Michal Sedlacko and Andre Martinuzzi and Inge Røpke and Nuno Videira and Paula Antunes

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Michal Sedlacko[1]*, Andre Martinuzzi[1], Inge Røpke[2],
Nuno Videira[3] and Paula Antunes[3]

[1] *Research Institute for Sustainable Development (RIMAS)*
Vienna University of Economics and Business (WU Wien)
Franz Klein Gasse 1
1190, Vienna, Austria

** Corresponding Author:*
michal.sedlacko@wu.ac.at
+43-(0)1-31336 5458

[2] *Center for Design, Innovation and Sustainable Transition (DIST)*
Aalborg University (AAU)
A.C. Meyers Vænge 15
2450, Copenhagen SV, Denmark

[3] *CENSE – Center for Environmental and Sustainability Research*
Faculdade de Ciências e Tecnologia
Universidade Nova de Lisboa (FCT-UNL)
Campus de Caparica
2829-516 Caparica, Portugal

Abstract

The paper describes our usage of and experience with the method of participatory systems mapping. The method, developed for the purpose of facilitating knowledge brokerage, builds on participatory modelling approaches and applications and was used in several events involving both researchers and policy makers. The paper presents and discusses examples of how different types of participatory interaction with causal loop diagrams ('system maps') produced different insights on issues related to sustainable consumption and enabled participatory reflection and sharing of knowledge. Together, these insights support a systemic understanding of the issues and thus the method provides instruments for coping with complexity when formulating policies for sustainable consumption. Furthermore the paper discusses the ability of the method – and its limits – to connect mental models of participants through structured discussion and thus bridge boundaries between different communities.

Keywords

sustainable consumption, systems thinking, knowledge brokerage, participatory systems mapping, causal loop diagrams, mental models

1 Introduction

When the Brundtland report popularised the concept of 'sustainable development' in 1987, it also emphasised the need for developing more sustainable consumption patterns: "Sustainable development requires that those who are more affluent adopt lifestyles within the planet's ecological means" (WCED, 1987: 9). The commitment to sustainable consumption has been confirmed at the 1992 Earth Summit in Rio, and in a number of programmes initiated by international organisations and governments at all levels since. Nevertheless, government action on sustainable consumption focuses on the individual consumer (perhaps using misleading models of consumer behaviour) and on improving environmental efficiency of consumption rather than addressing scale issues or the social context and systemic dimensions. Over the last decade several strands of research on sustainable consumption (particularly sociological and anthropological research) have provided evidence that suggests that this dominant policy approach might be the reason for the relatively modest success of sustainable consumption initiatives.

In the frame of an EU-funded project we tested the usage of systems thinking methods for the purpose of knowledge brokerage between science and policy to help 'manage the contradictions of sustainable consumption and economic growth'. This paper aims to contribute to the discussion on the use of systems thinking approaches for sustainable consumption by presenting the method of participatory systems mapping (PSM), developed for the purpose of the project, and discussing the insights into problems related to sustainable consumption produced by the method.

The next section reviews some of the sustainable consumption debates as the context of our undertaking and presents our definition of sustainable consumption. Third section describes our systems thinking approach and the intellectual roots of the PSM method and our use of causal loop diagrams (CLDs) as well as the project context in which it was used. Fourth section explains the theoretical concepts behind PSM, summarises our process-related experience with CLDs and exemplifies and discusses insights produced within PSM sessions. In the fifth, concluding section we provide a wider outlook and highlight some of the challenges of PSM.

2 The competing discourses of sustainable consumption

Over the 1990s and 2000s a number of programmes on sustainable consumption has been initiated by international organisations such as UN or OECD as well as by a number of national governments and the European Union (Fuchs and Lorek, 2005; Berg, 2011; Fuchs, 2013). Most of these programmes share the same basic understandings and, contrary to the call of the Brundtland Report, are quite far from any serious challenge to the lifestyles of the affluent. First of all, sustainable consumption is not seen to be in contradiction with continued economic growth in the rich countries, and there is no mention of reserving consumption growth for poor people. As UNEP states in 2000: "sustainable consumption is *not about consuming less*, it is about consuming differently, consuming efficiently, and having an improved quality of life" (UNEP and CDG, 2000; emphasis added). Policy documents on sustainable consumption are typically expressions of the ecological modernisation discourse that emphasises win-win strategies: consumption can become more sustainable, new business opportunities can emerge, and quality of life can improve, all at the same time. This should be achieved by increasing the resource efficiency of consumption, encouraged mainly by market-based policy measures. Labelling of green products combined with information campaigns should help consumers to make informed choices and thus make it profitable for business to provide green products. Simultaneously, environmental taxation of resources, in particular energy and water, and of emissions of polluting substances could promote resource efficiency and reduce pollution. The actual toolbox included other instruments like direct regulation (bans on problematic substances, tightening of building regulations) and subsidies to consumers, e.g. for insulation, but direct regulation was not promoted as a part of the win-win repertoire (Christensen et al., 2007).

Politically, it was also an attractive strategy to translate the alleged consumer sovereignty in free markets to consumer responsibility: if consumption does not become more sustainable, consumers can be blamed. As a result consumption itself is becoming political, to be carried out by responsible citizen-consumers. The viability of this strategy is in part related to its compatibility with the normative foundations of our dominant political and economic institutions, i.e. with agency attributed to autonomous and rational individuals.

