NAVIGATING SUSTAINABLE TRANSITIONS CONSIDERING UNCERTAINTIES AND EVOLVING GOALS/MEANS

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Abstract: Sustainable transitions are at the core of engineering design and in societal discourse of how to deal with climate and socio-economic challenges. As natural and societal conditions are different from place to place and are continuously changing transitions processes are to take place considering uncertain futures and changing pairs of goals and means.

To cater for this the focus in training of professionals within engineering and design as well as in economic/policy topics must take into account the lack of finite metrics and operate with navigational approaches that need adjustments as part of the process. The character of uncertainties and consequentially the challenges to stage actor-configurations and navigate changes are core to this presentation.

Based on results from studies of historic and contemporary transitions and their aspirations to achieve sustainable solutions as well as experiences from training design-engineers specialized in sustainable design the paper will present models of the mapping of arenas of development and how to navigate within and across these arenas. The paper concludes in outlining learning programs based on the navigational approach to sustainable transitions.

1 INTRODUCTION

Sustainability issues have gained increasing attention in research and teaching activities since the publication of the Brundtland report (Brundtland, World Commission on Environment and Development 1987). However, the meaning of the notion sustainability is contested and when used as a qualifier in relation to educational programs it is quite important to identify the more specific educational topics and practices involved.

Over the past 20 years, engineering educators have struggled to include sustainability in engineering education. Should sustainability be a fundamental aspect of all educational programmes or is it a subject matter that needs to be addressed specifically on its own programs? Does sustainability lead to completely new technical approaches and theories or does the challenge translate into new requirements that may condition but not fundamentally change the existing technical disciplines and specializations.

These discussion at engineering institutions demonstrate that the challenge may be rather fundamental to engineering knowledge and practice (Mulder, Segalas-Coral & Ferrer-Balas, 2010). The promoters of the view that it should be a fundamental aspect and thus not a new additional educational program or an additional course argue that the sustainability challenge is pervasive and does ask for new ways of conceiving engineering and technology. The search for sustainable solutions results in basic new design concepts and new technologies that challenge dominant part of engineering disciplines and knowledges tha have supported what is considered an overly resource and energy consuming technological society that both economically, socially and institutionally will have to change.

These considerations are in line with developments in engineering for sustainable development that have proven institutional mere policy driven promotional approaches to be inappropriate at research universities. Researchers and lecturers cannot be motivated to incorporate sustainable development principles in their courses and research, unless they develop a thorough understanding of its importance, the way the sustainability challenge influence their speicific field of knowledge which also demands a considerable work on curricular development (Kamp 2006; Mulder, 2006).

2 EDUCATIONAL RESPONSES TO THE SUSTAINABILITY CHALLENGE

To investigate how to incorporate sustainable development into engineering, a historical study of how the environmental challenge that resulted from the intensification, the new technologies and the growth resulting from the 1960s and 1970s radical change of the industrial society have been taken up in engineering science and education during the past four decades at the two main engineering schools in Denmark (The Technical University of Denmark and Aalborg University).

One contribution to this change was a pedagogical reform that was part of the foundational concept of Aalborg University (AAU) when established in the mid 1970s. The reform made project assignments a core part of each semester in all educations. This meant, in turn, that Aalborg graduates have been appreciated for their capacity to search for and identify new knowledge and solve problems, and has also fostered their entrepreneurial capacity and their ability to step into the practice of engineering firms and consultancies more easily than often is the case with new engineering graduates.

Some engneering programs at AAU maintained a focus on wastewater treatment with the classical technical hygiene perspective, indoor climate, sanitary systems, waste water handling as well as focusing on specific types of energy technologies, their optimisation and energy savings in low-energy buildings. In these parts of the AAU engineering programs following an engineering science tradition, the pedagogical reform has provided an improved understanding of the daily challenges and practices within existing engineering businesses. However, it has not provided an integration of knowledge and practices that favour a focus on societal challenges to the same degree as can be seen within the new environmental and energy planning programs that were established as part of the inter-disciplinary strategy of the new university which were concerned with urban, energy and transportation planning. During the 1980s thes programs also began to incorporate issues of technology and society studies, environmental assessment and strategic planning. In both cases, engineering students were trained in the same basic, core competencies of mathematics and physics but specialised either in more technical disciplines or topics related environmental planning and management or energy systems modeling.

