Dependency and Structure Modelling for Stakeholder Management: An Example in Landscape Regeneration

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Abstract: Stakeholder management often is a complex process in large, multidisciplinary projects with systemic implications. In this contribution, we adopt a systems engineering approach to stakeholder management in a large-scale landscape regeneration effort in the UK, namely the Cambridge Centre for Landscape Regeneration (CLR). Through stakeholder mapping and DSM clustering, we explore a current snapshot of involved (high interest high influence) project stakeholders and their lines of communication, identifying preliminary thematic clusters and key contributors.

Keywords: Stakeholder management, systems engineering, landscape regeneration, change management, design structure matrix

1 Introduction

The Cambridgeshire Fens are part of a former wetland that covered 4,000 km^2 in the East of England, which has been drained for agriculture from the 17th century onwards. The organic peat soils derived from the original fen vegetation provides a richly productive medium for arable farming. The Fens are currently the source of one-third of England's fresh vegetables and salad, and the businesses and industries supported by this production are a major source of employment, contributing about £3bn annually to the UK economy (NFU East Anglia, 2019).

However, the Fens face immediate and serious challenges as a result of a complex web of interdependent factors, which are mostly the unintended consequences of drainage, and which are exacerbated by climate change.

First, drained peat shrinks, causing widespread subsidence of the land surface. This not only damages roads and other infrastructure but creates a significant fluvial flood risk: the farmland now lies up to 4m below the level of the water in the river system (Great Fen, 2023). The increasing height differential between the fields and the river has forced ever greater investment in infrastructure and energy usage to pump drainage water up into the rivers. The rivers are heavily embanked to prevent flooding by over-topping, but they flow down a very shallow gradient and rising sea levels threaten to impede their continued drainage out to sea.

Paradoxically, the Fens are now short of water. The area is one of the driest in the UK, having an annual rainfall of c 570mm, comparable with Jerusalem. Growing demands for water for public supply due to housing development in the region and the effects of climate change (abnormally high summer temperatures and unpredictable rainfall) mean that agricultural drought is an increasing risk. The current system of continuous pumped drainage is unlikely to be fit for purpose in future and water conservation solutions need to be found.

Furthermore, the oxidation of the exposed peat and the consequent reduction in the soil carbon stock is now recognized as one of the largest sources of CO_2 emissions associated with land use in lowland Britain (BEIS, 2022). The loss of the very organic material that made the Fens so productive now threatens the future of arable farming in the area.

The region also now has one of the lowest proportions of land managed for nature in the UK. As a result of centuries of drainage and arable farming, characteristic wetland species have been pushed to the edges of the region: undrained wetland habitat now occurs in four nature reserves occupying less than 1% of the original area, although remnants remain in some of the extensive field ditch systems (Natural Cambridgeshire, 2021).

The human population of the Fens is largely concentrated on the edges of the original wetland and along ridges formed by the silt deposits of former riverbeds, which now lie above the general level of the fields. Fenland communities score poorly compared to the rest of Cambridgeshire on a number of health and wellbeing factors (Fenland District Council, 2018) as well as social mobility and other educational and wealth outcomes. Any solutions to the above challenges will need to take account of their acceptability to these stakeholders, in order to achieve a just and fair outcome for those who live in and gain their livelihood from the Fens.

There is growing consensus among many stakeholders in the Fens, from government bodies and the water industry, to farmers, conservation charities and community organisations, that urgent action is needed to arrest the loss of peat, conserve water, reduce emissions of greenhouse gases and help biodiversity to recover. However, this cannot be done without due consideration being given to the economic consequences of these actions and the acceptability of solutions to farmers and local communities. Crucially, it is recognized that the food security provided by Fenland arable production cannot reasonably be replaced by increasing imports, thus exporting the UK's carbon and water footprint to other countries.

Many stakeholders are actively working to address these questions (Natural Cambridgeshire, 2021) and there is a possibility that this activity, unless coordinated and conducted in a collaborative way, would be inefficient and possibly mutually obstructive.

