

# MURMURATION AS METAPHOR FOR SUSTAINABLE INNOVATION PROCESSES

Nina Koch-Ørvad<sup>1</sup>, Christian Thuesen<sup>2</sup>, Christian Koch<sup>3</sup> and Thomas Berker<sup>4</sup>

<sup>1&2</sup> Management Engineering, Technical University of Denmark, Produktionstorvet, Building 424, 2800 Kongens Lyngby, Denmark

<sup>3</sup> Construction Management, Chalmers University of Technology, Sven Hultings Gata 6, Gothenburg, Sweden

<sup>4</sup> Department of Interdisciplinary Studies of Culture, Norwegian University of Science and Technology, Dragvoll, Trondheim, Norway

The construction industry stands before an extensive and essential transition towards sustainability; however, the configuration of the innovation processes that lead to such transition is unclear. In this paper, the concept of murmuration, i.e. the collective behaviour of starlings, is introduced as a metaphor for sustainable innovation processes in construction. The murmuration metaphor captures the flowing, ever-changing non-structure that characterises innovation processes within sustainable construction. This conceptual hypothesis is based on an empirical observation, and the potentials of the metaphor are explored at two interdisciplinary workshops with actors from the Danish construction industry. The empirical validation shows that the murmuration metaphor can generate a useful framework for understanding and discussing sustainable innovation processes in construction. Furthermore, murmuration can be a fruitful addition to the understanding of the societal transition towards sustainability as an elaboration of the niche-to-regime processes emphasised in the Multi-Level Perspective.

Keywords: innovation, metaphor, murmuration, sustainable transition

## INTRODUCTION

The transition towards a sustainable construction industry has received a growing interest during the past years (O'Neill and Gibbs 2014; Nykamp 2017; Martiskainen and Kivimaa 2017), and globally, innovations to support and accelerate such a transition are highly in demand (UN Environment and International Energy Agency 2017). Still, the configuration of the innovation processes that lead to the sustainable transition is unclear and much literature calls for further research that can lead to a more profound understanding of innovation processes in sustainable construction.

An important strand of literature is based on the Multi-Level Perspective (MLP) as an analytical framework for studying sustainable transitions (for an overview, see e.g. Lachman 2013). The MLP argues that sociotechnical transitions come about through interacting processes within and between the incumbent regime, radical niche-innovations and the sociotechnical landscape (Rip and Kemp 1998; Geels 2002). Through the years, the MLP has received extensive criticism regarding, for example,

---

<sup>1</sup> ninko@dtu.dk

its undervaluing of agency (Smith *et al.*, 2005) and the simplified conceptualisation of the levels and their roles in the transition process (Berkhout *et al.*, 2004). We particular notice the critique by Smith (2007) that the approach gives insufficient consideration to the processes by which niches and regimes interact and are interdependent.

In the wake of this criticism, fruitful debates have emerged, leading to clarifications and elaborations on e.g. politics and power (Grin 2010) and agency (Fuenfschilling and Truffer 2016). Still, the MLP framework does not offer an operational understanding of the innovation processes that support the sustainable transition. With this paper, we wish to gain a better understanding of the dynamics and mechanisms of sustainable innovation processes that emerge from niche experimentation and lead to changes in the socio-technical regime, thus inducing the transition towards a more sustainable construction industry. In other words and with reference to the illustrative representation of the MLP (see figure 1 for a simplified version), we wish to study and discuss 'what happens in the arrows?'

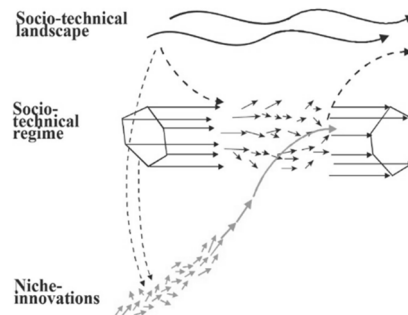


Figure 1: The Multi-Level Perspective. Adapted from Schot and Geels (2008, p.546)

The paper is structured as follows. First, the general characteristics of innovation processes within sustainable construction are introduced. Then, based on an empirical observation, a metaphor is introduced as an illustrative device for comprehending the profoundness of innovation processes within sustainable construction. The findings from an empirical validation are presented, followed by a discussion of implications for practice and theory. Finally, the conclusion sums up and offers recommendations for further research.