Growth in the number of students, the adoption of the Bologna process of the EU leading to a devide of educations into bachelors and masters programs, and the internationalization of master programmes in Denmark encouraged engineering educators to attract more students. Thus, separate master programmes in Environmental Management (2000), Urban Planning and Management (UPM) (2000), Sustainable Energy Planning and Management (SEPM) (2004), Sustainable Cities (2012) and Sustainable Design (2013) were developed. These programs all folowing the inter-discplinary strand of the engineering field seen as the specific contribution and characteristics of Danish engineering educations were all taught in English and gave the relatively small amount of Danish bachelor students the opportunity to become part of an international study environment that attracted students from several continents.

At the Technical University of Denmark (DTU) similar developments can be observed, but also some differences. The influence that students' achieved during the 1970s resulted in the creation of two new departments concerned with social science and ecology that introduced new courses into the modular structure of engineering education installed in 1972. Their research bases were disciplinary; the one combined ecological perspectives with assessing chemical pollutants and climate change issues, while the other brought sociological and economic perspectives on technology into engineering. What was novel about these initiatives was that they enforced demands and challenges articulated in the broader societal discourse over engineering education, However,.when during the late 1980s a new program of Environmental Engineering was developed its main focus was on traditional topics like water provision,

wastewater and soil. Many other activities that addressed environmental, energy and social issues in a more comprehensive ways were not integrated into this new education.

Questions concerned with the lack of integration and impact of societal issues and challenges on engineering competences and led to the creation of two additional, temporary units during the early 1990s: the Interdisciplinary Centre and the Technology Assessment Unit. The Interdisciplinary Centre was mainly concerned with the contamination of food in the production process, new strategies for organic food production, and the overall pollution from industry by looking at lifecycle of materials and products. The Technology Assessment Unit was instrumental in introducing Science and Technology Studies (STS), including new approaches to understanding innovation, technologies relation to society, as well as the foundation of engineering knowledge and practices.

Resulting from frustrations over the lack of effects of the enforcement of the Danish environmental laws from the 1970s, a number of professional engineers, consultants, regulators and engineering researchers began shifting the focus from dealing with pollution and emissions fighting the origins of these in the production processes. The results were the concept of Cleaner Technology and the life cycle assessment methodology (Wenzel, Hauschild &Alting, 1997). In combination with the focus on company management and practices as the origins of pollution and resource consumption this lead new research-based courses developed for the educational programmes in Mechanical Engineering and Chemical Engineering, which also included the teaching of topics within the field of production processes. These courses combined technical subjects on specific cleaner technologies with management courses focused on procedures and practices for improving the ways companies should handle environmental concerns.

Despite the successful research initiatives addressing environmental issues as integral part of production, organizations and society at large, they remained electives not being a core element of environmental engineering at DTU. This seems to reflect the strong impact of the existing engineering disciplinary knowledge. While the main focus on environmental issues stayed within the frame of pollution (especially water related), some new field of engineering concerns and domains of practices entered the realm of production and management engineering. As a general concern the environmental discourse remained a topic for specific courses within production and management programs and did not enter the engineering educational programs at large as cross-cutting subject. In comparison to the situation at AAU where the energy and environment was taken op as elements of planning the main focus outside classical environmental engineering at DTU was on production engineering and management.

Similar to AAU, DTU has developed new engineering programs emphasising

The content assigned to sustainability and environmental issues may entail quite different interpretations concerning the competences and knowledge needed by engineers. While in some educational programs sustainability cover a specific set of metrics, methods or technically preferred solutions, it may in others include a broader perspective on how societal planning can be performed in a more interactive and integrative fashion. Or it may raise demands for engineers to be able to analyse societal challenges that include all facets of sustainability making them able to navigate, design and give advice on the choice of technologies and how they are to be implemented.

At DTU, like AAU, the university management has been keen on inscribing sustainability in their vision and strategy for research and education. But what this implies for the specific demands to programs in general, to specific educations, and for research priorities remains open for interpretation at the individual departments and in the different educational programs. In some educational programmes at DTU, as well as at AAU, sustainable simply has been added to almost traditional engineering topics to improve their market credentials. In other cases, the sustainability perspective is transformed into courses and project assignments that include new methods and approaches that extend the knowledge base of engineering.

Research and planning in relation to energy systems has for several decades been an field in Denmark involving grass-root movements, authorities at the municipal and regional level, as well as ministries and regulatory bodies. In engineering education the interactive character has been translated into a focus on energy systems models and what they demand from institutions and policy to build the new energy infrastructures.