The focus on improving the efficiency of consumption has been termed ‘weak sustainable consumption’ (Fuchs and Lorek, 2005), as a differentiation from ‘strong sustainable consumption’ that would focus on the pursuit of fundamental shifts in consumption patterns and reduced levels of consumption in the rich countries. Considering the results of the first twenty years of consumer-oriented environmental policies, results have surely been achieved. Nevertheless, there are grounds for criticism. For instance, the combination of compulsory energy labelling, energy taxes and information campaigns has increased the efficiency of electrical appliances significantly, and various measures have reduced heat consumption per square meter. At the same time, however, critics point to an increase in the number of appliances and the area of heated space that counteract the achieved energy savings. In other cases, like transport and travelling, it has not been politically acceptable to follow the ‘recipe’: since mobility is considered decisive for economic growth and personal freedom, economic instruments have not been applied effectively, and energy consumption has increased considerably. Many areas of consumption are not addressed by environmental policies, and consumer-oriented environmental policies have not in any way questioned the continued rise in material living standards, the ongoing renewal of consumer goods, or the costly individualisation of consumption.

Around these policy topics a distinct field of research developed over the last 20 years and interacted with policy making (for anthologies see e.g. Princen et al., 2002; Reisch and Røpke, 2004; Jackson, 2006). It has collected knowledge on environmental impacts of consumption, with the consumption clusters of food, mobility and housing identified as having particularly large impacts (Hertwich, 2006). A lot of research applied an individualistic perspective and concentrated on the understanding of consumer behaviour, trying to explain the attitude–behaviour gap and investigating the results of various interventions like taxes, eco-labels and information campaigns. Some research saw a solution in the identification of different consumer groups and lifestyles and addressing them in different ways. Nevertheless, under ‘green consumption’ it is perfectly possible for consumers to demonstrate their ‘greenness’ by carrying out a large number of token green practices and simultaneously increase their environmental impacts considerably. Large segments of consumers have developed a sort of ‘compartmentalisation’ where only some categories of consumption are considered

in environmental terms, while much ordinary consumption and increases of normal standards go unnoticed.

Concurrently with the individualistic-oriented consumer research, more sociological and anthropological perspectives were developed (Gronow and Warde, 2001; Southerton et al., 2004). Here the embeddedness of consumption activities within wider social, economic and technological frameworks was emphasised, and the interplay between systems of provision and consumption practices was explored. So far this strand of research has not been influential in policymaking, but this may be about to change. The limited results of the win–win and individualist strategies in terms of the overall environmental impacts of consumption contributes to a search for different approaches (cf. Spaargaren, 2011: 814), including those that would work 'behind the back' of consumers (see also the 'fit and forget' metaphor of Van Vliet et al., 2005). Examples of some recent developments in different directions include: (i) individualistic-oriented research that increasingly takes 'context' into account (Thøgersen and Grønhøj, 2010); (ii) more policy-oriented advice that goes beyond the traditional ABC (attitude–behaviour–choice) by utilising sociological concepts of social practice and exploring novel concepts of agency (Shove, 2010); (iii) bottom-up experiments with more sustainable consumption and production patterns that call for studies on the possibilities for scaling up (Seyfang, 2009); (iv) more 'systemic' conceptions of production and consumption as socio-technical systems and their transitions, originating in sociology as well as science and technology studies and aiming at institutional actors (Geels, 2004; Shackley and Green, 2007).

The objective of our project was to tap the learning potential of a debate between various discourses and strands of research on sustainable consumption involving researchers and policy makers. In the frame of the project we organised a series of events that provide space for such a debate, facilitated by PSM. Although we adopted a 'strong' working definition where sustainable consumption is considered in a global perspective and not through improved resource efficiency of consumption,[1] we did not push for a specific understanding of consumption, but rather expected that

[1] Sustainable consumption is thus characterised along three objectives: a reduction of the overall consumption of resources to steer the socioeconomic system away from natural limits; the ethical challenge of redistribution of resource appropriation from rich to poor within and between nations; and the striving to achieve well-being, quality of life or a 'good life' (*buen vivir*) (see Scholl, 2011).

PSM would expose a plurality of systemic aspects to facilitate policy-relevant learning – that, for example, consumers can be understood not only in their role of buyers on a market, but also as practitioners that carry out meaningful practices and, at the same time, fulfil roles in broader socio-technical systems.

3 Systems thinking and the method of participatory systems mapping (PSM)

Systems thinking is a discipline developed from feedback concepts of cybernetics and servomechanism engineering theory (Senge, 1990) and spanning a number of schools and a range of approaches. It provides a framework for holistic thinking while addressing complex societal issues. The core of systems thinking is seeing 'wholes' instead of 'parts', making sense of interrelationships between system components to understand what drives dynamic behaviour of the system, i.e. the changes in stock and flow variables or even of the structure or purpose of the system over time. One of the key tenets of systems thinking is that behaviour of the system is latent in its structure, i.e. it is through the structure of interconnections between their elements that systems produce their own behaviour over time, and that the actual function or purpose of the system comes into being (Meadows, 2008).

