The shadowy side of innovation: unmaking and sustainability

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In the introduction to *System Innovation and the Transition to Sustainability* (2004), Boelie Elzen, Frank Geels and Ken Green contend that effective responses to problems of climate change and sustainability require innovations capable of producing major transitions in systems like those of energy or transportation. The papers assembled in that collection address the intellectual and policy challenges this presents, and in the process advance knowledge of system innovations and of the potential for steering them in a more sustainable direction.

The tantalising prospect of deliberately cultivating pockets or 'niches' of novelty and of seeding radical transitions that displace or dislodge unsustainable trajectories of production or consumption is ever present. As Elzen et al. explain capturing and exploiting this potential depends on better understanding systemic change, and in particular figuring out how environmental technologies might be adopted and embedded. In this volume and in other writing since, the method of blending innovation studies together with histories of technology has resulted in a wealth of conceptual models useful in describing and hopefully influencing transitions on the scale required. It has also generated important debate about what it means to govern emergent and inherently uncertain processes, and about the sorts of policy tools involved.

All of this is consistent with the forward looking orientation of environmental policy and with the traditions of innovation studies on which much of this literature builds. The conceptual and empirical emphasis on novelty is not at all surprising but in returning to this work I am struck by a series of intriguing and potentially important omissions. In concentrating on the conditions and circumstances in which *new* sociotechnical arrangements might arise, and on methods of stimulating and facilitating the 'breakthrough' of environmental technology, contributors tend to overlook the routes and pathways through which existing regimes disappear. In this paper I argue that the dynamic relation between incoming, outgoing and returning systems deserves more explicit attention, and that this is particularly important in relation to matters of sustainability. It is so on two main counts.

1. promoting disappearance

First, transitions towards a significantly lower carbon society will almost certainly require the downfall of established sociotechnical regimes. While this is so, the steps and stages through which such systems fall apart are rarely discussed. Instead, these processes are assumed to be the flip side of innovation: as new technologies take hold, so old ones are displaced. This way of thinking, which is extremely widespread, is routinely supported by graphs and figures representing changes in "market share" – for example, showing how cars replace horses and carts, or how steam ships take the place of those with sails (Geels and Schot 2007: 410). Of course there are situations in which individual technologies or products do substitute, one for another. But if we take a step back and attend to the transformation of sociotechnical regimes, processes of emergence and disappearance do not always coincide, nor are they always different sides of the same coin. Accordingly, one task is to think a bit more about pathways not only of innovation but also of decay and dissolution.

2. resurrecting the past

Second, innovation for sustainability may well involve moving towards a future in which certain aspects of old but less damaging ways of life are re-adopted in place of newer but more polluting, more resource intensive variants. The image of going backwards is not particularly appealing given the powerful political discourse of progress, and it is true there may be totally new ways of organising societies such that they fit within an envelope of sustainability. On the other hand, distinctly unsustainable ways of life are a relatively recent phenomenon. As a consequence, history is replete with models and examples of sociotechnical regimes and landscapes all of which were much less demanding in terms of energy, water and other natural resources than those of today.

It is probably not possible to recreate the conditions that pertained when western societies routinely consumed and produced within the limits of what 'one planet' could sustain. Nor is this – at a grand scale – a vision towards which governments or environmental NGOs generally aspire. For various reasons going back is not officially on the cards. And yet many of the practical steps people are advised to take to reduce the size of their carbon footprint entail some kind of 'return'. Amongst others, such suggestions include using the bicycle and not the car, recycling waste, buying organic food and eating what amounts to a diet from the past. The result is a curious situation in which the substance of sustainable action has this backward looking quality and yet intellectual priorities and policy agendas concentrate on the introduction and promotion of new technologies and associated ways of life.