## Innovation in Sustainable Construction

As a starting point, we present a brief overview of the current understanding of innovation processes in sustainable construction, and highlight the research avenues suggested by the literature.

Innovation processes in general are complex and characterised as chaotic and unpredictable (Cheng and Van de Ven 1996). The construction industry constitutes a loosely coupled context (Dubois and Gadde 2002) for innovation activities that are characterised as “messy, complex and dynamic” (Harty 2008, p.1038). Innovation in construction involves alterations, parallel and overlapping activity flows, setbacks etc. (Winch 1998; Slaughter 1998). Implementation often takes place in projects, and so innovation processes are collaborative engagements and a product of networks of actors (Harty 2008; Bygballe and Ingemansson 2014).

Focusing on sustainable innovations, extended usage is necessary to provide long-term benefits and create value for users, organisations, and society (Den Ouden 2012). The sustainability agenda includes a very broad range of issues to address and thus

sustainable innovations have to be reflexive, adaptive, aware of its consequences and therefore open-ended (Berker 2010). The extensiveness of the agenda, the requirements for flexible and open-ended solutions, and the loosely coupled context including involvement of multiple actors are factors that all contribute to the fact that sustainable innovation in construction is a highly uncertain and extremely complex process.

This outline of innovation processes in sustainable construction is widely known and acknowledged in academia as well as in practice. However, the characteristics are not very precise nor particular operational - yes, the process is highly complex and uncertain, but how to navigate in such context? Is there a way to gain a more cohesive understanding of the processes, so that practices and strategies can be designed to support more sustainable construction? This request for a more profound understanding of the processes that actually take place in practice - 'what happens in the arrows' - is mirrored in the literature on innovation and sustainable transitions in construction. For example, authors call for recognition of the complexity of the processes (Gibbs and O'Neill 2015), suggest more attention to the relations between the actors involved in innovation (Dubois and Gadde 2002; Bygballe and Ingemansson 2014), and requests wider debates on the nature of innovation (Harty 2008).

We are highly motivated by this unclear, however sought-after, understanding of the profoundness of innovation processes in sustainable construction, and have based our research on the aim of generating a platform for new insights into this field.

### **An Empirical Observation**

In our work with studying and clarifying the substance of innovation processes in sustainable construction, we have been inspired by an empirical observation made at a green building conference in Copenhagen. Here, a recognised Norwegian architect was asked to describe the process, she had been a part of, of designing and constructing a highly sustainable state-of-the-art building. The best way to describe this process of actors entering and leaving the project, continuously adding knowledge and value to the project, she said, was as a flock of birds, and she showed an image of a murmuration.



*Figure 2: Tine Hegli, Snøhetta, presenting on Building Green 2015*

This image and its narrative made a great impact on us. First, because it originates from a practical experience of working with innovation processes in an actual sustainable construction project. And second, because the content of the image, the flock of birds, represent a flowing, ever-changing movement that we sense has something to offer to our search for a better and more comprehensive understanding of what actually happens when innovation takes place in sustainable construction.

## **MURMURATION AS METAPHOR**

We propose that murmuration, i.e. the collective movement of starlings, is a useful metaphor for innovation processes in sustainable construction. Before discussing how murmuration can contribute to the understanding of innovation processes, we introduce the concept of metaphors; what is a metaphor and what can it do?