The Cambridge Centre for Landscape Regeneration (CLR) is a project arising from a grant by the Natural Environment Research Council (NERC), focusing on the challenges framed above. As a first step, CLR identified a suite of organisations and projects that are already engaged in research and practical attempts to address different aspects of the challenges facing the Fens. Working with, alongside and through organisations that have already established relationships of trust with each other and with local communities, and each of which has specific expertise that can be shared, is crucial to the success of such a project. Identifying and communicating with the most highly connected organisations, and attending their meetings and boards, provides an efficient way to discuss mutual interests with representatives of the great majority of the other stakeholders.

2 Background

2.1 Stakeholder management in landscape regeneration

The notion of stakeholders, intended as "any group or individual who can affect or is affected by the achievement of the organization's objectives" was originally formulated in management scholarship (Freeman, 1984). Over the years, this notion has been widely applied in system engineering, especially in terms of stakeholders' needs and their relations to systems requirements (Salado, 2021). In the Fens case, promoting a large-scale landscape regeneration effort requires the collaboration of a complex network of stakeholders of various kinds, including institutions, organizations, and communities. This complex network of heterogeneous, interdependent stakeholders determines a need for explicit coordination and structuring, as observed in other landscape regeneration contexts (Della Spina et al., 2023).

2.2 DSM for stakeholder management

Dependency and Structure Modelling (DSM, also known as Design Structure Matrix) techniques are a set of approaches to modelling, visualizing, and analyzing dependencies among system entities of various kinds (Ulrich and Eppinger, 2003). These techniques have been applied to organizations and innovation management (Durango et al., 2022, Maier et al., 2017); more specifically, DSM has been used to support the management of complex, collaborative networks of dependent stakeholders (Feng et al., 2010), including in complex water systems (Michel and Nazemi, 2018). DSM clustering (Behncke et al., 2015) can be used to identify meaningful sub-systems within complex stakeholder networks - even though sub-systems can overlap and maintain connections to other sub-systems (Maurer et al., 2006). The identified sub-systems can then be used for stakeholder management purposes, for instance through forming a set of teams or determining a specific collaboration process.

3 Methods

3. 1 Data collection

Within the agreed scope to understand and tackle the interlinked climate and biodiversity crises through a whole system approach to resource management, communities, and habitats of the Cambridgeshire Fens, we first identified the stakeholders with an interest in the regeneration of the Fens. For this, a workshop was facilitated with the focus in answering the question 'Who are the stakeholders?'. The outcome from this workshop was a common and accepted understanding of the range of stakeholders and their individual interests, needs, values, and perspectives. The outcome was a classification of the different stakeholders according to their interest and influence within the scope of this problem. Hence, we identified 4 stakeholders groups; low interest and high influence that have to be satisfied, low interest and low influence that have to be monitored, high interest and high influence that have to be managed, and high interest and low influence that have to be informed. The focus of this work is the third group of stakeholders with high interest and high influence. The method that we followed to facilitate the workshop is described in detail in the Engineering Better Care report (Clarkson et al., 2017).

3. 2 Stakeholder mapping

To gain an initial understanding of the network of high-interest high-influence stakeholders involved in Fen landscape regeneration from the perspective of CLR and its close partners, we developed a preliminary stakeholder map using Kumu (2023). For confidentiality reasons, the names of the stakeholders other than the direct CLR partners have been anonymized through conversion into numerical codes. This map, provided in Figure 1, depicts an initial snapshot of the main stakeholders involved, differentiated in terms of organizations, projects and key communities.

By organization, we here mean long-standing, stable institutional configurations, potentially spanning several projects, such as businesses (e.g., in the water industry), charities (e.g., in nature conservation), local government bodies (e.g., district councils), or universities and research institutes (such as Cambridge University). Importantly, organizations might relate to each other hierarchically, as in the various levels of the British local governance system. Conversely, by projects, we here mean fixed-term efforts set up by one or more organisations to address specific questions (e.g., research objectives), opportunities (e.g., new farming approaches) or problems (e.g., future water supplies in the Fens, climate resilience, or threats to biodiversity). Finally, we recognize the vital role of local communities, or categories of individuals (e.g. farmers), which we see as a third and distinct kind of stakeholders, potentially connecting with both organizations and projects at a grassroots level.

