Industrial Revitalization and Complex Adaptive Systems: A framework for exploring the context of collaborative planning

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Abstract

Although planning support systems (PSS) are meant to facilitate the implementation of innovative social or technological urban solutions, usability studies show a bottleneck in the adoption of these IT systems. One explanation is that IT developers are too far removed from the planning environment. Therefore, they lack important contextual knowledge concerning the diverse interests that steer the interactions of growing numbers of stakeholders in their response to economic and environmental uncertainty. Consequently, practitioners perceive PSS designs to be too technical and not sufficiently responsive to their needs for adaptability and process integration.

This paper aims to better inform PSS design through a method that explores conditions of high complexity and uncertainty in industrial revitalization projects. By applying the three main principles of complex adaptive systems (CAS) theory – agents, their interactions and the environment within which they interact – we identify the individual contextual variables that create a collective landscape of uncertainty and complexity, and we reveal the need for planning practitioners to respond flexibly to changes in the planning environment. We use these CAS principles to analyze the collaborative planning process of an industrial revitalization project on the Dutch-German border. Outcomes from this exercise suggest that key stakeholders seek to balance power imbalances for the purpose of collaboration; through balanced dialogue, key stakeholders can turn potential threats to collaboration into creative new ideas; identifying stakeholder interests in specific tasks can help to organize effective forums for collaboration and pre-existing physical, social and regulatory structures largely determine early-stage planning objectives. These findings represent key contextual knowledge to inform PSS design in promotion of practitioner adoption.

Keywords: complex adaptive systems (CAS), industrial revitalization, collaborative planning

1. Introduction

In recent decades, the decline of heavy industry and the proliferation of business and technology parks in parts of Europe have resulted in the underutilization of industrial terrains. These terrains often consume precious land resources in strategic locations near urban areas or major transport routes, which is why authorities should prioritize reinvestment in these areas over further land exploitation. Due to the variables involved, developing plans for these spaces is a highly complex and context-specific process. Consequently, delays often occur in revitalization planning especially during early-stage tasks that include project exploration, objective setting and scenario development.

Planning support systems (PSS) are computer-based tools dedicated to supporting planning within the context of specific tasks (Geertman, 2006). However, numerous studies indicate reluctance on the part of planners to adopt these systems into practice. Planners generally consider these descendants of geo-information systems (GIS) too generic, technology oriented and incompatible with needs for system integration (Geertman & Stillwell, 2004; Te Brömmelstroet & Schrijnen, 2010). Successfully integrating these systems into planning processes will require socio-technical approaches to design that consider the context of PSS use (Te Brömmelstroet & Schrijnen, 2010; Vonk & Ligtenberg, 2010).

Planning processes consist of a common set of variables such as actors, activities, regulations, flows, constraints and opportunities (Hopkins, 1999; Vonk & Ligtenberg, 2010). These variables change as they interact over time to form what we call contextual variables. Since contextual variables are in a constant state of flux, it is important to identify them and their interactions according to planning task. The aim of this paper is to develop a framework that identifies contextual variables and their interactions within a specific planning task. We use complex adaptive systems (CAS) theory to study interactions within stakeholder networks in revitalization projects and to observe how contextual variables impact these

processes. This study fits into a broader line of research to inform the design of PSS in a collaborative setting.

The structure of this paper is divided into six sections. The next section introduces complex adaptive systems theory. In Section 3, we construct a framework for exploring the context of collaborative planning using CAS theory. This framework is then applied to explore early-stage planning tasks in an industrial revitalization case study. Section 5 presents a discussion of the case-study findings, which are followed up in the conclusion by a brief discussion concerning the limitations to the framework and suggestions for future research.