### **Metaphors**

A metaphor is an illustrative device (Alvesson 2002) that offers a new awareness (Brown 1976) and “extends horizons of insight and creates new possibilities” (Morgan 1986, p.341). A metaphor is able to illuminate aspects of a system and shadow others, thus creating meaning and understanding of complex situations. A metaphor is not to be taken literally, as it then will appear absurd (Brown 1976), instead there should be an appropriate mix of similarity and difference between the metaphor and what it represents (Alvesson 2002).

A particular type of metaphors is called Generative Metaphors (Schön 1993). Such metaphors generate seeing rather than describing a situation. Schön exemplifies a generative metaphor with the story of the development of artificial paintbrushes, where researchers struggled to transfer the qualities of natural paintbrushes until one researcher pointed out that a paintbrush is a kind of pump. Using the metaphor, i.e. seeing the paintbrush as a pump, helped the researchers to better understand both their unit of analysis (the paintbrush) and the challenges they were facing (how to create a new paintbrush with the same functionality as the old one). We are interested in this type of metaphor to improve our seeing and understanding of innovation processes, and thus to contribute to solving the challenge of supporting the transition towards a more sustainable construction industry.

Schön (1993) discusses two interesting aspects of the generative metaphor that are useful to include in our case. First, he points out that adding normative dualism such as nature/artifice or health/decease to a metaphor helps to see a complex, uncertain and indeterminate situation differently, and to encourage in what direction to move. Second, he describes the life cycle of the making of a generative metaphor in four steps: (1) A notice or a feeling that A and B (e.g. the paintbrush and the pump) are similar, but without clarity on similarity with respect to what. (2) Description of relations of elements and the start of an analogy between A and B. (3) Construction of a general model where a modified version of A can generate understanding of a modified version B. (4) Once a generative metaphor is constructed (i.e. in this context, A can be seen as B) then similarities and differences between A and B can be explored and reflected upon. A final notion here is that, in line with Brown (1976), generative metaphors are not literal, which is what actually makes them useful; it is precisely because paintbrushes are not literally pumps that it can be beneficial to see them as pumps.

We are currently approaching step two in our development of murmuration as a generative metaphor for innovation processes in sustainable construction. Like the Norwegian architect, we too intuitively feel that the flying flock of starlings and the innovation processes are somewhat similar and wish to unfold the metaphor to see what insights it generates. The murmuration metaphor captures the flowing, ever-changing non-structure that characterises many of the innovation processes within sustainable construction that we previously have been studying. Further, it matches the characteristics of innovation processes in sustainable construction described in the

literature. Our next step, and what we will focus on in this paper, is to describe the relations of elements and generate an analogy between murmuration and innovation processes in sustainable construction. We start by exploring what murmuration actually is.

### **Murmuration**

Murmuration is the collective behaviour of starlings (King and Sumpter 2012), where thousands of birds, shortly before sunset, perform impressive aerial manoeuvres before choosing a place to roost for the night (Ballerini *et al.*, 2008a). The main goal of a murmuration is to maintain cohesion of the group when pressured for survival; the larger group you are in, the better the chance someone else will get eaten if a predator attacks - a behaviour also known as the selfish herd (King and Sumpter 2012). Even though the group is exposed to a high degree of uncertainty regarding the behaviour of each bird as well as disturbances from the environment, they are able to maintain cohesion and coherence due to simple, local interactions among the individual birds (Young *et al.*, 2013). Each bird keep a minimum distance from each other comparable to their wingspan as to avoid collisions. Furthermore, studies have shown that each bird interacts with a fixed number of neighbours (on average six to seven), rather than with all neighbours within a fixed distance (Ballerini *et al.*, 2008b). The number of interacting neighbours is independent of the number of birds within a flock or the flock density (Bialek *et al.*, 2012). It is shown, that interaction with this fixed number of six or seven neighbours optimises the balance between group cohesiveness and individual effort (Young *et al.*, 2013).