The transitions literature shares this orientation. For example, in his contribution to the 2004 collection, Belz represents organic agriculture in Switzerland as the result of an innovation process that 'started' in selected niches in the 1990s and proceeded through a series of phases including those of 'breakthrough' and 'regime transformation' (Belz 2004). If we take a longer term view, organic methods of production clearly predate the industrialized regime that supplanted them, and in relation to which they now seem to be regaining ground. This is not just a matter of choosing one time frame or another (Genus and Coles 2008). Although that is important for determining whether organic farming is defined as new or not, the more interesting issue has to do with how the story of change is framed. The meaning and practice of organic farming in, say, 1810 is not at all the same as in 2010, but that does not mean that the contemporary version is entirely 'new'. In presenting the recent emergence of organic agriculture as a tale of innovation and not as a narrative in which its status switches between an established, a displaced and now a novel form, Belz underestimates potentially relevant threads of continuity. This is not unusual, but it is limiting particularly given the importance of past configurations for the development of a more sustainable society. This is a topic to which I return but for the time being it is enough to make the point that theories of innovation and especially of substitution tend to obscure ongoing relations between 'new' and 'old' regimes and what these relations mean for the possibility, or otherwise, of reinvention or partial renewal.

In drawing attention to trajectories of disappearance and to changing relations between co-existing systems, I find myself thinking again about concepts of path-dependence and in particular about the fate of the dead ends, and of the paths not taken when regimes like those of 'conventional' agriculture or automobility gather momentum. What if events had taken a different turn? For example, what habits and patterns of mobility might now exist if the first few cars had rolled off the production line just a few years ago, and if there had therefore been more than a century of investment in cycle and rail infrastructure? Equally, what if it the invention of the bicycle had come many years after and not before that of the car? Such speculative games are not to be taken too

seriously, yet they are useful in reminding us that at one moment we confront a range of regimes that co-exist in space and time but that are caught at very different moments in their respective careers: some being on the way in, some on the way out, and some, on the way back in, but in renewed form. Thinking about paths not taken also jolts us into remembering that we live alongside the partial remains of sociotechnical arrangements that were once important but that have since been eclipsed or bypassed. In terms of transportation these might include coaching inns, canal networks and pilgrim's ways. These remnants are the traces of (sometimes much more sustainable) trajectories that have not developed further but that might yet become critical elements or resources in the future.

I don't want to push the argument too far, but if sustainability is not to be achieved by some new technical fix lying just around the corner, it may be important and perhaps necessary to explore ways of conceptualising co-evolution in reverse gear, and to think about means of moving towards less resource intensive arrangements that resemble those of the past. The chances of developing policies that send society back to some sustainably 'golden' but comparatively frugal era are slim and in any case there really are institutional and infrastructural points of no return. That said, there is still merit in turning the preoccupation with innovation around in order to focus on a) how previously or currently more sustainable arrangements disappear, and b) how unsustainable configurations might be undermined. This is not just a question of semantic switching or of swapping the terminology of innovation for one of dissolution and decay. As I hope to show, the project of understanding how systems break down is of value in its own right. Amongst other things, such an exercise draws attention to the manner in which new and old regimes co-exist. It also suggests that the remnants of paths not taken can be surprisingly important.

In the next part of the paper I begin to explore the 'undersides' of innovation, first thinking about ways of conceptualising trajectories of decline and then considering examples of partial disappearance and resurrection. I do so with reference to the rise and fall of cycling as a normal means of transport.