2. Complex adaptive systems theory

A complex adaptive system (CAS) is a network of *agents* and their linkages that is emergent, dynamic, evolving and that has the ability to self-organize (Choi et al., 2001). CAS theory is an analytical tool that explains the emergence of patterns at a systems level from local *interactions* (Lansing, 2003). Researchers claim the theory may explain the emergence of order from complex, seemingly chaotic *environments*. CASs exist at the edge of chaos (Langton, 1990) somewhere between chaos and equilibrium. If a CAS has reached equilibrium and is therefore stable, it is no longer capable of adapting to change. If the CAS is chaotic, it is incapable of finding productive patterns. If conditions of complexity exist, it is possible to improve the performance of CASs. Consequently, a CAS is greater than the sum of its parts because the system can adapt and change according to information that it gathers from its environment (Innes & Booher, 1999). The following subsections introduce key concepts to the CAS theory used in this paper.

Distinguishing between system and environment

The three principles of CAS theory highlighted above have helped researchers to understand complex phenomena in contexts from natural to technology environments. However, researchers organize these components differently to emphasize different interactions. For the purpose of this study, we delineate between the CAS, which consists of a specific set of interacting agents, and its environment (See Table 1). Doing so creates a clear distinction between the internal and external interactions of the CAS. In terms of external interactions (i.e. between the CAS and the environment), changes enforced on the CAS by the environment, "in turn induce changes in the environment" in a feedback loop (Choi, Dooley, & Rungtusanatham, 2001, p. 356). As these interactions play out over time, the CAS and its environment co-evolve.

Table 1. Complex Adaptive System Theory Principles

CAS Principles	CAS Description
Agents	Basic entities of action who act or react to other agents and the environment
• Attributes	Individual differences that determine fitness
• Behavioral rules	Schema that determine agent behaviors and attributes
Interactions	Mutually adaptive behaviors between agents
• Linkages	Paths of resource movement and level of connectivity it provides
• Flows	Movements of resources through agent networks and through system interactions with the environment
Environment	Is external to the CAS of focus and consists of other interacting agents and contextual variables that influence the CAS
• Dimensioning effect	The freedom of variation that the environment provides
• Complexity factor	Optimal fitness of the CAS is reached through high interdependence. The reverse is often the case for the environment as a whole

Agents, interactions and the environment

Agents interact according to schema that dictate their linkages with other agents and determine their internal characteristics, called attributes. These attributes serve as yardsticks for agent fitness, which is the ability to "achieve a positive payoff" (Nan, 2011, p. 508). Linkages describe the paths of resource flows

during agent interactions. Agents create linkages through their mutually adaptive interactions. This means that interactions both emerge from and influence agent behaviors (Lansing, 2003). Interactions also frequently occur between these linked agents and the environment, which is the larger institutional and cultural context that defines and confines the CAS. Complex environments have both strong dimensioning effects that create variety among their variables and a complexity factor that determines the level of interdependence among variables (Choi et al., 2001; Kaufmann, 1995). This variation and interdependency is what gives a complex environment the capacity to improve its overall fitness. In this study, we describe a CAS in terms of the multiple feedback loops that occur within an environment – those between agents within a CAS and those between the CAS and the environment. We explore these feedback loops after an introduction of the CAS framework in the next section.

3. The CAS Framework for Exploring Collaborative Planning

The proposed CAS framework creates a conceptual model of complex collaborative planning processes to examine indispensable contextual variables and their interactions. The framework builds on analytical methods used by planners in projects to manage stakeholders, identify opportunities and constraints, and weigh the costs and benefits of decisions. These analyses occur iteratively throughout the planning processes allowing the CAS framework to extract variables from a selected planning task, such as objective setting. The framework integrates the contextual variables from these methods to create a global view of the planning task. Placing information within a single assessment framework provides a holistic, structured way of exploring the context. Additionally, the framework explores the linkages between contextual variables, not just the variables themselves. In doing so, it deepens understandings of collaborative planning processes as complex systems without requiring a complete revision of existing evaluation methods.