Richmond (1993; cf. 1997) advanced a set of critical thinking skills which cater for more holistic policy-making processes and, among others, included the following: i) dynamic thinking (the ability to deduce patterns of behaviour of systems over time from underlying circular processes, rather than focusing on individual events), ii) closed-loop thinking (the ability to think in feedback terms and latent, endogenous causes of behaviour of systems, rather than linear pathways and external causes), and iii) operational thinking (the ability to explain change as causality-in-happening and grounded in shared reality, rather than as correlations or happening through abstract factors). Research related to natural resource management has incorporated notions of systems thinking since at least the early 1940s, and particularly since the publication of *The Limits to Growth* (Meadows et al., 1972). In the area of sustainable consumption, the importance of systems thinking has been increasingly recognised over the recent years (see, e.g., Klingert, 1998; Geels et al., 2008; Timmer et al., 2009a, 2009b; Mont

and Power, 2010; Soderquist, 2010; Prinet, 2011). Nevertheless, as of now, a more thorough application of systems thinking is still somewhat rare (see, e.g., Nemecskeri et al., 2008; Jackson, 2009; Green et al., 2010).

Approaches involving intended beneficiaries in systems thinking, applied since the 1970s, have over recent years evolved into, among others, group model building (Vennix, 1996) and mediated modelling (van den Belt, 2004). While providing structured platforms for participation and active engagement of inter-organisational stakeholder groups in policy and decision-making processes, these methods foster co-production of knowledge and group learning as outcomes of the modelling process (Videira et al., 2009), as well as development of critical thinking skills. In recent years, participatory systems thinking methods have been increasingly used in the context of public policy making on natural resources (e.g. Stave, 2002 and 2003; Hare et al., 2003; FLUF, 2010; van den Belt et al., 2010).

Causal loop diagrams (CLDs), based on principles of system dynamics and cybernetics, are probably the most-utilised systems visualisation and communication tool. Two widely recognised uses of CLDs are the transformation of verbal descriptions into feedback structure during early stages of model conceptualisation (Goodman, 1974) and the presentation of a 'distilled' understanding at the end of the whole modelling process (Morecroft, 1982). Lane (2008) provided a critical account of the advantages and limitations of diagramming methods wherein the implications of these usage modes were extensively discussed. We are testing the use of CLDs for the purposes of co-production of knowledge and group learning. Building on Richmond (1993) and Videira et al. (2009) as well as on the conception of CLDs as boundary objects in knowledge management (Star and Griesemer, 1989; Cash et al., 2003), we aim to (i) expand the participants' boundaries of thinking by enabling exploration and exchange of knowledge and paradigmatic and value positions accepted in various communities, (ii) and in the process transform perceptions and mental models of individuals and groups into a shared causal and feedback structure.

We have organised a number of thematic events in a workshop format in which participants representing different communities engaged with CLDs. Seven events were devoted to topics of sustainable consumption (food consumption, mobility, housing, information and communication

technology (ICT) and household finance and debts). Overall more than 250 participants took part in these events. To facilitate their engagement with CLDs we developed a method of 'participatory systems mapping' (PSM) that builds on participatory modelling approaches and applications (see Richardson and Andersen, 1995, Vennix et al., 1992; van den Belt, 2004; Videira et al., 2009). Application of PSM can best be described as preparation and execution of a facilitated group process of development of causal loop diagrams to provide insights into a particular problematic issue and enable knowledge exchange. In the seven mentioned events we have tested the method in more than 20 sessions in group sizes of 8 to 18 participants (excluding the facilitator) and with common moderation scripts and material (the CLDs are constructed 'physically').

By design, systems thinking and system dynamics are problem-led approaches and don't work well when the purpose is a general intention to 'model the system'. Systems mapping needs to be focused on a particular problem issue, otherwise the lack of even implicit system boundaries can paralyse the process. Although an issue reflecting the group's interests can be defined in the beginning of a PSM session, we have chosen to formulate a set of problem issues in cooperation with experts for each consumption area prior to the workshops[2] in order to help moderators prepare and to ensure that several criteria are fulfilled[3]. We identified two starting variables (the primary cause and the primary effect) for each issue, thus providing an implicit system boundary as well as a general causal direction.[4] For each issue we formulated a guiding question to give the mapping a diagnostic and exploratory direction (i.e. aiming to explain the dynamics of the problems in their current contexts as opposed to envisioning interventions or future systems). The guiding question also helps to manage the system boundary during the process and judge whether existing structures explain the issue sufficiently or new elements are needed.

Although to some extent the actual PSM sessions tended to be somewhat messy and improvisational to adapt to participants' concerns and inputs, pre-defined scripts were followed in the

[2] Some of the dilemmas of issue and stakeholder identification have been summed up by Prell et al. (2007, p. 6) in the following way: "If the issues are defined without consulting stakeholders, then the issues may not be relevant to their needs and priorities; and yet, the issue must be defined before it is possible to identify those who hold a stake in it."

[3] I.e. linking sustainable consumption with macroeconomic (growth-related) concerns, the potential to lead to unexpected insights, and viability for participatory mapping (e.g. having an appropriate level of abstraction and complexity).

