Reflexive interactive design and its application in a project on sustainable dairy husbandry systems

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Abstract: *Sustainable development in modern animal husbandry faces a multiplicity of challenges. If addressed separately, the solutions might well contradict one another. To avoid this conflict, there is a need for structural change in production and consumption systems. Such change cannot be attained by technological innovation alone, but demands a reorientation of the existing socio-technical regime. This paper presents reflexive interactive design (RIO in Dutch) as a systematic approach towards that end, and shows the first steps of its application in a project to deliver designs for sustainable dairy production and to contribute to a reformation of the current dairy production system.*

***Keywords**: sustainable development; reflexive interactive design; system innovation; dairy production*

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The challenge of sustainable development in animal husbandry

Animal husbandry in North-Western Europe faces a variety of problems created by its own modernization process – problems regarding ecology, economy and animal welfare and health. Pressure from society, politicians and globalizing market forces have led the sector and its periphery to reflect on a number of basic tenets and presuppositions, which have laid the foundations for its enormous success during the last three to four decades. Success here is defined as a continuous increase in production volume with continuously decreasing costs through efficiency improvements in inputs. This result of *first modernization* (Beck, 1992) is increasingly confronted with its self-generated and undesirable side effects, which limit the continuation of 'business as usual'. The EU agricultural policy had a major influence on this modernization, and the recent and anticipated changes in the Common Agricultural Policy (CAP) demonstrate the necessity to handle these undesirable side effects.

For the last two-and-a-half decades, the public debate on animal husbandry has tended to focus on single issues: first, the scientific notion of reduced welfare of animals in the newly developed housing systems in the 1970s; second, its impact on the local environment in the early 80s; third, susceptibility to infectious diseases in the 90s; fourth, the quality of life of the animals themselves, as perceived by society at the beginning of the twenty-first century; and fifth, the foreseen finiteness of the current way in which pathogenic diseases are dealt with on production farms, that is, the high use of antibiotics and vaccines. Each of these could still be seen as singular problems that could be solved one by one through adequate technological and institutional measures.

However, in recent years, all these aspects have come under scrutiny *simultaneously*, and they are complemented by new issues such as the depletion of tropical forests for feed production, the considerable contribution of animal production to climate change, and its worldwide water use. Taken together, these issues raise fundamental questions on the basic assumptions and structural choices on which this European production system has been built since the Second World War, specifically in the Netherlands, but valid for many intensive animal production systems throughout the world.

Public debate on animal husbandry in the Netherlands

This can also be identified in the character and scope of the public debate in the Netherlands. Awareness is growing that the future face of animal production should be (much) more sustainable than it is today, and on several dimensions. Recent examples of this include the Citizens Initiative 'Stop fout vlees' (Milieudefensie and Jongeren Milieu Actief, 2007a and b), an appeal to the Dutch Parliament signed by 106,975 citizens; the long-term vision of the Dutch Minister of Agriculture on sustainable animal husbandry (Verburg, 2008); and the movie *Meat the Truth* (Thieme, 2007), produced by the Dutch political party *Partij voor de Dieren* dealing with the links between meat consumption and climate change. Of course, a basic disagreement may exist on the fundamental question of whether animal production for human consumption is legitimate in itself. However, the vast majority of citizens and stakeholders in the Netherlands still affirm this basic premise. Moreover, as far as we can observe, this majority does not disagree on what sustainability should ideally imply in the long run: an economically feasible production of animal-derived food without passing the costs of it to those who do not benefit from it, for instance by harming animals, damaging local communities, environmental impacts through high losses and depleting local and global resources such as soil, energy and water. However, what this means for the future character of Dutch animal husbandry is less clear, and is currently food for fierce societal debate. Animal rights activists and environmental groups join forces for a considerable reduction and extensification of national production so as to mitigate its global ecological footprint and improve animal welfare (Milieudefensie and Jongeren Milieu Actief, 2007a; Thieme, 2007).