These diverse types of stakeholders are linked through active lines of communication. Specifically, organizations might establish lines of communication driven by shared and complementary interests, or by needs for input from each other. Furthermore, organizations might feed information related to funding, oversight, contact and skills to projects; obtaining, in turn, information on evidence-based outcomes or public engagement opportunities. Projects might, also, establish lines of communication with each other through research collaborations and outcomes, common members, division of labour and resources, and other opportunities for constructive collaboration and mutual enrichment. Finally, key communities might establish stable lines of communication with both projects and organizations.

We observe that some of the flows across these lines of communication are potentially quantifiable, such as funding or research output; other meaningful indicators of communication exchange and collaboration, however, such as strategic alignment, would be harder to quantify objectively. In addition, different quantified outcomes, measured in different ways, would be hard to aggregate meaningfully.

Overall, this initial visualization shows the starting position of CLR projects in relation to the broader network of stakeholders, and reveals key nodes with many connections with other nodes.

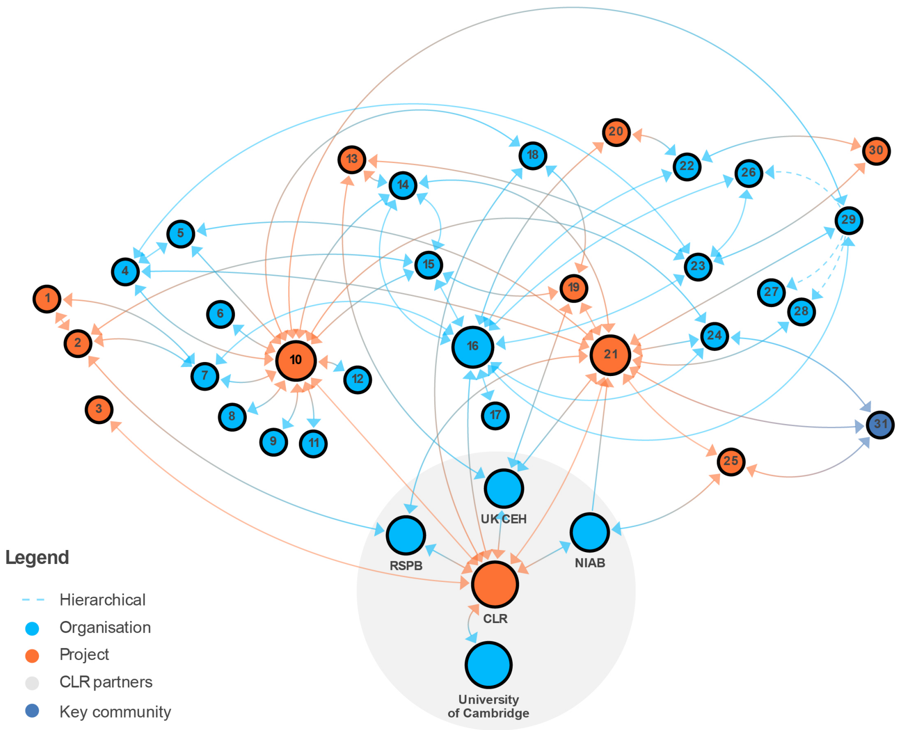

Figure 1. Initial stakeholder map for the Fens

In this map, non-dashed connections indicate lines of communication between elements, whether organizations, projects, or key communities. Different lines of communication occur across different kinds of elements.

Using this visualization as a starting point, a set of questions exploring the characteristics of this network from the point of view of communication between CLR and its partners was formulated:

1. How many primary links does CLR have on the map? How many of the nodes can be reached by the CLR partnership only via another node? Is there a third level of nodes that can be reached only via two other nodes?
2. A few nodes emerge as being 'hubs' with many more connections than others. What would the effect on CLR's connectivity with the rest of the stakeholder organisations be if one of these hubs ceases to operate?

