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A transition management methodology framework towards a circular economy in industrial contexts: reflections on the Humber Region scenario

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Abstract

Industrial activities are responsible for most of the use of natural resources and the generation of waste. 50% of greenhouse gas emissions are attributed to the production of materials and products. The circular economy (CE) has been established as a model that can change the way we produce products by cycling back materials as a route toward the recovery of waste. Implementing projects efficiently using resources in a system can be helped through governance tools that evaluate and facilitate a transition. The Transition Management (TM) framework can be used as an analytical approach that contributes to governing such transition. This framework aims to influence, facilitate, stimulate, and organise processes that contribute to the transition towards a circular model. The objective of this study is to analyse how the transition to a CE is developing since the emergence of industrial symbiosis (IS) in the Humber region. The study seeks to describe the main features that allow the region to make progress towards a CE, whether there are some stakeholders essential to this process, and to analyse whether the activities initially implemented are still relevant to transition towards a CE. The region was examined through a qualitative case study. The case was constructed and analysed through two types of data: documents and interviews. The document review included desk research of the Humber region to establish an understanding of CE strategies. The semi-structured interviews were carried out with stakeholders providing insight into how this region approaches CE as well as the activities that are currently taking place. The data was analysed under the TM theory approach. This was done through the MAXQDA software for qualitative and mixed methods research. The data collected gave an overview of how the industrial strategies used to operationalize IS in the Humber Region are transforming towards a CE system. The results would serve to refine the TM methodology framework by understanding the dynamics of this context that might help to frame the process conditions needed to transition towards a CE system through IS.

Keywords: transition management, industrial symbiosis, circular economy, sustainable development, case study.

Introduction

Industries are substantially responsible for the world's resource usage and waste creation and are hence liable for contaminating and damaging the environment (Prieto-Sandoval, Jaca, Santos, Baumgartner, & Ormazabal, 2019). Nonetheless, industrial systems have sought to attain sustainability through various modifications and reformations, such as resource optimization at the input stage and good waste management at the output stage (Gopinath, Bahurudeen, Appari, & Nanthagopalan, 2018). Thereby companies have tried to convert materials that would otherwise turn into waste at the end of their lifetime, into resources for other companies (Prieto-Sandoval et al., 2019) or processes (Velenturf, A. 2017a) to reach a (CE) model.

This CE model incorporates IS. While CE aims to reduce resource input into the economy and to keep products and materials in use for longer, IS focuses on turning wastes and by-products from production processes into resources for other industries. IS is considered a useful strategy for supporting the transition from a linear to a CE model (Abreu & Ceglia, 2018; Merli, Preziosi, & Acampora, 2018; Prosman, Wæhrens, & Liotta, 2017). IS-related circular models have developed on self-organised, facilitated, planned models various paths in China and Europe, which account for the majority of case studies of applying solutions to create these systems (Rincon-Moreno, Ormazabal, Álvarez, & Jaca, 2020). Countries in Europe have developed secondary materials markets that can compete and minimize reliance on primary resources (European Commission, 2015; McDowall et al., 2017; Zink & Geyer, 2017).

However, one of the problems related to an extended IS adoption is explained by Petit, Sablayrolles, & Yannou-Le Bris (2018) as the impediment to incorporating organisational perspectives with other components of IS (e.g. material flow analysis) due to a higher focus on IS adoption more related to technicalities (Cerceau, Mat, & Junqua, 2018). So far, a large proportion of research treats technical aspects (e.g., supply chain, waste, energy, emissions), whereas aspects that might deal with collaboration with different stakeholders such as information, sustainable development, and networks are not being treated equally as a typical topic in an IS (Abreu & Ceglia, 2018). Authors such as Mortensen & Kørnøv (2019) have similarly stated that one of the critical factors in IS adoption lies in organising this process to establish synergistic relations and initiate partnerships.