[4] It is also possible to start with a single effect variable as a starting point (as was the obesity variable in Vandenbroeck et al. 2007), or with simpler system structures.

sessions (each 2-day event contained two 90' PSM sessions). As with building of computer simulation models, development of a system map is an iterative process in which participatory input at the events (to open up and explore the issue) alternates with expert input outside of the events (to narrow down and focus the issue). These phases have also distinct logics. The participatory phases need to be geared both towards the process (an open and creative atmosphere supporting group interaction and knowledge exchange in real-time) as well as the outcome. Even though the experts involved in these different phases might be the same persons (policy makers and researchers from different communities), the nature and purpose of the work is different. Experts work diachronously and aim to improve the usefulness of CLDs, as due to the organic nature of participatory processes, CLDs resulting from PSM sessions typically contain inconsistencies, duplicities and under-developed system structures that are addressed in an expert input phase (with all respect for the original interests and concerns of the participants).

Causal loop diagrams are expressed in a formal language originating in system dynamics (Forrester, 1968, 1969) and cybernetics (Wiener, 1948; Ashby, 1956; Bateson, 1972). They depict causal relations between selected variables, focusing on positive and negative feedback loops and development trends. The CLD syntax implies some epistemological and theoretical positions. We understand systems as purposive and transcending the subject/object boundary by connecting relevant elements of individuals, social systems and the natural environment through pathways and feedback loops (see also the 'theory of the mind' by Bateson, 1972). Since it is the system that has a purpose (or function, in the case of non-human systems), systems thinking thus typically does not concern itself with the question of agency. Actors are thus 'hidden' in the assumptions or are present as social planners designing an intervention in the system. Furthermore, institutions (rules, norms etc.) are also rarely explicitly present; they, however, are the 'social infrastructure' enabling the depicted causal connections. Both actors and institutions can nevertheless be endogenised. This highlights the issue of boundaries. In relation to the context of participation and knowledge brokerage, we respect Churchman's (1970) understanding of boundaries as "social or personal constructs that define the limits of the knowledge that is to be taken as pertinent in an analysis", acknowledging that "[w]here exactly boundaries are constructed, and what the values are that guide the construction, will determine

how issues are seen and what actions will be taken" (Midgley, 2000: 35–36). Participatory design is also supposed to address the valid concern of Dryzek (2005) of a technocratic elite of systems thinkers dictating societal solutions based on inaccessible computer models. PSM serves to provide an explicit picture of how participants see the system, uncovering the richness of perspectives represented in the group, and empower them to think of and deliberate on viable solutions. Systems continually evolve and change their structures even without exogenous causes, and sometimes they collapse and are reorganised radically (see, e.g., the adaptive cycle; Holling, 2001). Therefore we understand CLDs as 'snapshots' of systems at certain points in time and stable only in a given timeframe. Still, speed (in the sense of propagation of change) is implicitly present in the system's causal relationships, as well as the length of its time delays.

The most important elements of CLDs are variables, which are relevant for explaining the behaviour of the system, and their interdependencies represented by arrows. Relationships are causal and exist between two variables. They are either positive (drawn as arrows tagged with a plus sign) or negative (for higher visibility as dashed arrows, with a minus sign).[5] Longer time delays between changes in the cause and effect variables are depicted by marking the arrow with a double slash sign. Central to CLDs are feedback loops (circular causalities linking a chain of variables) which are either reinforcing (i.e. positive, leading to exponential growth or exponential decay, marked by a plus sign or the letter R) or balancing (negative, leading towards an equilibrium or goal value, marked by a minus sign or the letter B). Small clusters of reinforcing and balancing feedback loops in certain arrangements are often referred to as the 'engines of the system'; the most-widely occurring patterns have been catalogued as 'system archetypes' (Senge, 1990).

[5] A positive causal relationship between cause X and effect Y means that an increase in X will lead to an increase in Y above what it would otherwise have been (assuming all other variables remain constant) and, conversely, a decrease in X will lead to a decrease in Y below what it would otherwise have been. A negative causal relationship is inverse, i.e. an increase in X will lead to a decrease in Y below what it would otherwise have been and a decrease in X will lead to an increase in Y above what it would otherwise have been. (For the discussion on the reading of causal relationships see, e.g., Richardson, 1997; Sterman, 2000; Lane, 2008.)

4 Achieving different types of insight with CLDs: a discussion

In this section we first present our observations and process-related experience related to a PSM session's length, size and composition of the group, and facilitation style. A viable duration of a PSM session seems to be between 80 and 120 minutes. With less time the chance of producing a useful result as well as 'spotlight time' per participant decreases and the risk of dissatisfaction grows. We have pre-tested longer sessions on a few occasions and we observed that due to concentration demand they lead to fatigue. Accordingly, we incorporated two 90' sessions in a 2-day event, one in every day.

It would seem that larger group sizes enable a higher plurality of perspectives and potentially provide more opportunity for knowledge exchange and learning. Nevertheless, they also limit the available time per participant and make consensus (to a large extent necessary) harder to achieve. An ideal balance seems to lie at about 10–12 participants. The more homogeneous the group is in respect to the communities and discourses its participants represent, the bigger can the group be. Our experience seems to indicate that higher homogeneity of the group correlates with a higher pace of the map's development as a lower number of controversial issues are tackled in the process so such a map may be richer in detail but poorer in terms of the diversity of underlying paradigms.

