experienced people)
The behavioral variables (indicated by diamonds) represent disposal habits. They measure the normal amount inappropriately separated (B2-waste) and the normal amount appropriately separated (A1-waste). They also determine both counterparts: the amount recyclable disposed for burning (A2-waste) and the non-recyclable disposed for burning (B1-waste).

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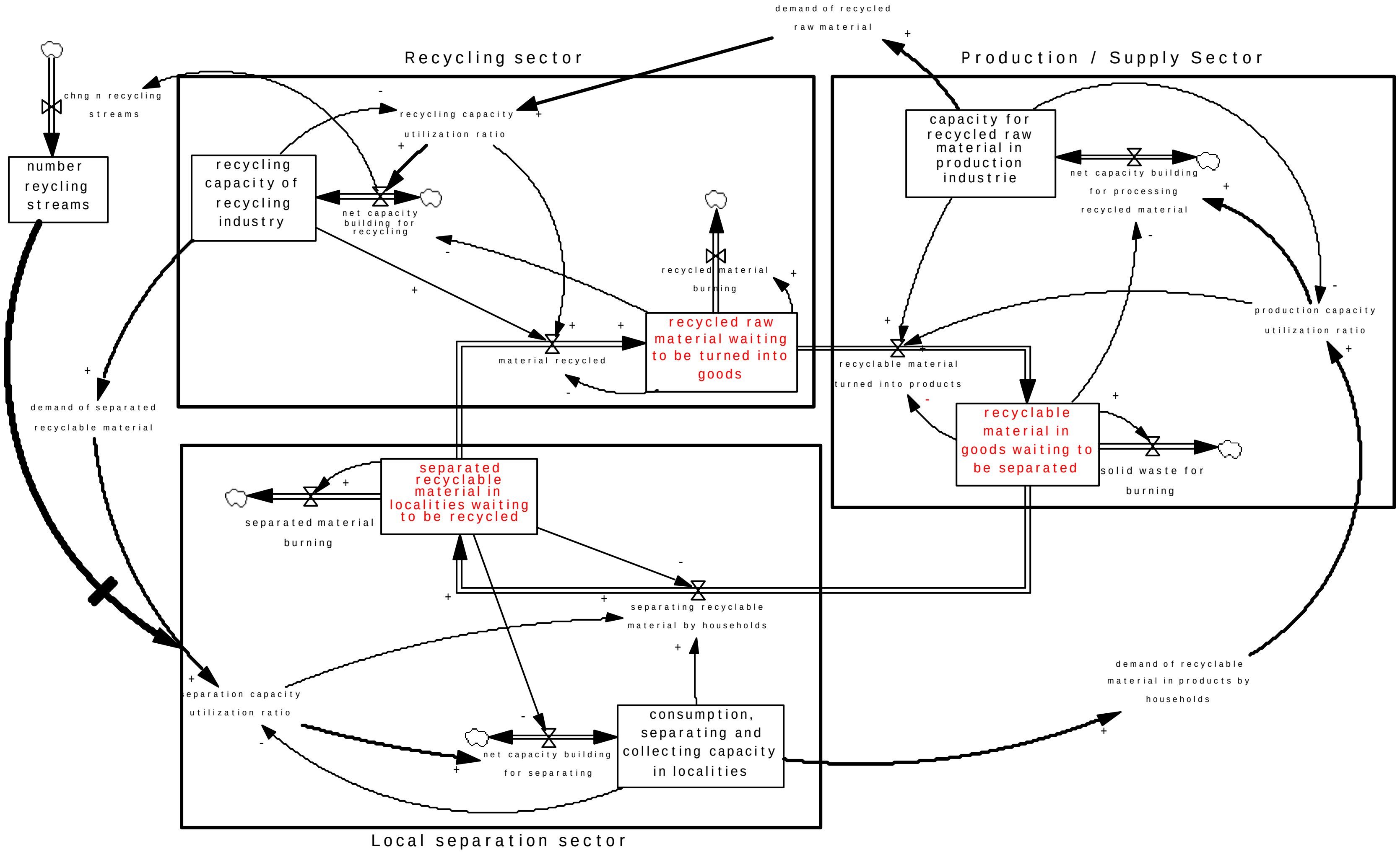

Figure 12: Conceptual overview: Effects of demand and backlogs on capacity developments

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