One of the arguments for the new program at AAU in Sustainable Cities has been that independent planning activities in isolated sectors has to be substituted by cross-sectoral perspective. Still the Sustainable Cities programme is based on a combination of courses presenting existing methods and metrics, including some of their disciplinary background, in combination with of project and problem-based learning.

The new engineering program at AAU in Sustainable Design is working with different societal actors in setting the stage for sustainable change and broader transitions, which challenge existing technological products, models and systems. This provides the students with analytical tools to handle the uncertainties, the interdisciplinary and socio-material integration inspired by STS (Science and Technology Studies), and the new models and solutions needed as part of their engineering design work. Sustainability within this educational approach is as much a part of the design challenge as the technical products and systems that are to be designed.

Though AAUs focus on students' problem and project based learning (PBL) not per se delivers the theoretical and methodological framework to handle these challenges, it has provided space for the incorporation of a comprehensive definition of sustainability and not just a narrow set of problems, techniques and metrics (Mulder, 2006; Steiner and Posch, 2006).

3 ENGINEERING METHODS, MODELS AND CONCEPTS

Several methods have been developed to support engineering in making improvements to technologies impact on the environment, to minimize the use of energy and resources in housing, products, etc. and to seek new ways of delivering services with reduced environmental impact.

First, the continuously increasing knowledge on the impacts of substances and the disposal of products on nature and the ecologies of species and basic circulation of e.g. water and carbon has provided an increased number of models helping to understand the flows. Specific knowledge of the accumulation of certain either toxic substancies or substancies that challenge the balance of the ecosystem and/or the climate. The responses to these new forms of knowledge has been to bring this into the engineering curriculum.

Second, the concept of Life Cycle Assessment (LCA) based on following the flows of materials and energy has lead to the building a model, that has helped in assessing how products impact the invironment not only during production, but also in the use and waste phases. These models have been extended to include the role of different actors in each of the life phases of the assessed product or system as designers, managers and othwise involved in delegating agency to the actors and elements and how these phases have impact on society. The life cycle assessment models have with lesser success tried to integrate e.g. social aspects of sustainability, but these are much more directly related to the core of the LCA model – the flows over time of materials.

Third, the LCA model has been used in strategic policy measures and in company strategies with the aim of reducing the 'footprint' of products and processes. The LCA models have also been used as a guiding framework concept within cleaner technology and cleaner production programs. As a strategic tool, LCA has demonstrated its strength, but in the detailed design practices and in relation to environmental strategies in companies the cost of setting up an LCA has turned out to hampering the use of the models in practice. It seem to demands to many detailed informations on flows and environmental impacts making it more usefull as a tool for navigation that for detailed calculation and optimization.

Fourth, new concepts that focus on reducing impacts like eco-efficiency, green growth, product-service-systems have been leading to more modest ideas that fit into the recent decades focus on innovations and guiding these by e.g. using principles from LCA in a more sutainable direction.

Recently, new ideas that present more radical version of the cleaner technology and clearner production programs have surfaced. These are e.g. Cradle to grave and the even more promising Cradle to Cradle

concept and the vision of a circular economy. All drawing on the LCA model but promising to deliver strategies for minimizing the impacts on environment and climate.

All these concepts have in common a focus on primarily the environment and climate impacts of technology and less taking into the account the social, political and developmental aspects. They also operate from the assumption that sustainable solutions can be calculated and optimized within a model univers building on materials and energy flows. No doubt that these tools and models provide important metrics for engineering, but they lack the dimensions of social change, design, intervention and implementation that is crucial for sustainable transitions (Segalas, Ferrer-Balas, & Mulder, 2010).

4 NAVIGATING TRANSITION ARENAS

To make operational design engineering in analytical as well as in performance terms the challenge of contributing to change in a basically uncertain future not only knowledge of environmental impacts and technological operations given a social and institutional support and maintenance structures are needed. The conditions for change are defined by a quite a set of actors of which some are performing societal actors others are the results of climate and environments response to socio-material longer term changes. The conceptual framework needed has to cope with the resulting uncertainties and consequently the non-linear and rather wicked problem solving situations. These challenges imply evolving changes in the goals and means of what are considered proper solutions that move change in a sustainable direction and even support more profound transitions of the socio-material orders of society and its use of technology. Such an actor-centered framework is the arenas of development framework presented in the following.