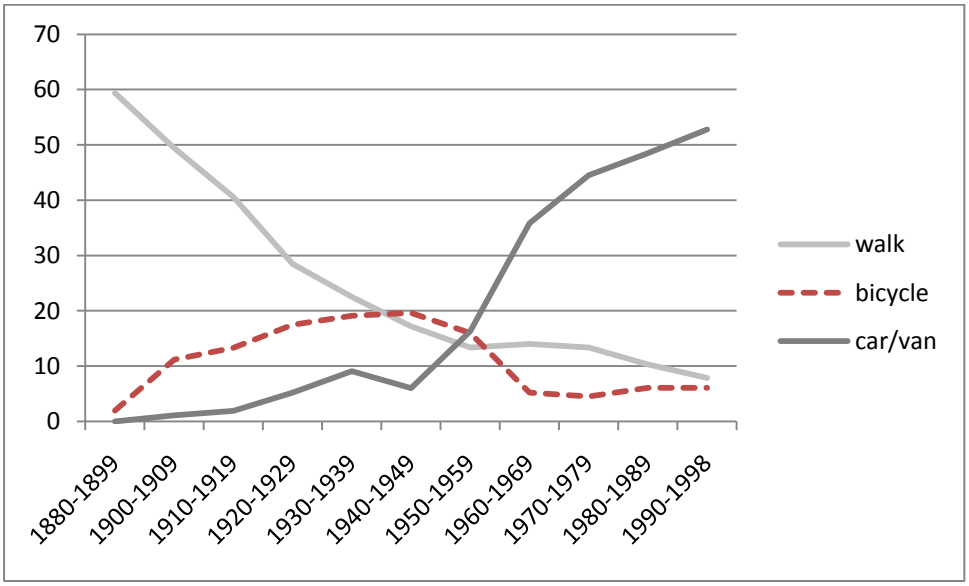
Conceptualising trajectories of decline

Cycling is now widely recognised as a practice that is thoroughly good for the environment and for personal health - Sustrans claims that 2kg of carbon are saved for every short journey made by bike (Sustrans 2008). It is also a means of transport that used to be very much more widespread than it is today. According to the Times online, "in 1949 in the UK, 34 per cent of all mechanised journeys were made by bicycle. Fifty years later that figure had fallen to 2 per cent" (Times 2008). By any standards this is a spectacular decline, representing a rapid and radical movement *away* from what was a distinctly low carbon sociotechnical configuration. Over the last half century what seemed to be established routines of riding; infrastructures of provision, storage and repair; conventions of commuting; understandings of time and distance and related forms of competence have all but disappeared. This, then, is a case in which policy makers bent on sustainability confront the challenge of *reinventing* and *reinstating* a regime that existed not so long ago, and that did so without fuss or fanfare, and without very much investment in persuasion, education or (in the UK) dedicated infrastructure.

The struggles involved in reversing decline and in resurrecting the past are instructive, revealing and frustrating. In the 1940s levels of cycling far exceeded the targets the UK government set for itself in the National Cycling Strategy published in 1996. The National Strategy aimed to double levels of cycling by 2002 and quadruple them by 2012 - had that goal been met the level of cycling in 2012 would still have been less than a third of that which was normal between the 1930s and 1950s. As it happens, the 1996 targets were not met and have since been abandoned on the grounds that there is simply no prospect of achieving them. This is so despite the fact that "23% of car trips are less than 2 miles, a distance that is easily cycled in less than 15 minutes" and that bike ownership is increasing "The National Travel Survey ... produced by the Department for Transport (DfT) shows that the percentage of households owning at least one cycle has risen from 36% in 1989/91 to 47% in 2002/2003."(Cyclists Touring Club: 1).

There are many ways of calculating the amount of cycling that goes on but whatever figure we take, the story is more or less the same. According to the UK Cabinet Office, "Cycling levels have shown long-term decline since the 50s. Between 1952 and 1970 annual distance cycled fell from 23 billion kilometres (13% modal share) to 5 billion kilometres (1% modal share)."(Cabinet office strategy unit 2009: 15). Life history data collected by Pooley and Turnbull provides a longer term view of how journeys to work have changed from 1890 to 1998, the overall picture being one in which cycle commuting increased from 1880 to the mid 1930s when "approximately one fifth of men cycled to work, and around one tenth of women."(Pooley and Turnbull 2000: 19) – and then declined.

Figure 1. Changes in the journey to work 1880-1998 (based on Pooley and Turnbull 2000: 15)



This figure is based on details of 12,439 journeys to work taken from 1834 life histories. Sample size for walk: 2083; for bicycle 1379, for car/van 3108.

While these trends might be a bit depressing from an environmental point of view they are easy enough to understand. In terms of innovation theory the explanation is simple: cycling displaces walking and the arrival of the car then squeezes cycling and walking out of the frame. For the bicycle and later for the car, processes of transition map neatly on to the models proposed by those who study the phases of sociotechnical change (Geels 2002). In both cases, first appearance is

followed by a second period in which expertise develops, networks of committed enthusiasts are established and rules (of use, technological design etc.) are stabilised. This creates the conditions for a third phase of wider diffusion or breakthrough, leading to the 'gradual replacement' of the established regime. As Geels explains, it is through sequences of this kind that 'the new technology replaces the old' (Geels 2004: 42).

In the decade between 1950 and 1960 many cycle-commuters put their bikes away and hung up their cycle clips forever. Some no doubt did so in an instant: the day they got the car was indeed the day the bike was relegated to the shed. But if we zoom back a bit and change scale, the erosion of the entire cycling regime is surely more subtle, more prolonged and in many respects less definitive.