The sector and the national government (Verburg, 2008) operate from the assumption that it is still possible – and even necessary – to maintain the current level of production in a much more sustainable way, through the development of new technology, an adaptation of current husbandry systems and the development of new markets with higher added value. They and others (for instance, Steinfeld *et al*, 2006) stress the enormous increase in the worldwide demand for food (of both vegetable and animal origin), as prosperity and populations grow. This trend in itself forces us to increase the efficiency of our food production systems and to reduce the environmental burden by at least half (Weaver *et al*, 2000; Steinfeld *et al*, 2006). Thus, as long as worldwide demand for animal products continues to increase and consumption patterns do not dramatically change in favour of vegetable proteins, sustainability in animal production cannot be reached by a mere reduction of production in the Netherlands alone.

This division of minds shows that the character of sustainability in animal production cannot be defined straightforwardly, and does have inherently normative and political components, which may require difficult choices between conflicting interests. We want to argue, however, that these conflicting interests should not be the point of departure, since they themselves are the result of the (historically contingent) co-evolution of values, practices and institutions in livestock production. Taking them as given would make them more absolute and irresolvable than they possibly are, especially if we adopt a longer time horizon. Instead, it might be more fruitful to interpret the wide array of perspectives on livestock production as an expression of the fact that very basic tenets of the production system (its structure and functions, related consumption patterns, global dependencies) have become a subject for re-evaluation. Animal husbandry has entered the stage of *reflexive modernization* in a risk society – a stage in which dealing with its self-generated risks cannot be successfully done in the same way as it evolved in its current form during first modernization.

Reflexive modernization

The idea of reflexive modernization (Beck, 1997; Beck *et al*, 1994, 2003) has a *descriptiv*e as well as a *prescriptive char*acter. In order to distinguish these, Latour (2003) proposes the term '*re*-modernization' to indicate the (postulated) empirical phenomenon. *Descriptively*, the notion suggests that modern society is forced to reflect on the basic assumptions that structured first modernization. Whether this is actually the case is still a matter of debate. Bruno Latour, for instance, concludes 'that the data to be gathered in order to prove the advent of a substantial phenomenon called *re*-modernization are not easy to come by and, so far, are not thoroughly convincing' (Latour, 2003, p 45). In the case of animal husbandry, however, the fact that societal debate enters a stage in which a diversity of fundamental characteristics of the system has come under scrutiny (and not only by those professionally engaged in the matter) does give evidence for the actual occurrence of such a phenomenon as *re*-modernization. The awareness is growing that the whole range of 'unintended side effects' of animal husbandry cannot possibly be solved by a mere *adaptation* of current knowledge and technology, farming practices, legislation and consumption practices, but demands a more thorough scrutiny of the presuppositions on which the sector has thrived for decades.

But can this be done? Reflexive modernization in its *prescriptive formulation* is the idea or master-narrative that modernization indeed *can* be done better, using the best of our reason to pre-empt and mitigate side effects while maintaining the benefits of earlier modernization efforts. It is the optimistic belief that we can improve on our current practices in such a way that we do not repeat the mistakes of the past, such as the negligence of rebound and side effects, and that this is possible by increasing the *reflexive* character of our modernization efforts – a systematic and continuous scrutiny of the assumptions from which we think, plan and act.

This is, of course, quite ambitious in a complex world that is changing rapidly, in which all kinds of hidden links may pop up at any time and human rationality is bounded. No-one can claim to oversee the whole, never mind the future. Nonetheless, we think it is worth trying, and we see at least four reasons why a sustainable future for animal production needs an increased level of reflexivity. First, increasing sustainability in animal husbandry requires simultaneous *changes on several and very different dimensions of sustainability*. If we do not achieve this, we run the risk of losing on one side what we gain on the other. Think, for instance, of the possible contradictions between increasing efficiency and improving animal welfare. Thus, any innovation should be designed for, and assessed on its effect on multiple dimensions. Second, increasing sustainability in animal husbandry requires the *inclusion* of an increasing number of *stakeholders and actors* (including animals). This requires a redefinition of the functions of the system at hand and of the roles of the actors within that system. In fact, it means a redefinition of the system boundaries and the relationship between the systems at hand and in the outside world (or 'super system'). Third, first modernization of animal husbandry has resulted in a range of *deeply entrenched beliefs, seemingly self-evident practices and goals, and material and institutional standards* that will limit the range of solutions if left unquestioned. Fourth, any redesign of animal husbandry will necessarily involve the implicit or explicit embedding of *values*, either new, old or redefined (Feenberg, 1999). Explication of this process should be maximized for reasons of both legitimacy and successful implementation.