In relation to the first question, we can observe from Figure 1 that CLR has nine primary links, four of which are to CLR partners institutions (NIAB, RSPB, UK CEH and the University of Cambridge) and three to the major hubs (10, 16 and 21). Most of the nodes on the map can be reached by CLR only via another node. There is a third level of nodes that can be reached only via two other nodes (1 and 27).

In relation to the second question, inspection of the diagram reveals that:

- If node 10 is lost, five organisations could no longer be communicated with by CLR within this network;
- If node 16 is lost, one organization could no longer be communicated with by CLR within this network, and some elements would become separated from CLR by more than three nodes.
- If node 21 is lost, all elements could still be communicated with by CLR within this network, but more elements (including key communities) would have to be reached via two nodes instead of one.

To further explore the relationships between the nodes in this network, and the role of the three highly connected hubs, a DSM modeling and clustering approach was followed, as described in the following section.

3.3 Design Structure Modeling

Using the Cambridge advanced modeller (Wynn et al., 2010), a Design Structure Matrix was built based on the mapped lines of communication between Fenland landscape regeneration stakeholders.

The DSM was clustered to identify possible sub-systems of organisations and projects mostly in communication with each other. Several automatic and manual clustering methods were performed and compared (see examples in Appendix I). In the end, the preferred approach consisted in applying the built-in Coordination Cost clustering algorithm in the Cambridge advanced modeller and iteratively editing the obtained clustering results manually, to allow for clusters overlapping and minimize the number of interactions outside clusters. This approach is in line with Eppinger & Browning (2012), who remark that clustering organizational DSM models remains somewhat of an art and is usually combined with manual manipulation.

Out of this exercise, seven thematic clusters emerged (Figure 2), namely:

1. “Environment Conservation”, including projects and organisations involved in environmental initiatives, conservation and wildlife protection in the Fens;
2. “Land and Peat”, including projects and organisations involved in issues related to Fens soil, land, and peat;
3. “Ecology and Hydrology”, including projects and organisations involved in ecological, geological and hydrological research and practice in the Fens;
4. “Local Governance”, including projects and organization concerned with the administration of specific areas within the Fens,
5. “Farming and Agricolture”, including projects, organisations and key communities involved in farming, agriculture and agronomy in the Fens;
6. “Water Level Management”, including organizations’ managing water levels and flood risks in the Fens;
7. “Integrative Projects and Organisations”, including projects and organisations mainly involved in general governance, interdisciplinary research, or broad, comprehensive development efforts in the Fens. This last cluster is recognized as a *framework,* intended with Endress et al. (2022) as “a sending and receiving bus at the same time”.