Paralleling CAS theory, the contextual variables in a planning task fall under three main categories: (1) stakeholder networks, (2) the planning environment within which they interact and (3) resources that flow among them. However the intended purpose of constructing a CAS framework is additionally to reveal forums for stakeholder communication, power structures, resource flows, and the engagement of certain stakeholders at certain times in the process. Stakeholder networks can be defined in many scales and dimensions. Municipal planners, investors, environmental agencies, civic organizations, regional authorities, to name a few, create a complex web of stakeholder networks, or stakeholder CASs. These networks collectively create "white noise" that often makes it difficult to sort out the cause-effect relationships that drive planning forward. The CAS framework is capable of filtering out dispensable information by identifying the intensity and symmetry of interactions between variables. These two characteristics are used to define a central stakeholder CAS, which subsequently defines the environment surrounding it.

The planning environment contains contextual variables that are external to the central stakeholder CAS. It consists of regulatory instruments, stakeholders that are external to the CAS, physical structures and socio-political norms. These contextual variables impose new schema on the CAS, thereby altering its state. Collaborative planning processes consist of high interdependencies between variables both internal and external to the CAS. For example, although stakeholders within a given CAS may be the main decision makers on a project, they are also significantly more involved with external stakeholders like citizen or environmental groups than in normative models of planning. The behavioral rules and attributes of stakeholders under observation provide information that reflects why certain stakeholders interact. This helps us to predict their capacity to both induce and adapt to changes in the planning environment. We hypothesize that the understandings of variables and their interactions provided by the CAS framework may empower planners with the capacity to predict, not just to react to changes in the planning process. To explore the utility of the CAS framework in exploring collaborative planning processes, we apply it in the following section to a revitalization case study.

4. Application of the CAS Framework in a Revitalization Case Study

The construction of the CAS framework involved an iterative design process that relied heavily on case study input and testing. The components of the CAS framework were adopted from operations management and management information systems literature that applied similar CAS frameworks to explore supply networks and IT use respectively(Choi et al., 2001; Nan, 2011). For the case study, we adopted an ethnographic action research (Hartmann, Fischer, & Haymaker, 2009) approach, which stresses an in-depth understanding of work routines to inform practice-oriented design. Following this methodology, we explored collaborative planning practices on a project that aims to revitalize and expand a 120-ha. industrial terrain situated between two cities on the German-Dutch border. We participated in project exploration and visioning workshops with project stakeholders, and we conducted sketch planning exercises with municipal planners and aldermen to set strategic objectives. To complement our practice-based findings, we referenced project documents and conducted retrospective interviews with seven municipal planners and alderman. The interviews focused on perceptions of stakeholder interactions and pivotal moments in the planning process.

We first used empirical findings from these exercises to establish our research scope and level of analysis. Since our framework should provide a holistic snapshot of the planning process regardless of stage or task, we chose to adopt the current planning task of the observed case study. At the time of observation, the project was undergoing extended project exploration and visioning tasks with the intention to set strategic planning objectives. Within this task, we identified a central network of bi-national municipal planners and aldermen who we refer to on a group level as the Dutch planners and the German planners. These planners interacted frequently with one another and with a group of nearly 120 local employers. The employers were either active in the existing industrial area or were interested in investing. We identified this network of municipalities and employers as the stakeholder CAS in this project.

Additionally, citizen groups, regional and local regulatory bodies, physical structures and other contextual variables from the planning environment set rules for interactions with and within the stakeholder CAS. Each of these variables is linked to other networks that have indirect influence on the revitalization project. Considering these links within this study would be unmanageable. Therefore, we limited the scope of the planning environment to only the contextual variables that directly interact with the stakeholders within the CAS. Figure 1 depicts the stakeholder CAS and its planning environment. We use this model to identify the feedback loop interactions within the CAS and between the CAS and its environment.