As will already be clear from the reasons above, reflexive modernization of socio-technological (and in our case, biological) systems implies a rearrangement of established structure at what can be called the regime level. In the multilevel perspective (MLP; Rip and Kemp, 1998a; Schot, 1998), socio-technical developments on three levels are distinguished: (1) niche experiments, which are more or less 'liberated' from the rules pertaining to the existing regime; (2) the socio-technological regime, which encompasses stabilized patterns of artefacts, institutions, rules and norms assembled and maintained to perform economic and social activities (Berkhout *et al*, 2004); and (3) the 'landscape': exogenous trends that may influence developments on the other two levels.

Investigating, analysing and describing socio-technological developments in these terms is one thing; purposefully 'doing' reflexive modernization is something different. System innovations involve changes in action as well as structure. The duality of structure (Giddens, 1984; Stones, 2005) indicates that, in principle, such a 'system innovation' is possible. In practice, however, conscious action to change an existing structure will face considerable resistance (Bos and Grin, 2008). Socio-technological regimes derive their stability from the cognitive, normative and formal rules guiding the perception and action of actors (Nelson and Winter, 1982; Dosi, 1982). Actors and organizations will be embedded in interdependent networks that represent important organizational capital. Path dependencies and lock-ins will favour incremental changes rather than system innovations (Geels, 2004). Thus, if one wants to work consciously towards sustainability by contributing to system innovations in existing practices, one needs a more elaborate and practical methodology. The approach presented here suggests a structured way of designing and introducing such novelties, based on a more elaborate idea on how to address and integrate a normative ideal such as sustainability.

Reflexive interactive design

Reflexive interactive design (RIO in Dutch) is an approach to *doing* reflexive modernization (Bos and Grin, 2008). It is a specific form of deliberative or participatory technology assessment (Gutmann and Thompson, 1996; Grin *et al*, 1997; Bellucci and Bellucci, 2002) that adopts the *design* of both technical and social features of societal systems for production and consumption as its central activity and focus of deliberation. In this way, definition of both the problem and the solution takes place in a reciprocal and iterative argumentative exchange between the actors involved. Those actors may be not only the actual stakeholders, but also those people needed for implementation of the solution. As Grin and Van de Graaf (1996) point out, the intended outcome should be understood neither as value consensus nor as a mere 'tit-for-tat' compromise, but rather as *congruency*: a course of action on the way modernization in a specific instance should proceed, which makes sense for each of the actors involved.

Deliberation therefore has an important place in RIO, but should transcend the more common involvement of stakeholders and co-producers in design. To reach congruency, more is needed than negotiation and trade-off between different interests. The latter would be a repetition of the way modernity tried to solve its problems. Deliberation requires that institutionally and technologically embedded assumptions, norms, knowledge claims, distinctions, roles and identities that are normally taken for granted must now be critically scrutinized.

RIO is an approach under construction. Parts of it have been tested in previous projects (for instance, Houden van Hennen, 2004; Diergericht Ontwerpen, 2003; Welzwijn, 2006). The core of RIO is to introduce feasible innovations in existing socio-technological systems in order to contribute to significant structural change ('system innovation'), which enables the attainment of multiple goals, for instance, in terms of sustainability. The innovations it creates should not be seen as mere technical replacements or as a technical fix. RIO is aiming at redesign in order to reduce the number of trade-offs between seemingly conflicting needs and the number of system failures that have been built up during years of co-evolution.