A 'tight' facilitation style seems to be the most productive, in particular towards the beginning of the exercise. By this we mean that the input by the participants is channelled into the map through the facilitator who retains a lot of control over the process: he/she focuses the attention of all participants on the argument currently discussed, helps to translate arguments into CLD syntax, reminds participants of the guiding question, helps participants to explicitly address boundaries and challenges participants' mental models.

4.1 Insights produced in PSM sessions

To highlight the possibilities offered by PSM in further text we will use a map from the sustainable mobility area (Figure 1) after two iterations of expert and participatory input. The objective was to map the issue "How does road construction influence transport volume and modal split (in European

cities)?"[6]. To enable a broad perspective and manageable size, the map is more abstract than typical urban development and transport planning models. As any model, a CLD is a necessary simplification of reality placing a focus on specific issues – in this case, the 'pull' between public transport and passenger car use (played out in the central variable of the 'rate of switching from cars to public transport') as well as a range of mental models and possible strategies. Reflecting participants' understanding of significance (see boundaries, above), some aspects were not explicitly included in the map (e.g. population size that was considered more or less constant, different models of urban development, economic aspects of location attractiveness, freight transport, or detailed treatment of speeds of change). Many of the causal relationships are simplified to reflect specific assumptions (e.g. the relationships between budget and public transport contain assumptions about quality or ticket prices) and all variables have been endogenised[7]. Let us have a look at the insights produced by particular ways of looking at this CLD.

[6] During the process of PSM, the guiding question was operationalised in ways that led to the production of the CLD depicted in Figure 1: Modal split was 'translated' into passenger car use and public transport use (not explicitly covering, e.g., bike use or pedestrian mobility). Road construction is represented by the variable road capacity.

[7] Variables don't all have to be endogenous, as in this map. In a CLD there can be external influences that, for the purpose of the given exercise, are not considered to be influenced by changes in any of the other variables – i.e. variables that only have outgoing arrows.