Couzin *et al.*, (2005) have studied movement decisions and leadership in travelling groups of animals. They found that in many cases, only few individuals in a group have pertinent information, such as knowledge about the location of food or the migration route, and only a very small proportion of informed individuals is required to achieve great accuracy. Informed individuals do not have to be able to recognise each other, and leadership can emerge as a function of information differences among the group members, and is therefore transferable. No inherent differences between individuals, e.g. dominance due to larger body size, need to be invoked to explain leadership.

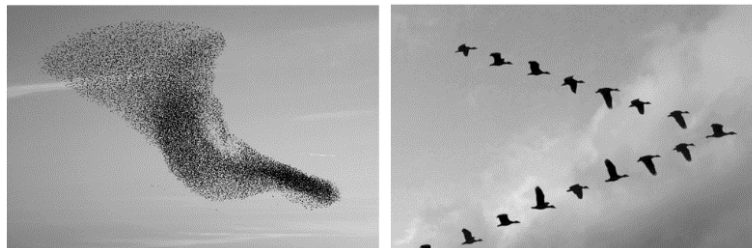
To sum up, murmuration occurs as a way for the group of starlings to sustain, offering both protection from predators and guidance towards food. Each bird interacts with its six to seven neighbours, thus balancing between increasing the group cohesiveness and reducing its own individual effort. The leaders of the group are not necessarily the biggest or the strongest birds, only a few leaders are needed, and the leadership can shift position as other birds become better informed.

### **Innovation Processes as Murmuration**

Seeing innovation processes within sustainable construction as murmuration offers an understanding of the dynamics that take place and that all together influence and change the regime to become more sustainable. We see that innovation can emerge from all sources. There is not one leader and it is not necessarily the strongest or largest company, and not necessarily a company within the construction industry, that can develop a radical innovation with potential for changing the regime. For such an innovation to rise from the niche level, enter the regime and make a transformative impact, it must be supported by other actors. A lonesome bird will most likely be eaten, but together in a murmuration, the birds can survive. This dependency on other supporting birds or actors also means that an innovation can travel from one actor to

its neighbours. Furthermore, several innovations can occur in the murmuration at the same time, and as they travel from actor to actor or project to project, the innovations can meet and interact. Such innovation interactions can be divergent or complimentary and thus hold the potential of generating new, improved information and with that influence the motion of the entire flock.

The leader of the formation is the one with the newest and best information, and by following the leading bird, others gain both better protection and potentially new information, and thus the opportunity of becoming the new leader. This group mechanism or collective behaviour is essential in a murmuration, and it makes sense that the same balance between group cohesiveness and individual effort is the key to secure a sustainable transition of the construction industry. However, as the construction industry is characterised by a highly divided value chain and significant internal competition, this collective behaviour is seldom performed in practice. Perhaps this is one of the answers to the omnipresent critique of the productivity and innovation rate of the construction industry - and perhaps an avenue that requires much more focus from both researchers, governments and practitioners.



*Figure 3: Murmuration and migration*

In contrast to murmuration, we find migration (see figure 3). This normative dualism, as Schön (1993) called it, adds further aspects to the murmuration metaphor. The migration formation is highly structured, well proven and very effective for reaching the intended destination. This could resemble a traditional, linear stage-gate managed project. It is an optimised process, but only when the target is known and the destination has been visited so many times before that it comes to lie inherently in the actors involved. When the target is unknown, when all we know is that we need to do something radical to secure our survival, we need a different formation that allows for creativity and changeability. The murmuration formation might not seem optimised, but it offers an ever-changing non-structure that enables the reflexive, adaptive and flexible innovations needed to support the transition towards a more sustainable construction industry.

### **Empirical Validation**

To explore the potential of murmuration as a metaphor for innovation processes, and to validate its applicability and relevance in practice, we have conducted two workshops with practitioners from the Danish construction industry. Each workshop were performed in cooperation with a professional network facilitation organisation. One workshops was held with a network focusing on innovation in construction, and the other with a network on sustainable construction. At each workshop, 10-12 practitioners participated, representing client organisations, architects, engineers, consultants, and IT/BIM specialists. The participants held positions at different levels in their organisations, spanning from project managers over department leaders to CEOs. Overall, a broad and diverse selection of practitioners who at large represent the stakeholders usually involved in innovation projects in sustainable construction.