The RIO approach is based on various sources in innovation and policy sciences (Grin *et al*, 1997; Grin, 2005; Grin and Van Staveren, 2007; Schot, 1992; Rip and Kemp, 1998b; Loorbach, 2007; Rotmans, 2003; Weaver *et al*, 2000), as well as more technically oriented methods

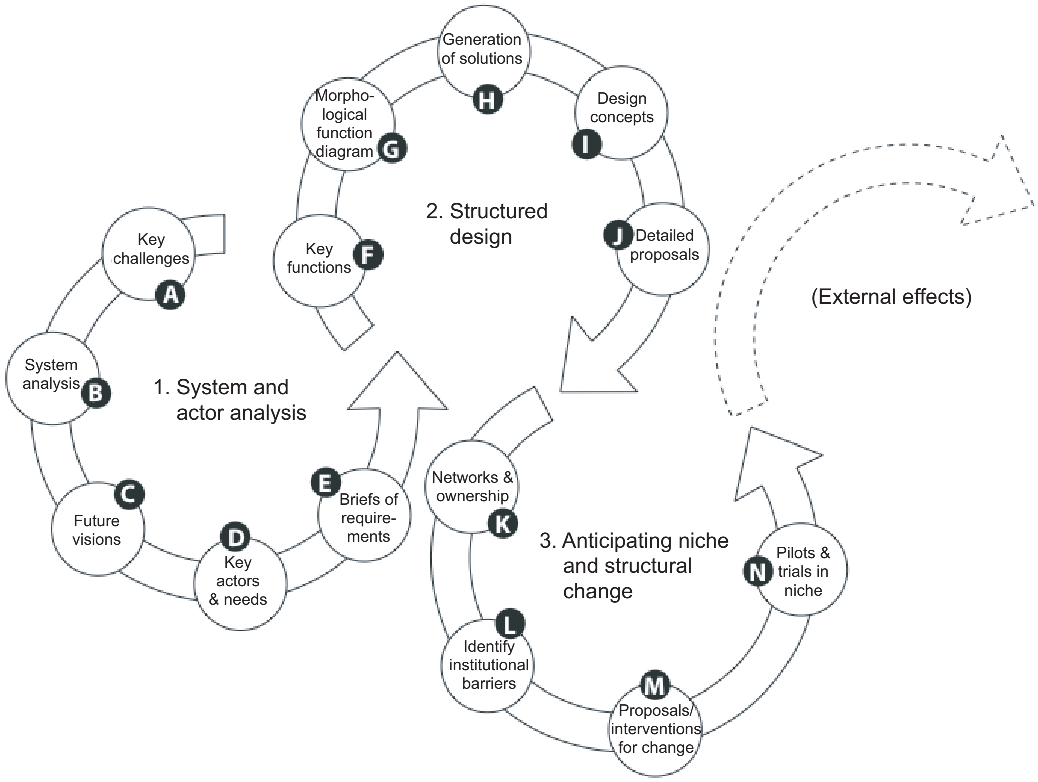

Figure 1. Three iteratively looped and linked cycles in RIO: system and actor analysis; structured design; and anticipating niche and structural change.
Note: Activities A–N are explained in the text.

from animal science (Bracke *et al*, 1999) and agricultural engineering (Siers, 2004; De Beer, 1997). The aim of RIO is deliberately to construct propositions for new socio-technical systems that are feasible in the first instance to ignite niche experiments in the foreseeable future, and to have a good chance of contributing to structural reform in the long term.