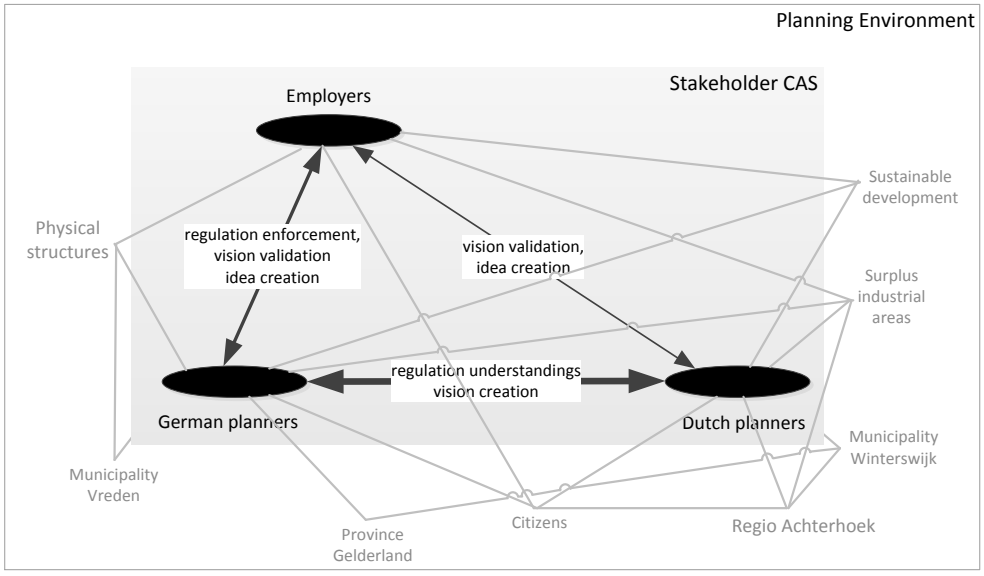

Figure 1. The Case Study Stakeholder CAS and its Environment

Interactions within the Stakeholder CAS

The CAS framework revealed the highest intensity of interactions between the German and Dutch planners. One statement in particular from a German planner exemplifies this, "because of this more intensive [collaboration] and through getting to know the structures of the other, we were able to orient ourselves more naturally within the Dutch political and societal system. This absolutely made the project possible." However, as Table 2 shows, the framework reveals asymmetries in both the content and intensity of exchanges. For example, the Dutch planners invest significantly more resources, particularly in terms of time, to create a cross-border revitalization vision that was attractive to their German counterparts. As a result, the Dutch planners have adopted the role of main driver in the project. As the main driver, the Dutch planners predominantly initiated communication with their German counterparts and organized workshops and symposia with the employers. Additionally, the framework revealed that planners and employers interact in the stakeholder network based on inherently different interests (or schema). The interests of the planners included visioning and idea creation, but also the administering of regulations introduced by the planning environment. These examples indicate that planners are interested in fitness at a system-wide level. This is not the case for the employers. They will adapt their behaviors according to regulations; however, they will not engage in a planning dialogue beyond the realm of self-interest.