The workshops were divided in two main sections. First, a presentation by one of the present authors, including an outline of the current knowledge on innovation processes in sustainable construction, and an introduction to the concept of murmuration and how it can be a metaphor for innovation processes. Second, a loosely facilitated discussion between the participants and the presenter. By 'loosely facilitated', we mean that only a few questions were asked initially to allow the discussion to flow as freely as possible, as the aim of the workshops was to validate the applicability of the metaphor in practice, and see in which directions the metaphor could take the practitioners. The questions asked were "How can we support innovation processes in sustainable building" and "Should we identify 'rules' for a murmuration process and support innovation based on these, or should we structure the process, make order and secure a focused progress (migration)". The discussions of the two workshops were recorded, transcribed and interpreted by the authors.

The discussions at both workshops primarily circulated around three topics. One topic was diversity, where the practitioners argued that the numerous actors involved in the construction industry is actually a gift as diversity inspires for creativity. Furthermore, 'knowing the flock' can be an advantage in innovation projects compared to constantly being part of new constellations. A second topic was leadership with emphasis on the point that everyone can be a leader or a driver of the development, and that a leader must allow himself to follow his instincts. A third topic discussed was the contrasts between murmuration and migration. In migration, the practitioners argued, there is only one leader, which entails a fatal risk of derailment - what if that one leader has forgotten or misunderstood the road to the final destination? Another argument was that murmuration is a way of creating space for creativity; however, many people feel more confident with linear thinking. Finally, it was argued that perhaps the right way to organise the transition towards a sustainable construction industry involves both formations: murmuration as the way of finding the destination, and migration as the way of reaching it.

## **FINDINGS FOR PRACTICE AND THEORY**

The workshops showed that the murmuration metaphor offers an illustrative language for understanding and discussing innovation processes. The practitioners intuitively grasped the metaphor and used linguistic references to Murmuration to elaborate on the challenges and possibilities within innovation and sustainable construction, for example when talking about 'leader instincts' or 'the flock'. Based on the discussions, we found that the murmuration metaphor generates new thoughts and understandings regarding: (1) Why is sustainable innovation difficult to perform in practice? (2) How can innovation processes be organised or managed? (3) How can the sustainable transition of the construction industry be supported?

The first question, why sustainable innovation is difficult to perform in practice, relates to the practitioners' discussions on linear thinking and leadership. Innovation as murmuration requires iterative and diverting processes, involvement of multiple actors, fruitful clashes of knowledge, and shifting leaderships. However, many people and organisations are accustomed to and comfortable with linear thinking, and prefer innovation projects where roles and tasks are clearly defined, and where the progress is systematically planned and led. Furthermore, the phase-divided construction process, where design is followed by planning, followed by construction and maintenance, is a poor fit for iterations, change of leadership etc. Thus, both the

personal, the organisational and the industry's tradition for linear thinking is complicating the performance of murmuration-like innovation processes.

The murmuration metaphor also generated insights into how innovation processes can be organised or managed. However difficult and untraditional it might seem, there are positive examples of how murmuration processes can take place in practice. Returning to the Norwegian architect who introduced the image of the birds, she represented a successful, innovative, sustainable construction project where a murmuration-like process had enriched the project. The key aspect in that case was the formation of an alliance, a group of interdisciplinary companies including architects, engineers, contractors, suppliers, researchers etc., where extraordinary interactions across traditional disciplines and phase boundaries were accumulated in order to design and construct an innovative, sustainable building. Such alliances, where murmuration is not only possible but also encouraged, utilise the diversity of the construction industry and the opportunity of 'knowing the flock', as highlighted at the workshops.