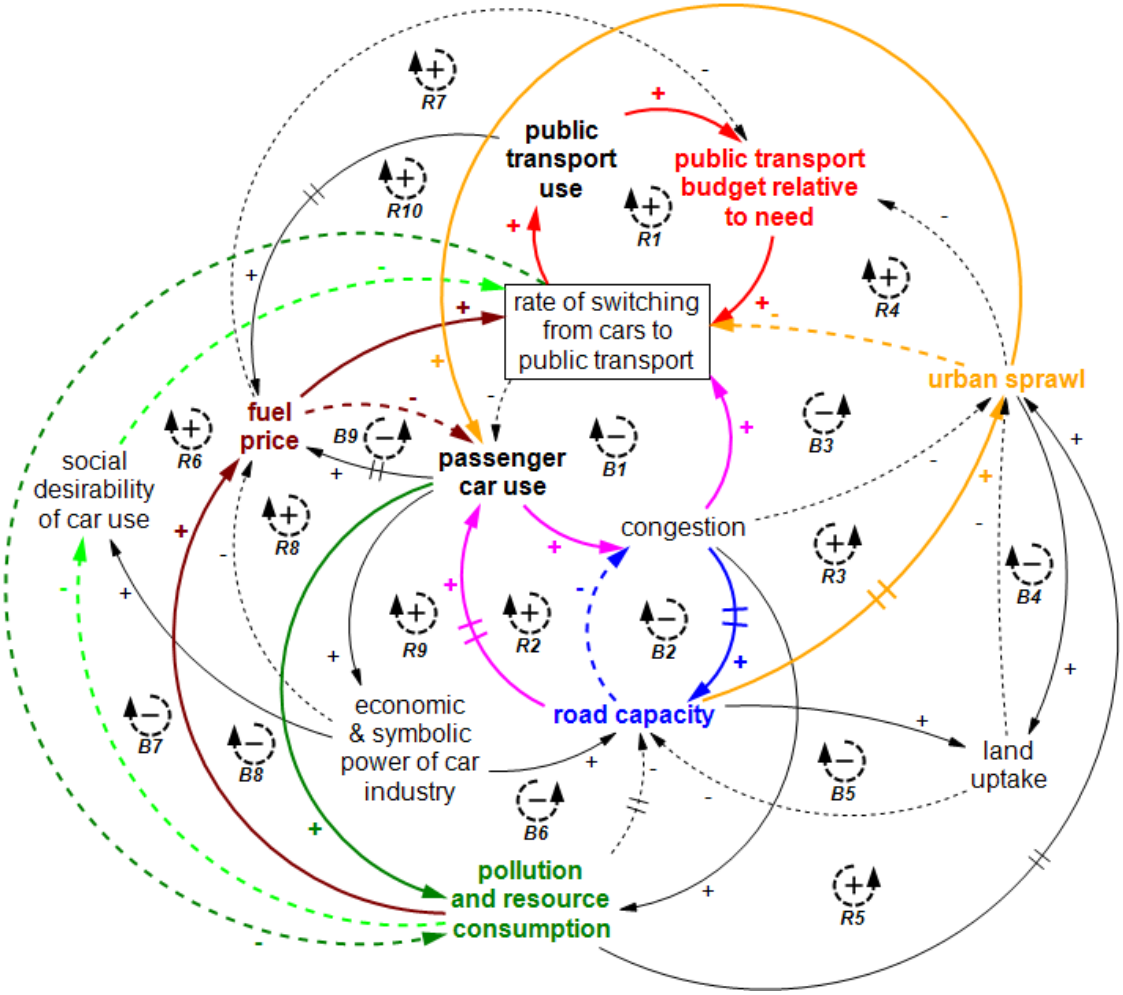

Figure 1. Public transport use vs. passenger car use map

Closed-loop thinking is a way to think about interrelationships between feedback loops that helps to understand and infer behaviour of systems over time. Even though inferring system behaviour is not reliable without a simulation, our experience shows that CLDs invited discussion on the relative strength of individual feedback loops and development trends. As an example, the participants theorised whether (and why) the loops that increase passenger car use are together more 'powerful' than the loops that function as limiting factors combined. When this resulting 'pull' of passenger car use is stronger than of public transport use, the rate of switching from cars to public transport is negative (i.e. users switch from public transport to passenger cars). The dynamics increasing car use involves the following loops: B2 (willingness to expand existing road capacity as a means of combating congestion; B2 is thus part of the answer to the original question "How does road construction influence transport volume and modal split?"), R2 (induced car transport as a result of

higher road capacity), R3 (higher urban sprawl, occurring due to better accessibility through higher road capacity, resulting in higher transport demand satisfied by car use), R4 (negative effect of larger service area on public transport budgets relative to need, resulting in lower quality of public transport than it would otherwise have been), R5 (increasing suburbanisation as location choice is motivated by the search for higher quality of life away from local environmental pollution caused by transport), R6 (social desirability of car use), R7 (negative effect of rising fuel prices on public transport budgets), R8 (power of car industry maintaining fuel taxes and prices lower than they would otherwise have been), and R9 (influence of car industry on urban planning). The loops that limit car use growth are: R1 (quality and attractiveness of public transport), B1 (prolonging of car travel times in congestion and incentive to switch to public transport, provided public transport travel times are not affected, e.g. in preferential bus lanes or suburban trains), B3 (the effects of congestion and limited time budgets for travel on increasing attractiveness of a high-density lifestyle resulting in urban sprawl being lower than it would otherwise have been), B4 and B5 (limited availability of land for road and housing construction), B6 (effects of environmental awareness on urban planning), B7 (effects of environmental awareness[8] on transport mode choices) and B8 (effects of increasing fuel prices, resulting from resource depletion or higher taxes, on car use).

An analysis conducted with the participants of the PSM sessions on mobility explored some of the implications of this structure. The surface size of the city would continue to grow unless land availability limits are hit or until pollution and resource consumption become so high that they have powerful effects on decision making and fuel prices. Part of the wickedness of the problem is that some of the negative side effects of increasing car use can contribute to continuing car use growth: (i) an increase in congestion can be combated by extending road capacity, thereby inducing more transport and again increasing congestion; (ii) an increase in local pollution will result in more urban sprawl than what would otherwise have occurred, putting strain on public transport budgets and contributing to increasing car use; (iii) through higher fuel prices, consumption of non-renewable resources affects also public transport budgets, possibly making public transport less attractive in comparison to car use; and (iv) if public transport speed is affected by congestion, this decreases its

[8] Environmental awareness is not an explicit variable but understood as a component of social desirability of car use.

attractiveness. Decreasing relative environmental impacts of car use (e.g. making car engines more efficient) could actually contribute to continuing growth of the scale of the problem, as some limiting loops would become weaker (B6, B7 and B8). The insights generated by closed-loop thinking would include better understanding of the structural causes for observed behaviours of the system and its unintended consequences and potential leverage points.

Another option that worked was examining in more detail variables critical for the structure of the system (in Figure 1 that would be e.g. urban sprawl, rate of switching from cars to public transport, passenger car use, road capacity or rate of pollution and resource consumption). Focusing on *factors of influence*, i.e. the causes of a particular variable (see Figure 2), facilitated a discussion about interrelationships between influencing factors: Are the depicted causal factors sufficient to explain the behaviour of the variable? Are factors complementary (i.e. a multiplicative relationship) or substitutive (an additive relationship)? What are the trade-offs between factors? Are some factors conditional or inhibitive to other factors' effects? Is the effect of a factor dependent on an additional factor? Insights generated through such a discussion include implied relationships between factors of influence and necessary conditions of influence. This way of engaging with CLDs furthermore helped to identify knowledge gaps by turning attention to the scientific evidence for particular causal relationships.