Focus on needs

In RIO, the needs of central actors play a pivotal role in the system to be designed, for methodical and substantial reasons. Methodically, needs are the starting point in the systematic design methodology by Van den Kroonenberg called *Methodisch Ontwerpen* (Dutch for 'structured design'; Siers, 2004; De Beer, 1997). Structured design (SD; see also Figure 1) makes the design process of artefacts such as buildings and machinery rigorous and traceable. SD emphasizes the importance of a rigorous analysis of the actors and users and their needs, and of translating these into an elaborate set of quantitative requirements, based on traceable sources. One of the benefits of this approach is that the requirements are formulated independently of the perceived possible solutions and solution space, which leads to a wider range of options. Another benefit is that the method stimulates more fundamental reflection on the needs of prospective actors. A substantial reason to take the needs of actors as a starting point lies in the origins and the current context of the application of RIO: animal husbandry. One of the big current challenges here is the amelioration of animal welfare. In order to design for animal welfare, one has to operationalize it and make eventual choices explicit. Bracke *et al* (1999) have proposed using the notion of 'need' as a basis for (objectifiable) criteria that can be used to assess animal husbandry systems in terms of their performance on animal welfare. Their basic assumption is that if the needs of animals are fulfilled, their welfare is beyond doubt. This follows from their proposition that for animals, only their *emotional* state is intrinsically relevant for their welfare.

The general approach of RIO is built upon three cycles of activities that may be fed back and forwards to one another (Figure 1):

(1) System and actor analysis. Systematic reflexion on the current structural arrangements of the system at hand and the needs of key actors involved; this is done analytically as well as in an interactive fashion in order to facilitate opening up of the problem and solution space (Voß and Kemp, 2005). The main activities are:

(A) identification of key challenges to be solved (for instance, in relation to sustainability);
(B) systematic analysis of functions and processes and their relationships in the current (including so-called 'wicked links'; Grin and Van Staveren, 2007) and desired situation (identification of possible structural rearrangements);

(C) interactive formulation of attractive future visions in which the main challenges are addressed;
(D) identification of key actors (human and non-human) involved in the proposed system, and assessment of basic needs; and
(E) formulation of a brief of requirements (BoR) for each actor based on needs.

(2) Designing new systems or arrangements using structured design (Siers, 2004). This is done in an interactive way in order to incorporate practical and tacit knowledge, and to prevent a research bias in value incorporation. The results are feasible and attractive concepts that might be realized in the near future. The main activities are:

(F) selection of key functions that are pivotal to realize the desired situations (that is, future visions);
(G) composition of a structured morphological function diagram, in which functions are arranged;
(H) identification and generation of a range of (new or existing) solutions per key function; creativity is involved;
(I) making a number of design concepts or drafts of new systems by combining single solutions into new structures; and
(J) elaboration into a detailed proposal (that addresses technical as well as social aspects); evaluation of the drafts against the brief of requirements.

(3 Anticipating niche and structural change. Strategically using concepts and reflections to facilitate effective reformism (Roep *et al*, 2003), that is, realization of niches, as well as proposals and interventions for structural changes in the current system that create the space for changes in daily practice:

(K) establishment of networks of stakeholders around the concepts in general, and around specific solutions; ideally, this should be a natural result of previous interaction in cycles 1 and 2;
(L) identification of barriers at the regime level (social, institutional, cultural) that may hinder niche formation and the realization of future visions;
(M) making proposals and actual interventions in order to lower or remove barriers at the regime level; and
(N) establishment of pilots and trials in niche experiments.

These three cycles do not represent a chronology in time, although the main focus in RIO projects will change over time from the first to the latter. Due to both the *reflexive and the interactive character*, several iterative cycles may be completed over time, in which problems may become redefined, proposed structures may be reassessed, and new actors may shed new light on the proposed solutions.

The cycles are accompanied by and reflexively monitored based on an explication of the 'intervention theory' of the project. This 'theory' makes explicit to participants what the expected result in terms of tangible output and effective outcome ('external effects' in Figure 1) will be in the short, middle and long term. The intervention theory guides strategic choices throughout the project.

RIO and the Power of Cows (*Kracht van Koeien*)

The present case is a project on sustainable dairy production, called *Kracht van Koeien* ('Power of Cows' in Dutch). The project is meant to deliver new concepts for dairy production that improve on sustainability in more than one respect simultaneously. The Dutch Ministry of Agriculture set the assignment in order to produce feasible concepts for maintaining the Dutch dairy sector, while realizing significant improvements in animal welfare and environmental issues. Detailed results are presented for the problem definition, system analysis and structural rearrangements, along with key functions. Some experiences and major results are presented for the outline of attractive future outcomes, the needs of actors and the intervention theory. A more elaborate paper on the outcomes will be published later.