Moreover, regardless of existing technical suitability and potential financial and environmental gains obtained in implementing IS (Doménech & Davies, 2011), scaling it up would require extensive collaboration with industry and other stakeholders (Velenturf, A. 2017b). So, moving away from a linear model goes beyond turning waste into valuable materials, including a deep knowledge and

understanding of relevant stakeholders (Hein et al., 2017a). This creates obstacles to a systemic IS adoption, hence it is vital to define what type of strategy would bring together diverse stakeholders to implement this solution.

To address this type of systemic flaw, changes must be fundamentally restructured via transitions. Transitions are defined as "processes of structural change in social sub-systems" that occur when dominant structures are put under strain, either by external changes or through an endogenous innovation process to offer direction for the wicked challenges that we are presently confronted with (Peterson, Baker, Aggarwal, Boyer, & Chan, 2021). Since industries are fairly liable for depleting resources, they are critical in playing a significant role in social transitions between the corporate environment and the larger environment to create a sustainable production model within a society (Bidmon & Knab, 2018). So, CE can be considered as a unified socio-technical system involving the change of industrial processes, with IS serving as a pillar to become the dominant industrial system used by many countries (Schot & Kanger, 2018).

Loorbach & Wijsman (2013) have recommended further research into this societal viewpoint of business as a driving factor in addressing social and environmental challenges. This insight has fuelled research into new kinds of governance, which have been generally labelled as TM or transition governance. The word "management" is derived from an overtly normative orientation of sustainability: specifying where we want to be, what should be done, and how it should be done (Peterson et al., 2021).

Therefore, the purpose of this study is to integrate and use concepts and learnings from the emerging area of TM to systematically investigate how to shift from a linear system to a more sustainable mode of production. To that end, the paper's specific objectives are as follows: a) apply concepts from the TM literature to past transitions in the Humber Region in the UK to develop a conceptual framework for TM of IS systems; (b) describe the main features that allow the region to make progress towards a CE, whether there are some stakeholders essential to this process to explore future transitions; and (c) analyse whether the activities initially implemented are still relevant to transition towards a CE. The structure of the paper covers a literature review, methods, and results consecutively, concluding with a framework that proposes how to create spaces for experimentation and collaboration, how and which actor networks to mobilise, and what action strategies to recommend implementing. These insights could then be applied to other regions in developed and developing countries, to avoid becoming entrenched in unsustainable management as they expand industrial outputs.

Literature review

Industrial Symbiosis

IS enforces an approach that takes inspiration from how industrial systems mimic natural ecosystems, and it can simulate the distribution of materials, energy and information flows (Mallawaarachchi, Sandanayake, Karunasena, & Liu, 2020). IS aids in the transition to a CE by minimizing dependency on virgin resources (Abreu & Ceglia, 2018; Nasir, Genovese, Acquaye, Koh, & Yamoah, 2017; Saavedra, Iritani, Pavan, & Ometto, 2018). For example, China's CE growth is built on policies that aim to construct a broad supply chain through regional industrial parks aimed at CE development (Fraccascia, Giannoccaro, & Albino, 2019; Mathews, Tan, & Hu, 2018). In the European Union, on the other hand, the circularity in production processes is focused on building secondary materials markets to minimize reliance on virgin resources, which has helped the expansion of IS efforts in some countries (Bassi & Dias, 2019; Petit-Boix & Leipold, 2018).

The European Commission (EC) considers that circularity in production processes has the potential to produce significant material savings throughout value chains and industrial processes, as well as generate additional value via the facilitation and implementation of IS (European Commission, 2020). As a result, the EC has set a new action plan to boost circularity in production processes at the supra-national level (European Commission, 2020). By doing so, the EC contemplates circularity in production processes as a critical component of a broader industrial transition toward net-zero goals carbon neutrality and long-term competitiveness.