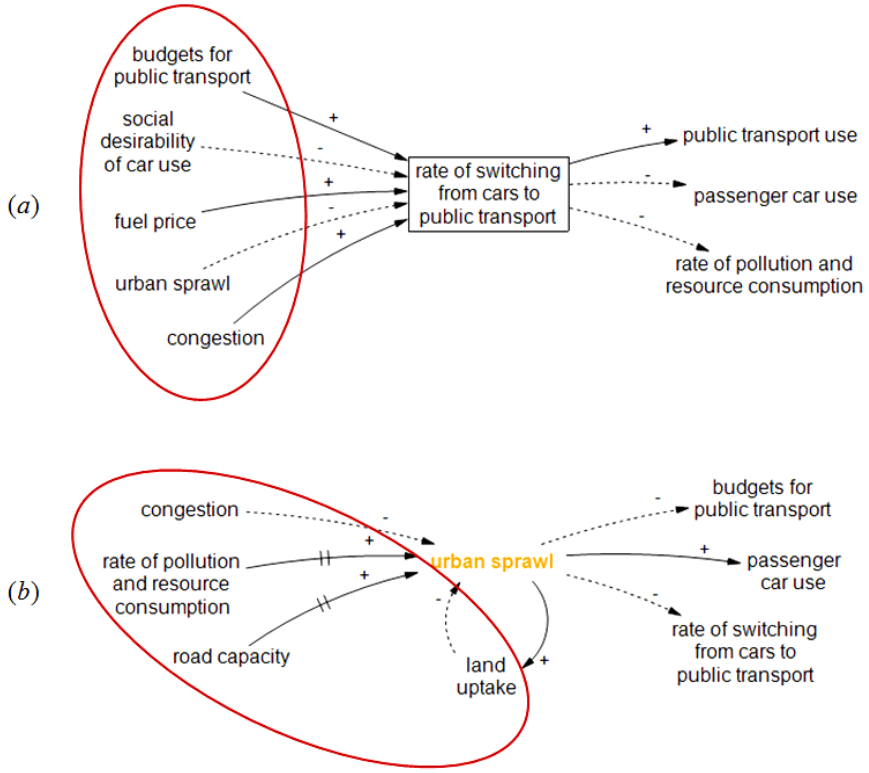

Figure 2. Rate of switching from cars to public transport (*a*) and urban sprawl (*b*) in focus

Another way of engaging with a CLD that we have tried out is exploration of different *mental models or strategies* that frame the problem in a particular way and thus make some solutions more attractive than others. In general it seems that different actors have different mental models of an issue (i.e. a different understanding of the causal structure of the system). On the basis of discussions with and validation by participants we identified several colour-coded mental models framing negative effects of growing car use in Figure 1.

- Blue represents a conventional 'more is better' approach framing the problem as a problem of congestion. A sensible solution would be building new roads and widening existing ones (B2). This strategy could even be justified on environmental grounds, as less congestion results in smoother traffic and lower fuel consumption per car.
- Magenta mental model includes the longer-term risks of induced transport (R2) and thus frames the problem as that of car use rather than congestion. An attractive solution is to reduce road capacity (e.g. decreasing the number of lanes), thereby increasing travel times and

disincentivising car use. (Incidentally, the same leverage point as in the blue mental model is manipulated, but in opposite direction.)

- Red mental model frames the problem as low public transport use and thus aims to strengthen the 'pull' of the public transport loop (R1). Logically budgets for public transport need to be increased in order to make public transport more available and attractive. It is expected that more people would then prefer public transport than otherwise, resulting also in an increase in ticket revenue that more than covers the costs.
- Dark green colour represents the 'ecological modernisation' mental model that frames the problem in terms of the link between car use and environmental pollution. Thus environmental impacts of car use should be decreased (by a technological solution aimed at increasing fuel efficiency of cars or decreasing their noisiness) and the reinforcing loop R5 weakened (i.e. less people would move into suburbia than otherwise). This strategy however inhibits the balancing function of loops B6, B7 and B8. Also, unless supported by other measures, this approach does not address the scale of the problem.
- Lime green frames the problem in terms of the symbols and values tied to the car and other modes of transport. A sensible intervention point seems to be to increase environmental awareness (i.e. affecting the link between environmental pollution/resource consumption and social desirability of car use) and expect individual consumers to make value-motivated transport choices that result in less car use (B7).
- Similarly to the magenta mental model, brown frames the problem in terms of the volume of car use, however pursuing internalisation of environmental externalities into fuel price. Besides a direct positive effect on transport mode choices (R8) it also negatively affects the adequateness of public transport budgets to the extent to which they are dependent on the regulated fuel (R7).
- The orange/gold mental model frames the problem is terms of the volume of car transport and transport choices made in favour of the car being dependent on urban sprawl. The preferred solution is to control urban sprawl by increasing concentration and densification of the city. In a more compact city the facilities, culture, leisure and jobs are more accessible. In

combination with other measures, such as limiting road capacity, this motivates people to prefer public transport and can also have positive effects on public transport budgets.

Focusing on mental models helped us and the participants understand that different worldviews might lead to different solutions and that expanding a mental model might be helpful for reframing the problem. This approach also tended to produce a 'bigger picture' integrating different perspectives and placing them into broader perspectives of actors and discourses, and enabled a discussion aiming towards comparison of various solutions, their mutual resistance or need for their combination (policy mixes).