Problem (re)definition

The problem definition of the project was not clearly stated beforehand. Contributing to a 'more sustainable' dairy production serves as a very general guideline for the assignment, but the extent and substantive content of this sustainability requirement was not specified, and was to be identified during the process, as a synthesis of problem perceptions of a diversity of stakeholders. Based on a literature review, expert meetings and sessions with farmers, farmer representatives and other central stakeholders, the challenges for sustainability of the current dairy production system were assessed. The result was reported back as a proposition to a panel of representatives (the 'platform') for discussion.

The challenges can be summarized as: (1) a reduction of the considerable environmental footprint (leakage of nitrate in soil and surface waters, emissions of ammonia, production of greenhouse gases such as methane and nitrous oxide); (2) improvement of animal welfare and health issues (claw disorders that affect the majority of cows in current systems, leading to locomotion problems; mastitis – infection of the udders; a general trend towards intensification of dairy production and consequently keeping cows inside all year round without grazing; (3) economic challenge to reduce costs caused by liberalization and globalization of the dairy market; (4) find an answer for/deal with the increasing competition for land and space, with the resulting big gap between the economic and agricultural value of land; (5) overcome the increasing constraints on the availability of the (especially cheap or unpaid) labour force.

System analysis

Most of these challenges are hardly new to those involved, except maybe for the contribution to global warming. The most likely explanation for this persistence is that they are deeply rooted in the basic structure of the dairy production system, and are almost inherently connected with some desirable effect. A system analysis was performed to assess the causal origins of the challenges and their interconnectedness, an approach suggested by Grin and Van Staveren (2007). Two system levels (In 't Veld, 1974) were distinguished: the (local) husbandry system (including cows, land, farmer and physical infrastructure) and the dairy sector in the Netherlands as an aggregate system; but these did also include important relationships with the wider (national, European and global) environment (for example, soy bean production, fertilizer, market conditions, and competition with biomass and fuels). The system analysis was subdivided into the following components:

(a) defining the system boundaries, the adequate system level and elements (living and dead) in relation to the problem and goals; and defining the systems approach: top-down starting from the complete system, or bottom-up starting from the elements, or alternating between these two;
(b) historical origins of the character of current dairy production systems; husbandry systems are dynamic transient systems, meaning that the current output of the system is not only the result of the current state of the system, but also stems from states in the past;
(c) identification of 'wicked links', that is, deeply entrenched couplings of desired effects and undesired side effects; and
(d) assessment of important trends (inside and outside the system itself) that may affect the sustainability of dairy production in the future.

As with any technological system, the dairy production sector has a fundamentally heterogeneous character. Its structure is built from the interaction between living entities and non-living matter (technical artefacts). Its operational functions, as well as its developmental path, are aligned by a socio-technical regime, in which economical, as well as deeply entrenched cultural features, play important roles. It has a range of different system functions (that is, those functions that serve goals and fulfil needs outside itself) that exceed the sole production of milk and dairy products. Finally, the dairy system is a significant stakeholder in Dutch spatial planning, because of the large amount of privately owned land. Due to this complexity, any system analysis will fail to cover the whole situation. In this case, the system was analysed from different angles (socio-technological, cultural, historical) with the aim of gaining a better understanding of the structural roots of the main challenges in the system. Below, nine important structural characteristics of the dairy sector in the Netherlands are presented, which lie at the root of the challenges identified, and which serve as starting points for the next design steps in the project.

Historically co-evolved characteristics

(1) For historical reasons, Dutch dairying has focused on bulk milk production as the primary goal, instead of (for instance) producing meat and milk at the same time. The main reason is the heavy EU subsidies for milk from the 1960s and onwards. The system (including the stock of knowledge, breeding, technology and farmers' status) has co-evolved around this. Another consequence is that the system never really had to compete on price, partly due to the EU milk quota system. This is changing with increasing market liberalization.
(2) This history led to an emphasis on the breeding of highly productive cows as the most important strategy to increase income per cow, without the parallel attention to the conditions (housing, management, feed) that must be met to sustain these yields without compromising on the health, life expectancy or welfare of the animals. This has resulted in several health problems of 'epidemic' proportions: claw disorders and locomotion problems, reduced fertility and mastitis.