Finally, the murmuration metaphor shed new light on how the sustainable transition of the construction industry can be supported. Connecting to the MLP, the Murmuration metaphor generates an illustrative description of the collective movement of innovation niches that potentially can influence and change the existing industry. Seeing the niche processes as murmuration generates an understanding of the dynamic and arbitrary aspects of such processes, emphasising that even though the movements seem chaotic and time-consuming, there is an underlying logic in that myriad of niche activities that in the end, and with the right support, potentially can accelerate the transition process. The murmuration understanding challenges and supplements the traditional migration approach found in many policies that tend to focus on implementing disciplined systems such as, for example, sustainable certification schemes. This linear, migration-like approach is unquestionable useful and valuable; however, there might be a noticeable gain by implementing strategies that encourage both migration and murmuration processes. As the workshop practitioners said, murmuration can be a tool for finding the destination, and migration is for reaching it.

## **CONCLUSION**

The purpose of this paper was to gain a better understanding of the sustainable innovation processes that lead to a transition of the construction industry. Inspired by an empirical observation, we have unfolded the potential of applying murmuration, i.e. the collective movement of starlings, as a generative metaphor for understanding innovation processes in sustainable construction. Introducing the metaphor to construction practitioners at two interdisciplinary workshops showed that seeing innovation processes as murmuration generates new understandings and fruitful discussions on why innovation in sustainable construction is difficult and how it can be done in practice. Furthermore, the Murmuration metaphor contributes to the MLP framework by illustrating the dynamic interactions that take place in and between niches in the movement towards sustainable transitions.

We realise that the murmuration metaphor is a new and rather creative addition to the fields of innovation and transition research. However, murmuration is not only an idealistic approach; it can be performed in practice. Having said that, we want to make it clear that the metaphor should not be used literally, and we further acknowledge that it does not - yet - provide a precise formula on how to organise and manage innovation activities. Further research on the configuration of innovation



processes is needed in order to clarify the theoretical aspects of how innovations take place and particular how niche innovations interact and collectively influence the transition of a regime. In addition, we call for further studies of successful innovation projects within sustainable construction to understand how innovation processes can be organised and managed in practice, and thus add further operational aspects to the murmuration metaphor. The murmuration metaphor is only at its infancy, and much more unfolding, elaboration and coupling to empirical cases is needed to create a solid contribution to existing knowledge. Still, we sense a significant potential for murmuration to open up discussions and to generate a holistic and fruitful language for both practitioners and researchers to support and accelerate the sustainable transition of the construction industry.

## REFERENCES

- Alvesson, M (2002) *Understanding Organizational Culture*, London: SAGE.
- Ballerini, M, Cabibbo, N, Candelier, R, Cavagna, A, Cisbani, E, Giardina, I, Lecomte, V, Orlandi, A, Parisi, G, Procaccini, A, Viale, M and Zdravkovic, V (2008a). Empirical investigation of starling flocks: A benchmark study in collective animal behaviour. *Animal Behaviour*, 76(1), 201-215.
- Ballerini, M, Cabibbo, N, Candelier, R, Cavagna, A, Cisbani, E, Giardina, I, Lecomte, V, Orlandi, A, Parisi, G, Procaccini, A, Viale, M and Zdravkovic, V (2008b) Interaction ruling animal collective behavior depends on topological rather than metric distance: Evidence from a field study. *Proceedings of the National Academy of Sciences*, 105(4), 1232-1237.
- Berker, T (2010) Dealing with uncertainty in sustainable innovation: Mainstreaming and substitution. *International Journal of Innovation and Sustainable Development*, 5(1), 65-79.
- Berkhout, F, Stirling, A and Smith, A (2004) Socio-technological regimes and transition contexts. System innovation and the transition to sustainability. *Theory, Evidence and Policy*, 44(106), 48-75.
- Bialek, W, Cavagna, A, Giardina, I, Mora, T, Silvestri, E, Viale, M and Walczak, A M (2012) Statistical mechanics for natural flocks of birds. *Proceedings of the National Academy of Sciences*, 109(13), 4786-4791.
- Brown, R H (1976) Social theory as metaphor: On the logic of discovery for the sciences of conduct. *Theory and Society*, 3(2), 169-197.
- Bygballe, L E and Ingemansson, M (2014) The logic of innovation in construction. *Industrial Marketing Management*, 43(3), 512-524.
- Cheng, Y-T and Van de Ven, A H (1996) Learning the Innovation Journey: Order out of Chaos? *Organization Science*, 7(6), 593-614.
- Couzin, I D, Krause, J, Franks, N R and Levin, S A (2005) Effective leadership and decision-making in animal groups on the move. *Nature*, 433, 513-516.
- Dubois, A and Gadde, L-E (2002) The construction industry as a loosely coupled system: implications for productivity and innovation. *Construction Management and Economics*, 20(7), 621-631.
- Fuenfschilling, L and Truffer, B (2016) The interplay of institutions, actors and technologies in socio-technical systems - An analysis of transformations in the Australian urban water sector. *Technological Forecasting and Social Change*, 103, 298-312.
- Geels, F W (2002) Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, 31(8-9), 1257-1274.