However, despite the efforts of the EC to promote a CE, only a few nations in Europe are following CE concepts in which IS now plays an important role that may be regarded as effective in tackling the difficulties of CE according to the European Union criteria (Mazur-Wierzbicka, 2021). The expansion of IS has been discordant in Europe due to enacting policies at the country level, allowing the proliferation of IS activities in only certain countries (Bassi & Dias, 2019). Moreover, IS remains a niche approach with several obstacles (e.g., legal, legislative, and financial impediments, organisational concerns) (Ormazabal, Prieto-Sandoval, Puga-Leal, & Jaca, 2018) and has been embraced in a some industries (Brown & Bajada, 2018; Cramer, 2020a; de Jesus & Mendonça, 2018).

As a consequence, IS deployment in some industries is unknown, despite being demonstrated as a potential strategy to promote the CE transition (Yu, Yazan, Bhochhibhoya, & Volker, 2021). Most of the reasons for lagging in implementation are attributed to a hesitant industry ecosystem willing to embrace the transition (Kirchherr et al., 2018). Likewise, experimental cases demonstrating implementation are not a widely extended practice (Kalmykova, Sadagopan, & Rosado, 2018). Such a

low level of implementation is a drawback to the advancement of CE (Panwar & Niesten, 2020). According to Abreu & Ceglia (2018), implementing CE through IS initiatives is critical to engaging corporate and non-business actors to achieve complex synergies. Collaboration amongst stakeholders such as enterprises, governments, and institutions to enable the transition can support solutions from an IS viewpoint (Saavedra et al., 2018).

Transition Management

The literature has recently reported adopting a system perspective rather than firm perspectives to implement IS business models focused on the system's governance and the stakeholders involved that made up that particular circular system (Fraccascia et al., 2019). This focus on a system perspective helps to understand how IS firms are incentivised, motivated, or forced to change through the various mechanisms and how different stakeholders' interest needs to be studied in future research within their context (Yuan, Evans, Wen, & Ma, 2019). Transitions research offers insights to mobilise transformative capabilities from the current system toward a more sustainable production and consumption system known as socio-technical systems (Geels & Schot, 2010). The results obtained during the transition process can be upscaled to the mainstream level starting from the strategic level to a more operational one (Elia, Gnoni, & Tornese, 2020; Jurgilevich et al., 2016).

Loorbach, Frantzeskaki, & Avelino (2017) suggest TM research as a proxy for a deliberative process to accelerate change through a shared strategic vision. TM is a multi-actor process including stakeholders from many socioeconomic groups such as government, non-governmental organizations (NGOs), businesses, academics, and intermediate organisations. The fundamental aspect of TM is to facilitate transitions by gathering stakeholders to develop a cooperative instead of a competitive relationship (Köhler et al., 2019). Through constructive conversations, they conceive, negotiate, and discuss to change their understanding of and attitude to challenges (Dóci, Rohracher, & Kordas, 2022).

The elements of the TM framework distinguish four levels: arena, agenda, experiments, and monitoring (Figure 1). This process contains four management tasks that may not occur in sequential order but might occur in parallel with a continual back and forth between them. These components or transition fields can help solve societal processes, persistent problems, fundamental change, and innovation processes such as the challenge to create circular systems. Likewise, the TM framework provides a set of tools that develop transition-based governance strategies, including a broader range of governance instruments (Loorbach et al., 2017).

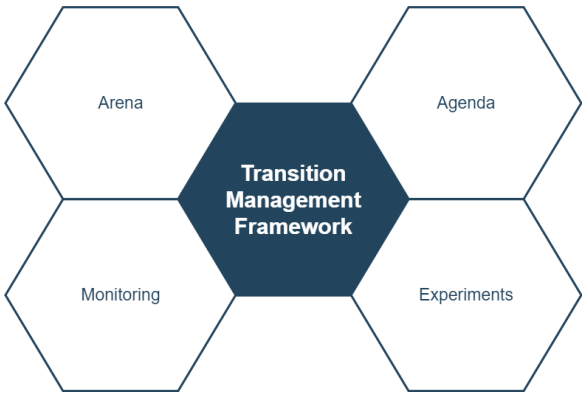

Figure 1 *Transition management framework*

The four levels of the framework are explained below (Loorbach & Wijsman, 2013):