Geels agrees that replacement is likely to be a gradual process, but I wonder whether the concept of replacement captures the reconfiguration of *both* driving and cycling as the relative dominance of one changes in relation to the other. As is well recognised, innovation journeys are themselves transformative: the image, the practicalities and the practice of driving a car evolve as the trajectory of automobility unfolds, as driving becomes 'normal' and as cars and cities are re-designed. But what when the direction is reversed? It is tempting to think that cycling simply went into decline. But are there not also 'steps and stages' of relative disappearance – parallel thresholds, that signal the breakdown (not the break through) of cycle-commuting, that herald its new status not as a mass pursuit but as the practice of a few; and that mark its arrival as a strange and not a normal thing to do?

To go further it would be necessary to set the terminology of replacement and substitution aside and concentrate instead on how cycling and driving are positioned one in relation to the other, as their trajectories develop and decline.

Figure 2 provides a very crude sketch of what this might involve. At point A (1959 or thereabouts) car driving (the dotted line) is moving out of a 'niche' initially dominated by the elite and associated with leisure and is entering the 'mass' market. Meanwhile cycling (the solid line) is heading in the opposite direction, rapidly losing its status as a form of transport for the masses. As the decline continues, bicycles are increasingly associated with leisure, and increasingly ridden by men. By point B, the relation between cycling and driving is completely reversed.

The transition between leisure and functionality is intriguing in that it connects to what might be a more general pattern. In explaining how the 'need' for everyday technologies was invented, Pantzar describes a number of examples in which novel devices, initially viewed as 'toys' (for example, mobile phones), were redefined as normal and necessary 'tools' as they became embedded in society and as their 'purpose' was established (Pantzar 2003). The trajectory of cycling in the UK suggests that on occasion this route might also work in reverse: having been disassociated from ordinary commuting and daily use, bicycles have been reassociated with more specialist forms of sport and leisure. As Lumsdon and Tolley notice, "In contrast to everyday use, the General Household Survey reports steady increases in the number of people cycling for recreation since the mid-1980s (DETR, 1999): it appears that many Britons now see cycling as a healthy recreation activity rather than as a useful everyday mode of transport." (Lumsdon and Tolley 2001: 293).

Who knows what will happen as we head into the grey zone of the future (on the right of diagram). Will the remaining networks of committed cycling enthusiasts establish and stabilise 'new' rules and

conventions of use, and will this result in a third (or, should it be sixth, since we are here dealing with breakthrough the second time round) phase of wider diffusion as shown in the scenario sketched at point C?

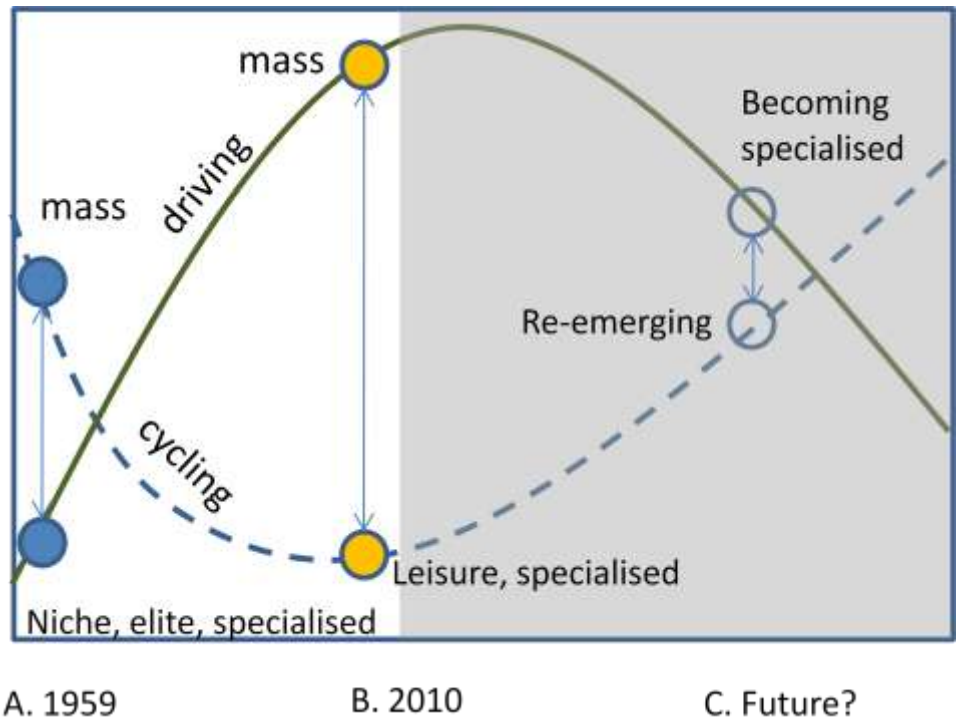


Figure 2: The relational co-existence of cycling and driving.