Table 2. Framing Revitalization Environment as A Complex Adaptive System

CAS Principles	CAS Description	Application to Revitalization Environment
Agents	Basic entities of action who act or react to other agents and the environment	The Stakeholders: • Dutch and German municipal planners and aldermen who are the key decision makers on the project • There are more than 120 employers either already active in the industrial terrain or interested in investing
• Attributes	Individual differences that determine fitness	• Planners have high influence throughout the process and possess comprehensive knowledge of the planning environment • Employers have high influence on specific issues and have tacit knowledge of the planning environment
• Behavioral rules	Schema that determine agent behaviors and attributes	• Planners take decisions on ideas according to strategic vision and regulatory frameworks; seek to maximize system fitness • Employers support or reject ideas according to self-interest; seek to maximize personal fitness
Interactions	Mutually adaptive behaviors between agents	These are the interrelations between stakeholders that constitute the stakeholder network (or Stakeholder CAS)
• Linkages	Paths of resource movement and level of connectivity it provides	• High-intensity connections between Dutch planners and German planners via frequent telecommunication, meetings and objective setting workshops • Planners host employers to periodic workshops/symposia; German planners and employers interact on regulatory/economic matters
• Flows	Movements of resources through agent networks and through system interactions with the environment	• Knowledge flows between Dutch and German planners to gain common understandings of regulatory frameworks and to agree upon strategic objectives • Knowledge is expressed by employers in terms of interests and level of demand for planner ideas; during workshops they also engage in idea creation and strategic objective validation
**System fitness is measured by the ability of agents in the stakeholder network to build a strategic vision and create new ideas*		
Environment	Is external to the CAS of focus and consists of other interacting agents and contextual variables that influence the CAS	The stakeholder CAS defines this environment which consists of external stakeholders and their networks, physical structures socio-political norms and regulatory instruments
• Dimensioning effect	The freedom of variation that the environment provides	NL land use plan- flexible process, rigid tool, DE land use plan- rigid process, flexible tool.
• Complexity factor	Optimal fitness of the CAS is reached through high interdependence. The reverse is often the case for the environment as a whole	Through frequent interaction, the planners and employers have established a set of strategic objectives. However, complications as the result of regulations and agreements to other networks have complicated and slowed the process

Interactions between the Stakeholder CAS and its environment

According to the framework, high interdependencies between stakeholders within the CAS tend to increase the fitness of the CAS; however, the contrary is more likely the case for linkages between the stakeholder CAS and the planning environment. In the case study, the CAS framework revealed both regulatory instruments that constrain planning and pre-existing structures that largely determine the content of the revitalization project. Pre-existing structures are variables present in an environment that predate the project itself. These structures that include buildings, resource grids and stakeholder networks add a new dimension of complexity to the planning environment. Land use plans are examples of regulatory instruments that have different dimensioning effects on the structure of planning in either country. The German *Flächenutzungsplan* is a significantly more flexible tool than the Dutch *Bestimmingsplan* because it allows for the incremental development of the industrial terrain. These examples represent just a few of the many conflicting interests that arise within the stakeholder CAS because of influences from the planning environment.

5. Discussion

The above analysis of a case study using the CAS framework suggests several new contributions to our understandings of collaborative planning processes. We summarize these in the following six key findings with regard to interactions of the CAS with and within the planning environment.

First, the CAS framework offers a methodical manner to differentiate between internal and external variables by exploring the intensity and symmetry of interactions. High-intensity interactions often occur between the stakeholders most heavily involved in the planning process. Interaction intensities often indicate the central network of stakeholders that constitute our stakeholder CAS. Linkages between stakeholders within the CAS tend to be more symmetric because they engage in dialogue. Asymmetric linkages (Wellman, 1983) are more common between the stakeholder CAS and external stakeholders. For example, regional authorities introduce new policies or planners publicize their ideas to the general public. Asymmetric linkages among variables can be an important indicator of imbalances in power structures, whereas power structures within symmetric linkages may appear deceivingly balanced.

Second, while a stakeholder analysis may sufficiently reveal the highly collaborative nature of the Dutch and German planner interactions, the CAS framework delves deeper and uncovers the asymmetric linkages that underlie their collaboration. This provides some indication of the power structure between the planners. Since the existing industrial terrain resides on the German side of the border, expansion towards the Netherlands is an option for the German planners. However, it is necessary for the Dutch planners to collaborate on this cross-border project to adhere to an anti-competition agreement they signed within a different stakeholder network. Despite a lack of physical resources, the Dutch planners have become the main drivers of the project by investing the majority of time and effort into the collaboration. The case demonstrates that stakeholders have the capacity to adapt the frequency of their interactions and flow of resources in order to balance the power structure in a stakeholder linkage. This shows that while power structures may differ, it is important to have a balanced dialogue among the stakeholders within the CAS.