- **Transition arena:** long-term activities in which the future is jointly deliberated and envisioned.
- **Transition agenda:** activities aimed at the medium and long term, with a focus on changes in existing organisations, institutions, rules, and physical or financial infrastructures.
- **Transition experiments:** short-term activities that focus on experiments and actions that practice, test, and exhibit alternative ideas, practices, and social interactions.
- **Transition monitoring:** activities targeted at learning about the system's current state and dynamics, as well as probable future states and the path from present to future: These include continual operational, tactical, and strategic actions that provide (collective) learning.

In the literature, Cramer (2020a) has dealt with this issue by focusing on CE implementation built upon TM theory and processes that may indicate change orientation. The author advocates implementing CE initiatives as a continuous transformational change process to influence initiatives that speed up changes and can be scaled up towards a full CE in a local context. As the adoption of IS as an enabler of the CE has been slow and among many reasons the lack of strategy in the regions is one of them, it is relevant to unfold implementation activities. Industries are reasonably accountable for depleting resources, they play a pivotal role in societal transitions between the business environment and the wider environment to achieve a sustainable model (Bidmon & Knab, 2018). Case studies describing the creation of regional symbiotic networking strategies are among the gaps in the literature that should be filled. Consequently, studies that allow comparisons under the umbrella of the TM process to generalize outcomes are valuable (Cramer, 2020b).

Methods

The Humber Region in UK is studied through a qualitative case study using the conceptual TM framework (Figure 1**).** The conceptual framework was described and analysed through interviews and developed to generate action strategies to recommend implementing it.

Case study research

Transitions study, when viewed as processes of change with complicated chains of causation, multiple players, and changing framework conditions, arguably necessitates process-oriented approaches to analysis (Geels & Schot, 2010). Typically, how transition processes are analysed has been in the form of comparative meta-analyses, case studies, and surveys (Köhler et al., 2019). The substantial dependence on case-based approaches has more to do with the process than with outcome or indicator-oriented modes of theorising. Thus, for this study, the case study approach will be used as it reconstructs transition processes over decades, leading to a better knowledge and explanation of transition dynamics (Köhler et al., 2019). Case studies are a well-accepted method of inducing theory from qualitative material buried in practice (Yin, 2003). Case study research is frequently employed in novel areas and when aiming to explore and comprehend rather than quantify and confirm (Yin, 2009). Given the relative novelty and emergence of industries engaging in initiatives related to an IS within a CE, case studies are thought ideal for investigating this phenomenon.

The Humber region was selected for this study for the opportunity to learn about early actions done by one of the first UK IS initiative, the Humber Industrial Symbiosis Programme (HISP) which was first attempted to start in 2000. This effort sparked the adoption of similar programs in other parts of the UK (National Industrial Symbiosis Programme (NISP) as well as the completion of smaller projects in the Humber area (Cervo et al., 2020). Cases were created and analyzed using two different forms of data: documentation and interviews.

Document review: To gain knowledge of the Humber region's initiatives, documents such as sustainability agendas and environmental programs were analysed. A literature review was carried out to gather information about IS over the last 10 years. The first step involved a search in the scientific literature database Web of Science Core Collection (WOS), the most commonly used and robust source for literature review (Kamalski & Kirby, 2012) to carry out this analysis. WOS's Cited Reference Search tool was used as a starting point for selecting relevant publications. This step allowed it to generate a list of 1113 records that mentioned the keyword "industrial symbiosis". Likewise, the search was limited to peer-reviewed journal articles, review articles and book chapters (all published in English) as this is the dominant mechanism for quality control in conducting unbiased knowledge synthesis in most scientific disciplines (Bornmann, 2011). This step led to an output of 893 relevant publications.