This simple image has two functions. One is to highlight the changing relation between cycling and driving and to suggest that such a relationship exists even when the 'regime' of cycling has been overtaken. In other words, related *but not entirely symmetrical* processes of innovation and disappearance constitute each other. The second suggestion is that this interaction is persistently relevant for the accumulation (or not) of different forms of infrastructure along with associated conventions, expectations, habits and routines, and hence for the terms on which cycling and driving relate to each other now and in years to come.

As Figure 2 implies, if cycling is to start its innovation journey all over again, if it is to spring for a second time around from a specialised niche (associated with leisure) and if it is to (re)emerge as a normal way of getting around, it will do so in an environment that is, in important ways, marked by the material and cultural traces of previous configurations of cycling and driving. In other words, the cast of 'relevant social groups' (Bijker 1997) is not at all the same, nor is the context in which they act.

This is not a new insight, but highlighting the *ongoing relation* between paths that have and that have not been taken has practical implications for those seeking to foster transitions (back) to sustainability, and to prevent the loss or further decline of environmentally benign arrangements. Theories of sociotechnical transition provide a means of understanding processes of innovation and decline as equal parts of the same story. They also recognise that such processes reconfigure regimes and landscapes and change the conditions in which future innovations might take hold. There is nonetheless more to say about how 'innovation' processes differ between the first and the

second time round, and about how fragments of failed regimes live on. In the next section I expand on this theme with reference to the partial disappearance and revival of cycling in different European countries.

Partial disappearance and revival

In their very useful review of what makes cycling 'irresistable' Pucher and Buehler observe that rates of cycling dropped massively between the 1950s and 1970s across much of Europe. For example, "From 1950 to 1975, the bike share of trips fell by roughly two-thirds in a sample of Dutch, Danish and German cities, from 50%–85% of trips in 1950 to only 14–35% of trips in 1975 (Dutch Bicycling Council, 2006). Similarly, a study by the City of Berlin (2003) found that the number of bike trips there fell by 78% from 1950 to 1975." (Pucher and Buehler 2008: 502). However, not all fell as far as they did in the UK, and in some countries rates have since risen by as much as 20%. As a result, current patterns differ by factors of ten (in terms of average kilometres cycled per day – 0.2 in the UK, 2.5 in the Netherlands) or more (1% of trips are by bike in the UK compared to 27% in the Netherlands) (Pucher and Buehler 2008: 497).

These differences are significant for sustainability and for understanding how regimes fall apart and reappear. At a macro level the collapse of cycling is readily understood as a consequence of suburbanisation and car-use, something that was surely not confined to the UK. There is also some commonality in that the goal of promoting cycling and reversing its decline has been broadly shared from the 1970s on. There are therefore two interesting and related questions: one is why cycling regimes disappeared to different extents in different European questions, and the other is why some attempts at resurrection have proved to be rather more effective than others.

On the first topic, it is undoubtedly important to notice that although levels of cycling plummeted everywhere, they did so from 'peaks' of very different heights. Adri de la Bruheze (2000) gives a sense of this variation by comparing the bicycle share (of journeys) from the 1920s to the 1990s in a number of different cities. This shows that the highest rates in Manchester (around 30%) were in any case much lower than those in Amsterdam or Hanover (80%).