Wicked links

(3) The efficiency and yield of cows was able to be increased by the availability of cheap proteins and energy from other parts of the world, in close connection with imports for human consumption (soy). This resulted in net local surpluses of reactive nitrogen (that is, all nitrogen that can be chemically reactive, for example, N_2O, NH_3, NO_3 and NO_x) and phophorus.
(4) Artificial fertilizer (AF) has a privileged position in EU regulation, and its application in agriculture is much more optimized than the application of manure. Therefore, despite the surpluses of reactive nitrogen, AF is still used on a massive scale in agriculture. AF is produced using high energetic costs and is a significant contributor of emissions of N_2O, one of the most potent greenhouse gases known.
(5) The fundamental choice of using ruminants for producing protein, in order to upgrade low-grade vegetable sources such as grass into proteins suitable for human consumption, is fundamentally coupled with the production of methane from the fermentation process inside the cow.
(6) There is a belief that growth (in number of cows per farm) is the only way to make the farm future-proof, a belief fostered by advisers, the historical records and the fact that 'larger' farms tend to have lower costs than smaller ones. At the same time, economic figures suggest that *growing* bigger is not the same as *being* bigger, and thus seem to refute the idea that growth is a sensible strategy in the majority of cases.
(7) There is also a deeply entrenched belief that it is necessary to earn a complete family income from the farm. Combined with the fact that labour is still largely unpaid, this is one of the driving forces to increase the size of farms, with the parallel reduction of net income per hour and free time.

Relevant trends

(8) Spatial policy in the Netherlands puts constraints on the size and appearance of buildings. In combination with heavy competition and speculatively high prices for land (also partly due to the character of national spatial planning), this exerts considerable pressure in terms of reduction of the space per cow (at least in the winter) because of the (perceived) costs.

(9) There are increasing difficulties in transferring a farm to a successor, because of its increasing capital intensity (mainly possession of land).

Identification of possible structural rearrangements and key functions

The first step to accomplish feasible integrated sustainable concepts was to identify the possibilities to decouple so-called 'wicked links' (Nos 3–7 in the previous list). In RIO, a distinction is made between needs, the system functions and actor functions to fulfil those needs, operational functions that maintain the system, the actual solutions for those functions, and the effects of these solutions. Specific solutions may have desired and (sometimes undesired) side effects. In this case, we speak of a wicked link.

But how can one unlink a desired effect from an (undesired) side effect? This was investigated using the following heuristics (four ways, meant as heuristic guidelines for creative assessment, not as foolproof methods).

First, one can think of a replacement as the solution that is closest to the generation of the undesired effect: for example, by the regional production of concentrates, which reduces the net surplus of reactive N in the system. It might even turn out that the historical conditions that laid the basis for the existence of this solution (for instance, the cheap price of imports, or the need for chemical fertilizer in Western countries), actually do not exist any more or will vanish in the near future.

Second, one may redefine the need, the related function(s) for which the solution exists, in order to make the solution superfluous: for example, a redefinition of growth in a number of (smaller) units, or in a system of shares in other dairy farms, instead of cows per unit. If growth is a desired effect that stakeholders want to facilitate, the solution space is opened up by extending the concept itself.

Third, one can critically assess the need that the function is supposed to fulfil: for instance, do we need milk, or do we rather need protein? If the latter is the case, is it possible to produce the same kind of protein from grass without the 'solution' of cows or ruminants in general?

Finally, one can turn an undesired effect into a desired one by introducing a new system function. An example of this is the redefinition of a surplus of reactive N (manure as waste) into a possible resource (manure as food) for a product that is much needed in other parts of the world, competing with artificial fertilizer. This resembles the heuristic strategy proposed by McDonough and Braungart (2002), called *cradle to cradle*.