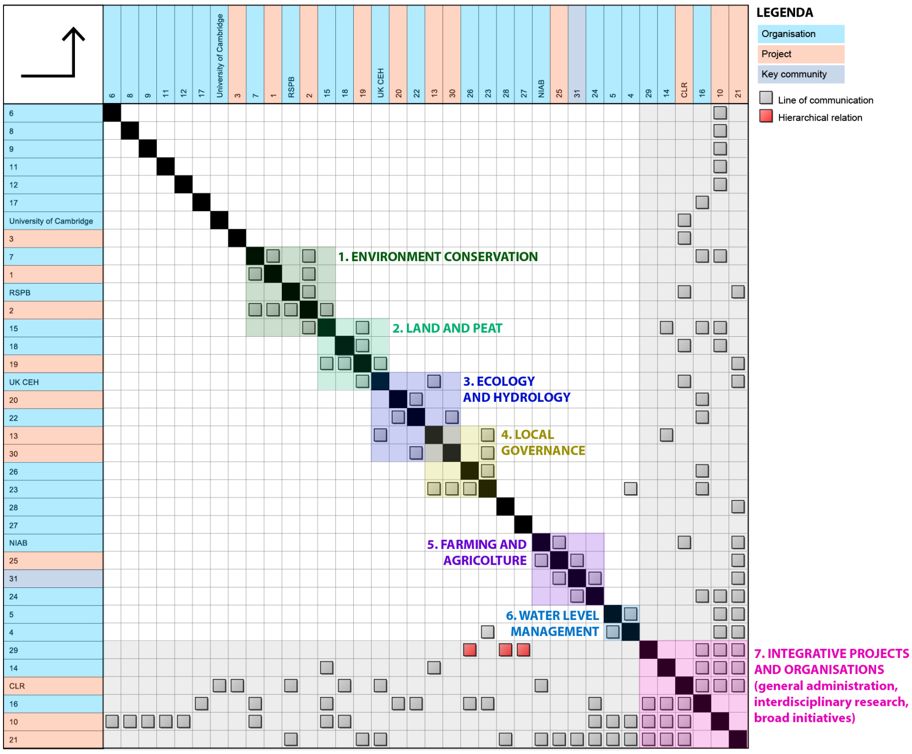

Figure 2. Clustered DSM depicting possible thematic sub-groups Fens stakeholders

Within the *framework*, we can recognize an important role of CLR and the other main nodes in the stakeholders map in linking organizations both within and across clusters (Figure 3).

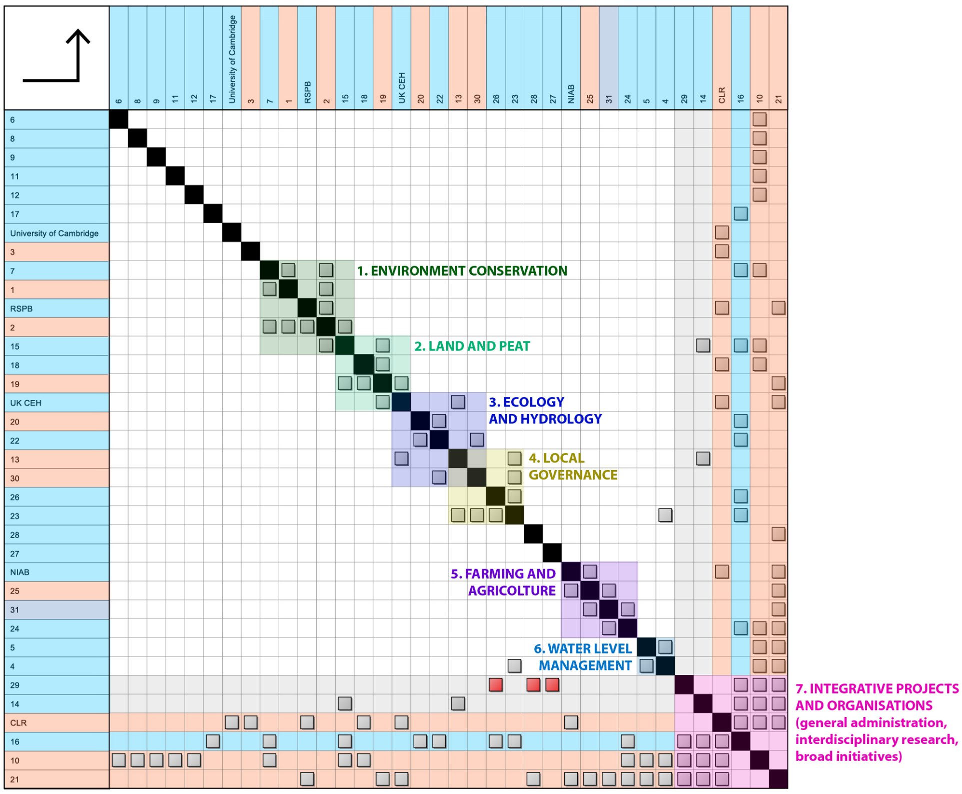

Figure 3. Highlight on CLR and other main nodes in the DSM of Fens stakeholders

3 Preliminary results, limitations and directions for further research

This initial clustering exercise reveals a possible connection between the lines of communication currently occurring within the initial Fens stakeholders map and different themes relevant to landscape regeneration. In addition, the exercise reveals the key role of some projects and organisations in connecting Fens-relevant themes in terms of communication within and across clusters. If confirmed through further work, the obtained clustering could be used to re-organise work across the broad Fens context, particularly through a division in thematic work groups – possibly including the least well-connected organisations in the upper-left corner of the matrix. The establishment of new lines of communication could also be considered; for instance, the somewhat surprising lack of direct communication lines between the "Ecology and Hydrology" and the "Water Level Management" clusters could be further investigated.