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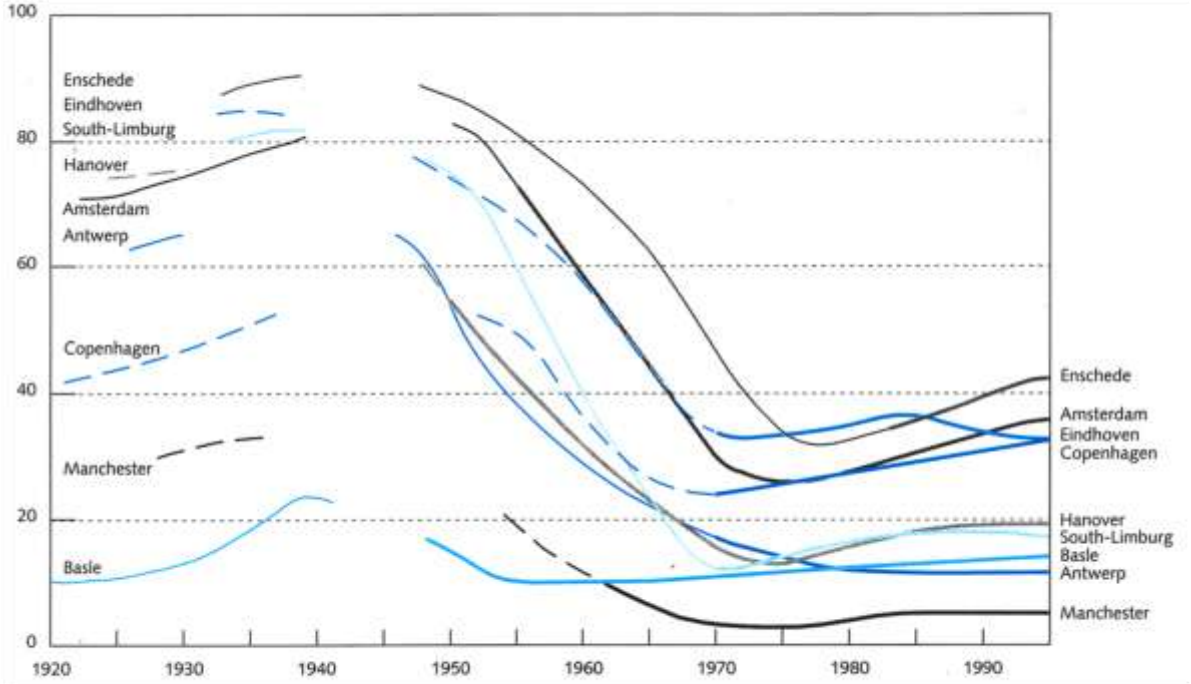

Figure 1: Reconstructed trend lines of the bicycle share in the total number of car, bicycle, motoped and public transportation trips in nine West European Cities, 1920-1995 (in %)(Source: A.A. Albert de la Bruheze and F.C.A Veraart, 1999: 34)

Given that the conditions responsible for the decrease in bike riding (cars, suburbanisation) persisted through the 1990s the puzzle is why the decline did not continue, especially in countries where it had further to fall. In response, de la Bruheze points to countervailing pressures in the form of new concerns about the environment, energy/oil crises and the quality of life. In the UK these seem to have had little or no effect, but in the Netherlands, Germany and Denmark "a massive reversal in transport and urban planning policies in the mid-1970s" meant "that cycling was *revived* to its current successful state." (Pucher and Buehler 2008: 496).

Policies to promote innovation or foster revival appear to work in different ways and to have somewhat different characteristics. One distinctive feature is that strategies and opportunities for revival depend on the extent to which the subject has really 'died'. De la Bruheze suggests that it was not too difficult to re-discover cycling in the Netherlands since "bicycle use had remained rather high" and because "cyclists were still being accepted as normal full-fledged traffic participants" (de la Bruheze 2000: 4). In his analysis part of the story has to do with how cyclists did or did not figure in national transport policy in the aftermath of the cycling regime (i.e. after about 1960). He claims that Dutch transport policy consistently considered cycling as part of traffic and urban/land use planning, but that in other countries it was seen as an outdated mode of transport. In these situations cyclists were considered to be a bit of a nuisance. Lumsdon and Tolley provide some support for this position, arguing that in the UK "For most of the post-war period the decline in cycling has been exacerbated by government policy. In 1991 for example, the Department of Transport's view was that it was not the Department's policy to encourage cycling because of safety

hazards associated with cycling in traffic (House of Commons Transport Committee 1991)" (Lumsdon and Tolley 2001: 293).

Though systems of automobility took hold and to a large extent replaced cycling in both countries, it seems that the saddle-based regime was more comprehensively obliterated in the UK than in the Netherlands. The idea that there might be different thresholds of disappearance and that aspects of supplanted arrangements sometimes persist is important. In the Dutch case the continued existence of elements from the 'old' regime seems to have made it easier to reinstate cycling to at least some degree. By contrast, similar efforts have met with limited success in the UK, perhaps "because bicycle use had declined too far in the meantime and because a material and social bicycle culture had disappeared" (de la Bruheze 2000: 4).