The fourth fruitful way of interacting with CLDs is examining *connections between several problem issues*. It has been suggested that 'distilled' depictions of the system structure underpinning particular issues can be linked in the manner of 'cascaded archetypes' (Wolstenholme, 2004: 350), illustrating how unintended consequences of one issue can become drivers in the next. Such a linking has remained a rarely-addressed 'major research challenge for system dynamics' (ibid.). Figure 3 shows how separate dynamics – that of urban sprawl and regional food production – can act as mutual limits, balancing each other out and mutually preventing growth in scale. These two issues are connected through demand for land and conflicts over its use. Pressure on land use result from increases in geographical dispersion of settlements through road construction, as well as take up of land through a shift towards regional food production (it could even be theorised that most policy instruments redistribute public space). This structure also explains some sources of policy resistance, as the stronger the policy goals, the more pressure would there be on conflicts over land use, and the more resistance from the other loop. It also defies a simple solution. Should, for example, the productivity of regional food production rise significantly, it would much less contribute to an increase in conflicts over use of land. The result could be growth in road construction and urban sprawl until they meet another 'layer of limits' (Meadows, 2008).

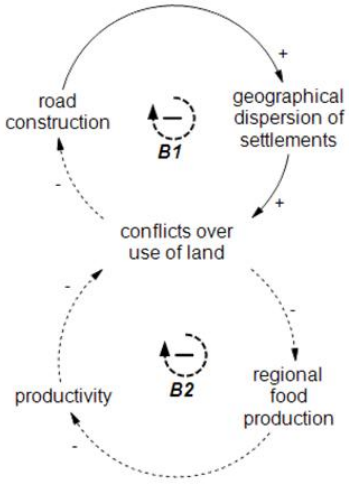

Figure 3. A possible connection between two problem issues in different sustainable consumption areas

Another way to link issues is a cascade where change in one problem issue causes changes in the same direction in other issues. For example, policies aiming to decrease meat consumption could, provided they overcome policy resistance, over time contribute to the popularity of lifestyles of health and sustainability (LOHAS), which encompass more dimensions than just meat consumption. Increasing popularity of LOHAS could therefore plausibly result in an increase of preference for regional and seasonal diet or in an increase of public transport use to a level higher than it would otherwise have been, thereby potentially contributing to an improvement in the problem of car use. This dynamics has been described in literature as behavioural spillover effect (Thøgersen and Ölander 2003).

Examining connections between problem issues helps expand boundaries of thinking and produce insights on a higher level of system organisation: the ways how issues are interlocked, causes of policy resistance and the need for coordination.

5 Conclusions

In this paper we followed two objectives. The first was to describe our usage of the method of participatory systems mapping (PSM) in several events with knowledge brokerage as their aim. The second was to discuss several types of interacting with causal loop diagrams (CLDs) and production of

different insights on issues related to sustainable consumption, i.e. the rationale for that usage. Based on our experience with PSM we suggest that *causal loop thinking* helps explore structural causes for the observed trends as well as infer unintended consequences and identify potential leverage points. Focusing on *factors of influence* turns the attention of the participants on the assumptions behind depicted causal linkages, validity of representation and knowledge gaps. Exploring *mental models or strategies* places various problem framings in the centre of attention and helps linking them to existing actors and discourses. Lastly, examining *connections between several problem issues* expands the boundaries of the issue under analysis and helps identify interactions between various problems and their solutions. Our experience suggests that by producing these insights CLDs serve as a very useful tool for participatory reflection and sharing of knowledge (while not necessarily generating new knowledge) on issues related to sustainable consumption, and thus help 'manage the contradictions of sustainable consumption and economic growth' in serving as a tool for coping with complexity.

The method of PSM is not neutral and poses a number of challenges. Participants typically note that re-articulation of their mental models into the CLD syntax – though helpful for increasing intelligibility across different problem framings and uncovering hidden assumptions – highlights some aspects while pushing other into the background. CLDs not only support but also constrain in that they make formulation of some types of arguments and referring to them more difficult. This concerns in particular arguments exploring the overall consistency of assumptions lying behind individual mental models (or their elements). Working with CLDs seems to be theory free and giddily creative but every word and every arrow hides unexpected depth. It is actually not possible to create a CLD without at least some, though perhaps implicit, theory of how things work – or, more specifically, without an ontology. The less precise the underlying ontology, the more unwieldy the CLD will prove to be in further use and the more definitional problems will arise. It would seem that some inherent barriers to linking mental models that rest in different paradigms within one CLD do exist. In systems thinking debates this issue comes up rarely and needs to be addressed by future research.

Even though the policy participants usually at first did not object to non-individualistic framings, further interaction has shown that treating individuals as less autonomous runs counter to their mental models reflecting the dominant discursive and institutional structures of our political and

economic systems – and thus later comes up as problematic. A prolonged and patient interaction with CLDs in participatory contexts helps uncover ontological differences that would remain hidden otherwise. This fifth type of insight concerning mental models' deepest level is perhaps the most effective in the long run.

As a contribution to the discussion on systems thinking approaches to studying sustainable consumption we suggest that the usefulness of CLDs rests on their ability to elicit and then connect mental models of the participants in the room through structured discussion (bridging boundaries between various communities) and on the plurality of produced insights. We hold that reflecting upon and expanding mental models upon which policy solutions are based can contribute to the prevention of unintended and delayed side effects which are the main threat to sustainability (Sterman 2000). Our project is to be seen in the context of a growing stream of studies, initiatives and exercises that might collectively contribute to change of policy in line with a more systemic understanding of sustainable consumption.

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