Third, Choi et al. (2001) propose that as allied agents align their schema, the fitness of each agent improves; however, this may not always be the case. Based on our observations of the case study stakeholder CAS, the planners and the employers had distinctly different sets of interests that only partially align. We found that interests are important schema that both define stakeholders and determine the intensity and timing of their interactions on specific planning tasks. We suggest that each task within the planning process requires a different construction of the stakeholder network at different stages. Therefore, the aim of collaborative planning should not be to align all stakeholder interests within the

CAS. It should be to identify stakeholder interests in specific tasks and to organize appropriate forums for collaboration.

Fourth, stakeholders maintain different linkages with other agents in the environment, making complexity a paradoxical phenomenon. On the one hand, linkages to external stakeholders and other contextual variables have a dimensioning effect that reduces the fitness – in this case the ability to adapt – of the CAS by placing constraints on stakeholder actions. On the other hand, these linkages can introduce new ideas that foster creativity and can potentially lead to more optimal solutions. By way of frequent communication through balanced dialogues, the Dutch and German planners were able to identify the differences in their respective land use plans. This may be one reason the revitalization project will begin by extending the existing industrial terrain and growing incrementally towards the Netherlands according to demand. This model will likely become the common land use planning approach for the project once a common legal framework for the terrain has been established. Thus, the planners combined their knowledge to enrich understandings and to create new solutions (Bennett, 1998; von Krogh, Ichijo, & Nonaka, 2000).

Fifth, pre-existing structures in the planning environment largely set the constraints but also the opportunities of a project. Gaining a more focused understanding of the interactions between the CAS and its environment based on these pre-existing structures may help to push forward the early planning stages of objective setting, scenario building and ultimately selecting the optimal alternative future. The CAS stakeholders have confronted pre-existing structures to reach agreement on the project's strategic objectives: (1) incremental, demand-based development, (2) expansion of renewable energy networks, (3) cross-border collaboration and (4) opening new product markets. We propose that through an analysis of pre-existing structures using the CAS framework, stakeholders can dismiss unnecessary complicating variables from the planning environment and use the others to inspire creative solutions.

The final finding may have significant implications for PSS design. We have established that variables within collaborative planning change and therefore should be viewed as context specific. However, by applying the CAS framework we observed that some features of these variables are, in fact, rather generic. For example, although stakeholder interactions evolve in response to changes in the environment, the behavioral rules that determine stakeholder reactions remain the same. These features could be transferrable to other projects or may remain unaltered throughout different stages in a single planning process. This finding may suggest a first step in the integration of PSSs into ongoing planning processes.

6. Conclusion

In summary, to explore practice, we have introduced a CAS framework that builds on existing project analysis methods by setting contextual variables into relation. This framework has revealed important information about the interactions of variables such as power structures among stakeholders, forums of communication, resource flows and the timing of stakeholder engagement. We acknowledge that by limiting the scope of analysis to a central stakeholder network, we are only able to analyze complex planning processes from a single vantage point and that at the moment our analysis of interactions is limited. Further research may attempt to structure an examination of more complete stakeholder networks and interactions in a manageable manner.

Furthermore, we have proposed that to create PSS design methods that align with – and therefore can be integrated into – collaborative planning, a clearer picture is necessary of what these planning processes look like in practice. To first gain clearer understandings of planning processes, we limited the discussion in this paper to constructing a CAS framework and applying it to a case study. We suggest several points for further research into PSS design methods based on our findings:

- Since project drivers are the most invested stakeholders in the project (i.e. have the greatest knowledge and motivation) they may be the ideal early adopters of PSS technologies in the project and therefore should be directly involved in the design process.
- The use of visualization tools to compare differences in stakeholder interests and communicate new ideas may help stakeholders to move the planning process forward more rapidly.
- There is a need to explore the interaction between agents and contextual variables dynamically over time to show in future planning-related tasks how stakeholders engage with objectives to set planning strategies, how they engage with strategies to design scenarios and how they engage with scenarios to reach consensus on a possible future.

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