This argues for analysing forms of disappearance, and for identifying the conditions in which elements of old regimes endure. This is not an agenda with which the transitions literature has engaged, but it is also not entirely uncharted territory. As the next few paragraphs show, there are clues as to how to proceed, and relevant resources that can be bent to this task. The concept of obduracy is one.

In science and technology studies, obduracy is used to describe arrangements that obstruct or hinder the arrival of the new. Writing in this vein, Hommells explains that "obduracy, instead of being caused by material factors alone, is the result of interactions among social groups—interactions that are constrained by specific ways of thinking" (2005: 334). In the case of cycling, and in relation to reverse transitions, the notion of obduracy is useful not in understanding blockage or delay but in thinking about the stickyness or durability of material and social cultures, and their capacity to survive despite, beyond or alongside regimes and sociotechnical systems that have rendered them at least partially redundant. Whether we focus on cycling, organic farming or diet, better understanding of durability of fragments of regimes promises to be relevant for understanding the conditions and chances of resurrection and revival.

Recent efforts to develop typologies of transition are also of potential value (in reverse). In the 2004 collection, Berkhout et. al. (2004) identify four conditions under which transitions might get underway. Their typology separates situations in which innovations are and are not planned, and in which trajectories are shaped by pressures from within or outside existing regimes. Geels and Schot (2007) offer another scheme, emphasising the extent to which niche and landscape pressures reinforce or disrupt regimes and the synchronicity (or otherwise) of these developments. In both cases the aim is to specify conditions of change, not to plot the types of dissolution or demise that these engender. Since these features are likely to be related it is in theory possible to imagine parallel typologies of collapse and decay. For example, what Berkhout et. al. describe as 'purposive' transitions, engineered from the outside, might tend to overthrow incumbent regimes and destroy the elements of which they were made more thoroughly and more comprehensively that the types of transformation that Geels and Schot describe. In more emergent situations, it is perhaps more likely that elements (materials, images, competences) mutate or merge. The work of describing, characterising and assessing genres of disappearance is work that remains to be done. However, the idea that bicycle use in the UK declined 'too far' for it to be readily reinstated implies that there might be thresholds and phases not of breakthrough, but of breakdown, beyond which there is no return. As such the task of capturing this shadowy side of innovation is of more than academic interest.

It is so in that different policy approaches are likely to be required if the task is one of reinvigorating merely dormant arrangements, or of resurrecting systems that are, as it were, dead dead. In very practical terms, strategies like those of educating and persuading people to get on their bikes in

Manchester are likely to prove futile if there are no remnants or remains of cycling culture/infrastructure on to which these injunctions might latch.

Implications and conclusions

In summary, I have sought to make the case for thinking again about how systems and regimes disappear. I have done so on the grounds that lower carbon ways of life are likely to involve the destruction of current arrangements and the resurrection of at least some 'old' ways. In writing about cycling I have concentrated on this issue of revival and on the challenges it presents for transition theory and policy.

Theories of innovation and of sociotechnical transition have proved useful in specifying and analysing methods of moving towards a lower carbon society, but for the most part they focus on the introduction of new technologies and related forms of consumption and provision. It is true that this often *implies* the death or demise of other arrangements but as I have argued, the details of disappearance rarely get the attention they deserve. In coming to a conclusion I am still wondering if this really is a problem. One of the strengths of a distinctly sociotechnical approach is the recognition that the three levels of landscape, regime and niche are mutually defining and mutually constitutive. Second, given that the underlying model of change is evolutionary in character, processes of selection (and extinction) are already built in, part of the argument being that very few niche-level 'seedlings' survive for long . Third, not all accounts of transition suppose substitution and total overthrow, and some are in fact rather good at describing how "new regimes grow out of old regimes through cumulative adjustments and reorientations" (Geels and Schot 2007: 407). Accordingly, there is a sense in which it is quite unfair to suggest that the traces of past arrangements are overlooked.