Then, to select literature in the final sample, the publications were assessed to meet two criteria of eligibility (Gottinger, Ladu, & Quitzow, 2020): (i) the study addresses IS in the UK; (ii) the study deals with the Humber region. After excluding literature that did not meet the criteria, a full selection of 93 studies was selected. The studies in the sample were published between 2011 and 2021. The bottom-up change was also explored with the interviewees to build a more integrated vision of how the transition has emerged in the region.

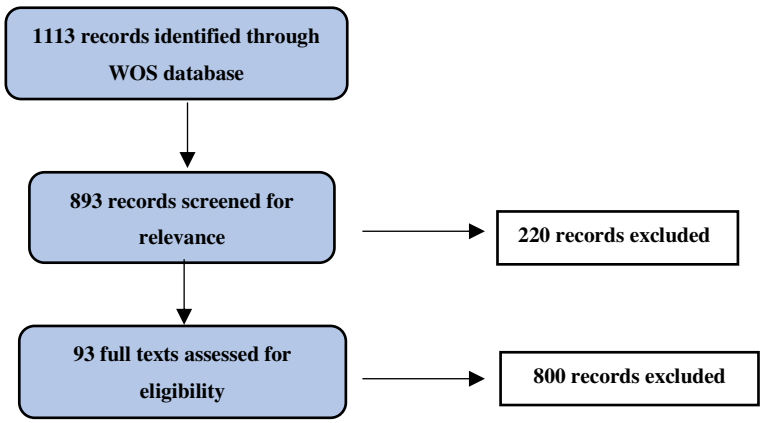

***Figure 2** Literature review process*

Semi-structured interviews: eight semi-structured interviews were performed with a different group of stakeholders (business, business association, local and regional administration and agencies, and research institutions) in the Humber region to gather insights into how different stakeholders have been working in the region ever since the HISP was initiated. At least one actor from the stakeholder's type (Table 1) involved in IS in the region was interviewed to provide insight into how the region approached IS as well as the initiatives that are currently occurring. This not only guarantees that the information gathered is similar but also allows an interviewer to pursue an intriguing line of questions (Kvale & Brinkmann, 2009). The purpose of this type of interview is to learn about interviewees' organisational experiences in a focused and detailed manner, revealing perspectives, feelings, intentions, and actions, as well as the context and organization of their activities, to better understand the reality within organisations (Saunders, Lewis, & Thornhill, 2009). Stakeholders were specifically questioned about efforts centred on by-products to promote resource efficiency and value creation from waste.

Table 1 *Overview interviewees*

Stakeholder type	Role	Organisation type
Business	Environmental manager	Chemical
	R&D manager	Manufacturing
	Company Manager	Services
	Director	Renewable energy
Business association	Program Manager and Energy Hub board member	Services
Local and regional administration and agencies	Climate Change Manager	Services
Research institutions	Researcher	Services
	Lecturer	Services

Data analysis

The interviews in this study were video-recorded and subsequently transcribed to assure the accuracy of the data. The interview transcripts were reviewed and classified separately. An explanation-building strategy, albeit iterative, was utilized as a deductively based analytical way to evaluate a theoretical notion (Yin, 2003). While gathering and analysing data, an attempt was made to construct an explanation by initially matching certain categories obtained from prior research and literature to develop a transition towards CE (de Souza et al., 2020).

The coding approach produced results that aided in comparing initial categories and iterating this process until a satisfying explanation for links between IS activities and stakeholders were obtained (Yin, 2003). The created codes were then analyzed using the MAXQDA software, which is widely used in qualitative research to investigate the relationships between multiple responses (Saunders et al., 2009), and in this study to seek new insights on how specific experiments and actions towards the CE can be deepened, broadened, or upscaled to a cleaner mode of production.