Arenas of Development are shaped as well as delimited by the actors engaged in shared matters of concern related to the socio-material ordering of society and technology. This may involve controversies over future routs to be taken and the related attempts to order and stabilize such change pathways. It also may include consensus or co-existence making change possible. What guides actors' involvement and actions are shared, aligned or contested matters of concern that shape the arena through the performed action and controversies and the implied work defining the boundaries of the arena (Jørgensen 2012).

The communality of the matters of concern within an arena is delimited by the socio-material constituencies that result from the performed interventions of the actors. When scholars want to name certain dynamics that involve several conflicts and discussions in a given process they use notions like field, domain or arena. While fields and domains has a focus on the investigation respectively on the ordering of actions, the concept of arena in this theory intends to nominate that what is being discussed or worked upon and the set of actors that are involved in the process. The matter of concern, however, is never defined in any final, singular, and unitary form – it is continuously under scrutiny. It is open, multiple and heterogeneous. Actors invest energy and work in debating and defining what the problem is and which types of solutions that might be of relevance.

Arenas of Development can be identified through something that is being designed, debated, and often controversial: a transport system (Pineda 2009); a television standard (Jørgensen & Sørensen 1999); a energy sector change (Jørgensen & Strunge 2002); or a re-conceptualization of hygiene (Jørgensen).

Central to an arena are the performances of actors that stage the basic presence (participation), engagements and interventions on the arena. These can be negotiations, structuring and promoting certain visions, installing new technologies, changing regulations, and many other ways of attempting to produce order. Some actors are trying to organize themselves and other actors in the arena through any of these strategies. At any given point any actor is both making an organizing effort and also being subject to other actors' organizing efforts. Within an arena innovations are the work of actors who successfully manage and work on relations of different natures by way of networking, recruiting, stabilizing, and destabilizing relations that involve other actors. While the primary focus in the analysis of an Arena is on presence and performance, actors who attempt to engage with other actors in the Arena

should be included in the account even if deliberate action leads to their exclusion (Jørgensen & Sørensen 1999).

Put in another way, arenas comprise of a socio-material space populated and furnished by a number of different actors that all are involved in building the agency and the development path of the Arena. Any actor whether human or non-human who is performing (being actively present) on the arena is consequently also involved in shaping the arena regardless of their size, scale or location. During the development of an arena, some relations within the arena may stabilize and become obdurate. They may even become black boxed and consequently the relations are taken for granted and will not be objects for controversy or discussion any more. They become undisputed reference points and might take the form of e.g. inventors, institutions, standards, legal frameworks, design features, infrastructures, etc.

The framework operates from the outset with a 'flat approach' that does not make any a priori assumptions about the nature and position of involved actors and influences inspired by contributions from the field of STS (Science and Technology Studies). Thus, through emphasising the flux and temporality of social processes it also views social action through the lenses of performance and continued re-construction (re-production). Arenas are temporal, reflecting the socio-material processes in flux. Arenas are therefore not confined to traditional social science attempts of social structure and orderings. Neither are they in line with traditional engeneering education conceptions is of problem solving working within given technological concepts and solving rather well defined problems. Instead it traces the actions performed by actors and aims at understanding how they engage in controversies, build alliances, align, interact and interrupt existing relations to sustain relations or produce change. The social-material order is – to pinpoint the consequence of this approach – the outcome, not the structuring frame of actors' performances on arenas.

An example of a transition is the building of the modern, technological infrastructures of the city that had a tremendous impact on the growth and the potential of the city as the place for industrial development and further improvement is a matter of fact. But how this achievement was reached and what this transformation entailed cannot be explained within an either socio-political or in technological framework alone. It entails a broader change in the socio-material configuration that incude as one element the hygienic transformation of the city as a core matter of concern for the arena instrumental for framing and setting this change in motion. While a focus on the technologies involved may show the importance of the water supplies and wastewater handling or even the other infrastructural changes involved, it does not emphasise what made possible a complete remake and further growth of what socially, politically, and in terms of health was viewed as an evil. The arena in this case included a remake that comprised of the building of new professions, the creation of infrastructures, a political revolution concerning the involvement of citizenship, and a change in what was considered healthy and hygienic.

What makes this relevant in contemporary challenges of sustainability is the new role that infrastructures in society plays not as simple commodified areas of service and supply but as features structuring new fields of innovation. These fields overcome the singularity and efficiency visions related to e.g. visions of green technologies or green innovations just projecting the neo-liberal market institutions and the ideas of technology as progress into the future.