- Gibbs, D and O'Neill, K (2015) Building a green economy? Sustainability transitions in the UK building sector. *Geoforum*, 59, 133-141.
- Grin, J (2010) Understanding transitions from a governance perspective. In: J Grin, J Rotmans and J Schot (Eds.) *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*. New York: Routledge, 223-319.
- Harty, C (2008) Implementing innovation in construction: contexts, relative boundedness and actor-network theory. *Construction Management and Economics*, 26(10), 1029-1041.
- King, A J and Sumpter, D J T (2012) Murmurations. *Current Biology*, 22(4), 112-114.
- Lachman, D A (2013) A survey and review of approaches to study transitions. *Energy Policy*, 58, 269-276.
- Martiskainen, M and Kivimaa, P (2017) Creating innovative zero carbon homes in the United Kingdom - Intermediaries and champions in building projects. *Environmental Innovation and Societal Transitions*, 26, 15-31.
- Morgan, G (1986) *Images of Organization*. London: Sage Publications.
- Nykamp, H (2017) A transition to green buildings in Norway. *Environmental Innovation and Societal Transitions*, 24, 83-93.
- O'Neill, K J and Gibbs, D C (2014) Towards a sustainable economy? Socio-technical transitions in the green building sector. *Local Environment*, 19(6), 572-590.
- Den Ouden, E (2012) *Innovation Design: Creating Value for People, Organizations and Society*, London: Springer.
- Rip, A and Kemp, R (1998) Technological change. In: S Rayner and E L Malone (Eds.) *Human Choice and Climate Change*. New York: Battelle Press, 327-399.
- Schot, J and Geels, F W (2008) Strategic niche management and sustainable innovation journeys : Theory, findings, research agenda and policy. *Technology Analysis and Strategic Management*, 20(5), 537-554.
- Schön, D A (1993) Generative metaphor: A perspective on problem-setting in social policy. In: A Ortony (Ed.) *Metaphor and Thought*. Cambridge, UK: Cambridge University Press, 137-163.
- Slaughter, E S (1998) Models of construction innovation. *Journal of Construction Engineering and Management*, 124(3), 226-231.
- Smith, A (2007) Translating Sustainabilities between Green Niches and Socio-Technical Regimes. *Technology Analysis and Strategic Management*, 19(4), 427-450.
- Smith, A, Stirling, A and Berkhout, F (2005) The governance of sustainable socio-technical transitions. *Research Policy*, 34(10), 1491-1510.
- UN Environment and International Energy Agency (2017) *Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector. Global Status Report 2017*. Global Alliance for Buildings and Construction/ UN Environment and International Energy Agency
- Winch, G (1998) Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research and Information*, 26(5), 268-279.
- Young, G F, Scardovi, L, Cavagna, A, Giardina, I, and Leonard, N E (2013) starling flock networks manage uncertainty in consensus at low cost. *PLoS Computational Biology*, 9(1).