Subsequently, the key functions were identified so that a proposed system should be able to perform in an adequate way. The goals for dairy production were translated into two main functions: namely, milk production and production of highly valuable nutrients such as nitrogen and phosphorus. Three subfunctions were identified: that is, production of energy, production of meat and by-products, and the contribution to a valuable cultural landscape and nature. The system analysis in the case of milk production in the Netherlands revealed that the following key functions were vital to redesign the system, and would have to be paired with better solutions, that is: produce grass; produce concentrates or substitutes; graze pastures; house cows; manage husbandry system; maintain cow health/manage cow diseases; generate farmers' income; allow for easy access to capital; generate labour; collect, manage and store urine and faeces; produce energy (by photovoltaic cells, wind, biomass); generate plant nutrients (nitrogen and phosphorus).

Combination into outlines of attractive futures

The second step was the combination of several promising structural rearrangements into a number of future visions, which might be attractive for a variety of actors (or their spokespersons) involved in the current system, and bear the promise to solve some of the challenges identified earlier. These visions of the future did not and should not have to be complete solutions or blueprints, since their function was to provide an inspiring working proposition for the next phases that could be shared and altered by the actors involved. The project team purposely proposed several combinations in order to prevent an unsubstantiated universalistic approach to a complex system with a lot of variety in actors and their respective needs. The future visions in this case had three different themes: mineral production; intensive energy and biomass production; and growth by downscaling. In each vision, considerable steps in the sustainability of dairy production itself were attained by synthesizing it with another, yet compatible function.

Investigation of actors and their needs

Once future visions have been formulated and assessed by a multiplicity of actors involved (including spokespeople for animals, nature and the environment), a brief of requirements (BoR) is formulated for each actor that can be identified to be part of the system served by or affected by the (proposed) system. Their needs are assessed using interviews and workshops (in the case of human actors such as farmers), scientific and practical knowledge (in the case of animals), or a combination of qualitative and quantitative techniques (in the case of citizens/consumers). In any case, needs are never taken at face value, but are abstracted as far as possible so as to prevent solutions being confused with needs and specific requirements. Subsequently, needs are quantified and qualified into requirements in the BoR, as a yardstick for the designs. As far as possible, the BoRs are checked in consultation with those involved. Further information on this can be found in Bos and Groot Koerkamp (forthcoming).

Intervention theory

Despite the rigour involved, these ideas or innovations will not and cannot in themselves change entrenched structural arrangements. This would suggest an overly optimistic belief in technology or rationality. Interactive design of feasible concepts is a conscious *intervention* in an existing and stabilized system. Both the ideas and the process that leads to them have to be starting points for structural change. Any action during the process will thus be assessed on its potential capacity to do this. This cannot be planned in detail beforehand, but some general aims can be identified. We call this the 'intervention theory' of the project team: the set of goals and hypotheses that will guide the project's interaction with the outside world. The team identifies this theory beforehand in order to evaluate the project's success later, and to be explicit about its goals.

Afterword

Reflexive interactive design is a structured approach that contributes to effective reform (Roep *et al*, 2003) of existing systems. Some elements of the approach are in place and tested (for instance, the structured design and the needs approach); others are under construction (for instance, the system analysis, conception of systems, functions, requirements and effects, as well as the way to attain future visions); and still others are largely based on intuition and previous experience (for instance, the strategic use of concepts and process in effective reform). Notwithstanding the above, consciously designing projects for structural change in existing complex systems is rather new. RIO attempts to synthesize the insights of such diverse sources as ethology, engineering, social theory and science and technology studies in a coherent whole. This interdisciplinary approach has the inherent limitation that disciplinary criteria for quality and evaluation cannot be applied easily. Although factual knowledge claims and assumptions can and should be in line with current standards, the main results of the RIO approach cannot be evaluated against disciplinary standards. The intervention theory is one way to make interactive design approaches such as these more accountable.

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