And yet discussion of the potential for radical reinvention (for example of cycling) suggests, there are blind spots, the articulation of which promises to enrich the study of system innovation. One has to do with the debris that is left behind when certain 'elements become aligned and stabilise in a dominant design' (Geels and Schot 2007: 401). The focus on analysing the production of configurations that work and the re-alignments involved is such that the remains of regimes past have been largely overlooked. Either that or they are assumed to be re-absorbed or reconfigured within and by the new arrangement. But in cases of radical innovation, what happens to the skills, the understandings and rules and the materials that are left over or left behind? Although regimes of cycling declined across Europe, different forms of vanishing resulted in the patchy and partial existence of selected elements, the survival of which matters for the possibility and for the manner in which these regimes might be radically reinstated. The traces that endure are not preserved intact. Nor are they unchanged by intervening events. And yet they do seem to be relevant for what might happen next.

A second gap relates to the so far limited representation and analysis of disappearance and reinvention. In innovation studies the story usually comes to an end when novelties are established and when the 'S' curve of normalisation reaches the top of the page. Although the phases of the innovation journey have been thoroughly analysed we have no language with which to describe subsequent or parallel stages of breakdown and collapse, and no different vocabulary with which to capture reinvention. But again, is this such a problem? If we are interested in how organic farming, cycling or recycling might catch on why not simply treat these as innovations in waiting? To say that these forms had some previous existence is to do no more than recognise that conditions and circumstances change and that innovation journeys take place in relation to regimes and landscapes that are themselves in flux. Put simply, forwards is the only way to go. There is no question about that, but there are still some questions about how to conceptualise elements of continuity, how to

understand the enduring influence of paths not taken, and how to dislodge or radically remove systems that have blotted out or suppressed previously (more) sustainable regimes.

These are critical issues for the types of advice transition theorists might provide to policy. When the goal is that of promoting environmentally benign technologies the messages are already clear: create a protected niche; help construct "social networks that carry, nurture, and develop novelties"; promote "heterogeneous learning processes to improve performance", and get involved in building "a working sociotechnical configuration" and in articulating " expectations and visions to guide learning processes and attract attention and funding."(Geels and Schot 2007: 129).

However, experiences of trying to promote cycling in the UK and the Netherlands suggests that the challenges of radical reintroduction are not exactly the same as those of innovation. Analytically, revival might be characterised as innovation under new circumstances, but there are likely to be certain distinctive features. One is that relevant forms of knowledge and expertise already exist: revival is therefore about rescuing and remembering and perhaps adapting but not generating competence from scratch. Another is that relevant cohorts of 'lead users' might turn out to be those who are least experimental in orientation, and who are in fact 'laggards' doggedly clinging to old ways. Third, and in many ways most significant, reviving lower carbon ways of life might be best approached by seeking to undermine or remove incoming regimes that have led to their partial demise. This might mean directly attacking systems of automobility, or figuring out how to unmake suburbia and suburban ways of life as a means of reinstating the bike. This is the sort of approach that Pucher and Buehler take in advocating 'car-restrictive' and cycle friendly policies of the kind that make 'cycling irresistible'(Pucher and Buehler 2008: 523).

As discussed above, the relation between cycling and driving is of defining importance for both. As we have also seen, the detailed history of that relationship is critical for the timing of relative decline and for related thresholds of collapse. Separate cycle routes have not always existed in Denmark and the Netherlands, but they have existed for longer than in the UK. The fact that these bits of infrastructure have been developed from the 1970s onwards means that they have been designed and installed alongside parallel investment in roads, house building and city planning. In the UK the sums spent on cycling infrastructure are now rising, but in coming very much later (in the 1990s, not the 1970s), these resources are being put into a material and cultural system in which driving is already more firmly embedded. In practice this suggests that those wanting to promote cycling (or lower carbon diets, or recycling, or organic food etc.) in different countries and cities would do well to begin by evaluating where and to what extent the 'remains' of such systems still exist (niches of persistence), and whether and how they might be reactivated.

To finish, there are good reasons to go on with the project of seeding radical transitions organised around the development and diffusion of novel, environmentally benign, technologies. But as I have argued, there are also reasons to develop systemic theories of innovation such that they can be of use in reinstating old but also benign technologies and in promoting equally radical forms of regime revival. There is surely more to say about the politics and practicalities of unmaking unsustainability and about the theoretical and empirical work required to analyse and better understand transitions in reverse. In this short paper I have provided some suggestions as to what this might involve, and I have explained why I think this is work that could and should be done.

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