This initial, exploratory work has important limitations. First, the heterogeneous and unquantified nature of the mapped network makes it hard to analyze meaningfully the resulting matrix through traditional DSM methods. Secondly, the use of manual clustering makes the obtained overview contingent and non-reproducible.

However, this first exploratory mapping can provide an initial theoretical framework to underpin the pragmatic approach taken by the CLR project, concentrating effort in building communications with a relatively small number of highly connected stakeholders in the relevant areas of study. Further, this initial work can constitute a starting point to inform more sophisticated modelling, based on the collection of more structured data within the stakeholder network. These future efforts could include quantified relational mapping, MDM-based approaches (Ahmad & Clarkson, 2009), and change propagation modelling and visualization (Keller et al, 2005). Ideally, these future efforts will unveil further opportunities for optimizing the existing Fens stakeholder network and the efficiency of the CLR within it, in the context of a broad, complex context of ongoing landscape regeneration.

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Appendix I

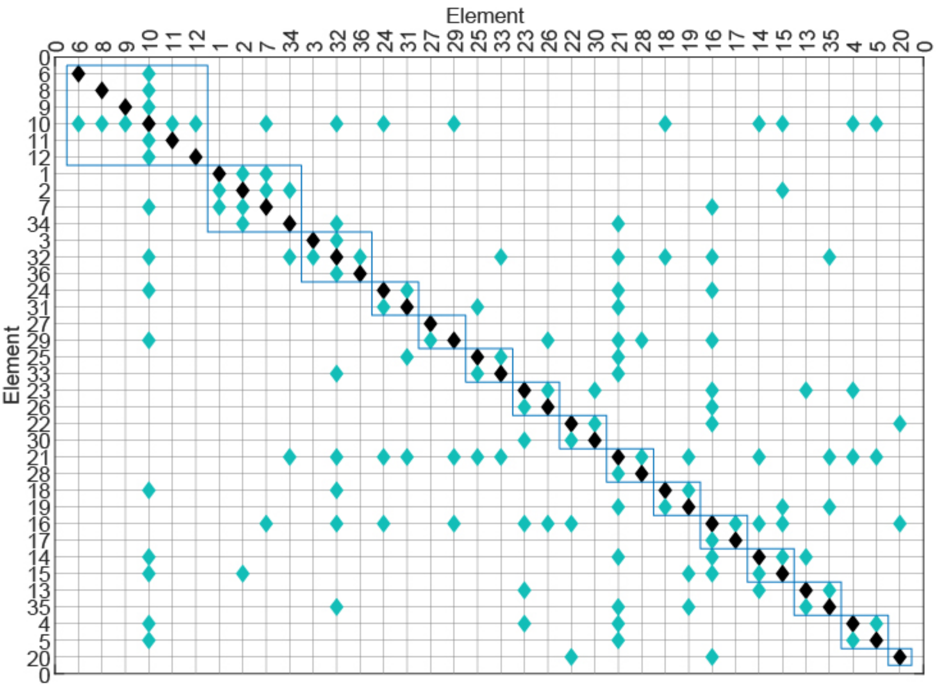

Figure 4. DSM clustering results obtained through the MATLAB Macro for Clustering DSMs developed in Thebeau (2001).