Another example is the growing car dominance over transport systems seem as well to be a matter of fact, though the transformation of mobility and the transport systems that have been the result does not simply reflect the dominance of cars. On the contrary it demonstrates a continued controversy over the achievements and consequences of this transport technological revolution. Not least due to congestion, especially around urban areas, the private car has never reached the dominant position as a means of transportation that it seem to have in the imagery of a means of freedom and mobility. The reason for this seem not least to be the continued controversy over mobility rights and costs as well as the controversy over the qualities and impacts of private car transportation.

The interior as well as the boundary of an arena are co-produced by actors' decisions and navigations (i.e. performed strategies). Other concerns and arenas can be acknowledged by actors in an arena, but these are part of the boundary constitution unless they do not, through performed actions, create presence on the specific arena in question. These performed practical actions whatever means of

engagement they may involve are identified as the navigations of actors. All such navigations are at the outset based on a limited, incomplete understanding of the arena.

In some cases, the re-structuring of arenas result from clashes between arenas and boundary crossing controversies. This point to the obvious co-existence of arenas with different matters of concern and different actor constellations, but in many cases without important inter-actions. Controversies that hitherto were marginalized and black-boxed as boundary objects not core the performances on the arena enters or re-enters as entities to be included within the matters of concern.

The challenge to engineers working with sustainable design issues – it be products, services or systems – is to learn to navigate on the relevant arena or arenas. It is basically a challenge that has to do with the combination of the ordering resulting from successful design work and the uncertainty related to the sphere in which the design has to be functional it be the actors support and accommodation of the design solutions and the changing conditions and environment it has be operational within. The challenge could be seen as either an anything goes situation, based on the idea that the arenas are in flux and malleable, or as an unsolvable wicked problem due to the uncertainties facing the design process. Neither position is operational. Both tend to simplify the challenge to engineering. The first overlooks the hardness and dependencies of the involved actors performance and the need to recruit, involve or even sometimes exclude actors and institutions to produce working designs. The second withdraws engineering from the virtue of producing new designs that helps sustainable transitions to happen.

Navigation is within this approach defined by design actions (the performed interventions) that engineers and other actors can engage with. To navigate means to be able to perform, act and propose designs the enact change within an only partially structured configuration of actors with somehow shared ideas, values or maybe even just in agonistic terms practical interests. To avoid doing this either ideasticly by ignoring other actors and arenas this implies an approach capable of mapping and analyzing the conditions for doing design and a capability to stage change processes. This is the topic of the next section.

5 LEARNING TO NAVIGATE WITHIN UNCERTAINTY

The arenas and navigation approach provides an analytical framework to produce maps of socio-material configurations in flux. Such maps are per se not singular, nor static but provide a framework from which the changes and movements among actors related to their performance, their articulation of matters of concerns, their relations within socio-material networks and the resulting changes in institutional configurations. Due to the uncertainty, such a mapping can never become complete, but it is possible to substantiate the maps and the dynamics they present to a level of confidence where it provides a basis for action in relation to other actors.

Based on such mapping some tools or methods commonly known and developed for a number of different purposes can be employed to help outline the impacts of actions and to help define the intervantions that a group of actors can choose as their intentional strategy for change – their performance on the arena. These tools are a combination of developing design concepts and the use scenarios to outline the staging and intervention following the concept into test and use. The scenarios can help identifying the concepts anticipated impacts over time.

The next step is then to provide a critical analysis of how the changes will perform in relation to a number of stuainability criteria and to make choices among the involved actors concerning their specific pathway of action. The critical analysis of the sustainability challenge does not present a singular and integrative measure of sutainability as the critical analysis itself will demonstrate elements of uncertainty that the actors will have to oversee and make choices about in the way they choose to navigate.

By employing these elements into sustainable design the uncertainties do not become eliminated, but their existence and impact does not render the mere attempt to navigate and to improve products, services and systems in a sustainable direction either rationally impossible or random.

Acknowledgements

This article builds on studies of engineering programs done in PROCEED: 'Project on the opportunities and challenges to engineering educations in Denmark' done in cooperation with Andrés Valderrama and Søsser Brodersen and experiences achieved from building and teaching design engineering in the programs on Sustainable Design and Sustainable Cities at Aalborg University in Copenhagen.

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