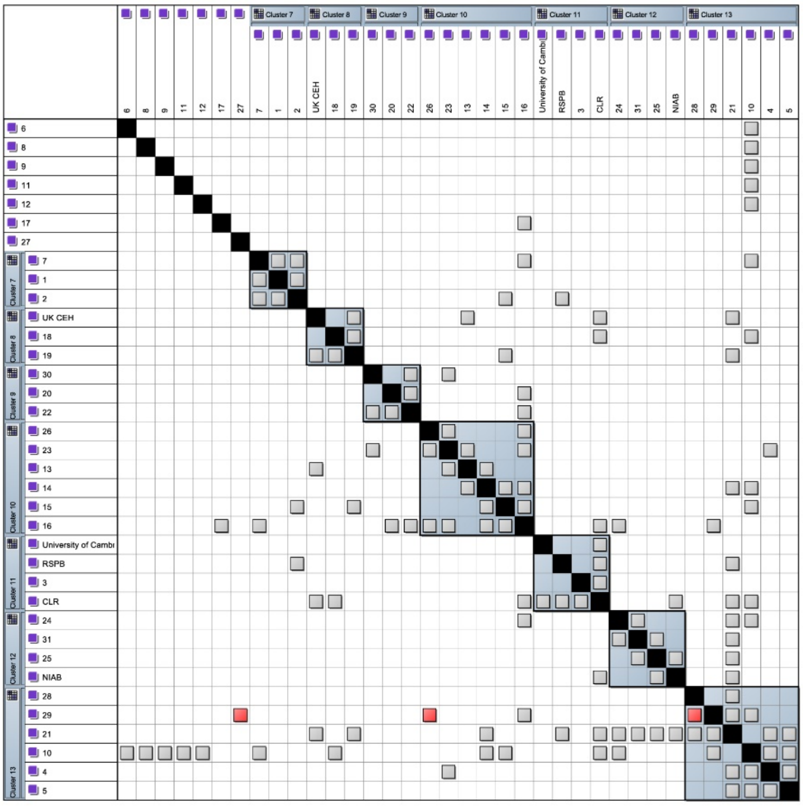

Figure 5. DSM clustering results obtained through Cambridge advanced modeller (Coordination Cost clustering algorithm)

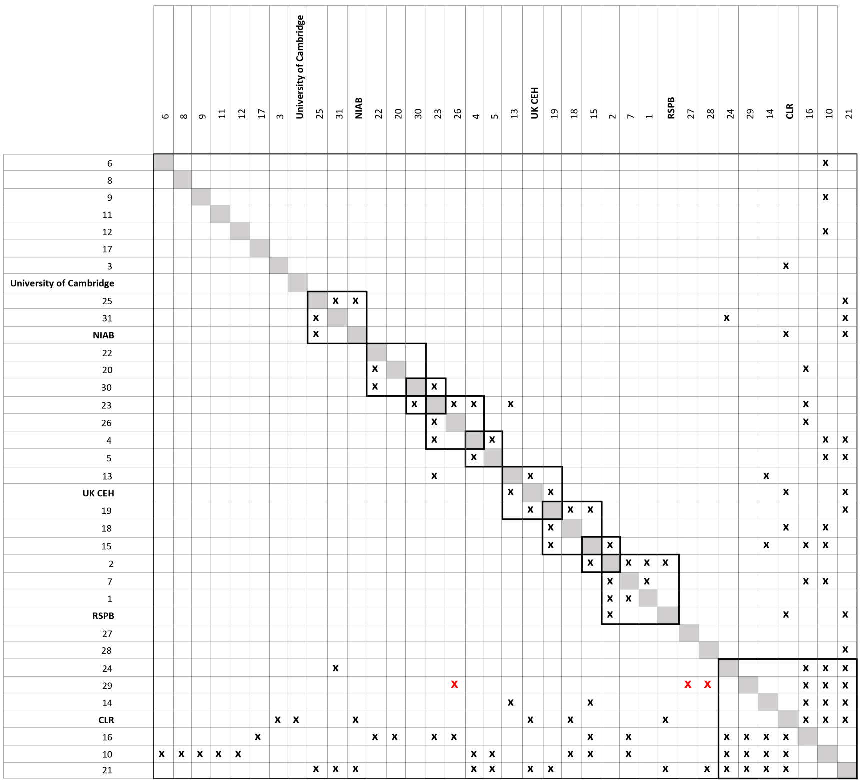

Figure 6. alternative DSM clustering results obtained through manual manipulation.