Results and Discussion

This section shows the results obtained in the Humber region. The observations obtained during the literature review phase were contrasted with the responses obtained in the interviews to generate new information that would allow us to apply the concepts from the TM literature to develop a conceptual framework. And to describe the main characteristics that would allow the region to move towards an efficient resource management model through the analysis of the activities initially implemented and their relevance for the transition.

Transition arena

The first component is establishing a transition arena where goals and modes of collaboration with local stakeholders are developed. Based on information gathered from literature and interviews, the need to establish a governmental zero waste to landfill policy and the commitment to promote IS were key in establishing a common goal for this transition. One reason why the success of IS in its early days is attributed to the landfill tax, is because this forced companies to change their strategy from sending waste to increasingly expensive landfills. By doing so, the UK policy framework supported the establishment of IS networks by providing a necessity for businesses to enhance their environmental performance (Jiao & Boons, 2014). A private entity initiated the facilitation of industrial symbiosis to help companies reduce costs and risk, and open new business opportunities. They helped companies to find partners who could use their waste as raw materials to grow synergies between companies (Abreu & Ceglia, 2018; Costa, Massard, & Agarwal, 2010). Eventually the UK government funded pilot initiatives including in the Humber region, before the National Industrial Symbiosis Programme (NISP) was established.

Factors such as institutional framework, governance arrangements, and solid commercial potential were deemed crucial (Abreu & Ceglia, 2018; Lombardi & Laybourn, 2012), and different programme attributes influenced the development of the IS programme in the Humber region (Table 2). Although many companies expressed interest, the sense of commitment to the program, as well as the degree of contact among them was initially low. In addition to limiting the opportunities for material networks, weak technological compatibilities within sectors were linked to organisational cultures with low degrees of experience with inter-firm cooperation, which has resulted in some reluctance to participate in the program in its origins (Mirata, 2004). This was the result of fragmented industrial development, and it depicted, a technical environment with limited opportunity for synergies to emerge within various sectors. Similarly, Humber facility managers' restricted decision-making powers were another factor holding back the program. So, agreements presented and facilitated by a consultant and voluntary

participation in the program with no fees charged but paid for by the government in services such as opportunity identification improved NISP's effectiveness (Jensen, 2016).

Table 2 *Characteristics of the IS in the Humber region (Mirata, 2004)*

	Industry structure	**Position of coordinating body**	**Project championship**	**Original institutional and framework**	**Awareness raising and commitment**
Humber region	Difficult to integrate due to technicalities	No clear coordination	No industry-led frontrunners	Low level of cooperation	Fragmented

Likewise, IS network development and operational characteristics were influenced by several interrelated elements. The coordination tended to place too much emphasis on initiatives, which was incompatible with the important and valuable intention of engaging industries from various sectors in the program. The most prevalent tasks of coordination were mostly assisting with informational and organisational concerns, as well as obtaining various types of support for the programs, including financial support. A few crucial aspects and their possible impact on IS networks are summarised in 5 categories: 1) technical, 2) political, 3) economic and financial, 4) informational and 5) organizational and motivational. So, the Humber area has established great knowledge in waste-to-resource technologies as a result of its involvement in initiatives to promote IS for over a decade (Jensen, Basson, Hellawell, & Leach, 2012; Mirata, 2004; Velenturf, A 2016). Facilitating such synergies between companies played a key role for as long as the funding has lasted. Since 2012, public organisations and local administrations involved in the development of IS in the Humber region have either lost public financing – most notably NISP itself – or has been dissolved or faced substantial funding cuts (Velenturf, A. 2016). As a consequence, the feasibility of maintaining a collaborative culture based on these processes and the role public actors could play in IS projects outside entities like NISP became more of a hurdle.

The UK government withdrew from the NISP initiative, expecting it to be mostly driven by the private sector. It was thought that because NISP was so successful, companies would start paying for the service. Alternatively, established actors such as waste managers could facilitate industrial symbiosis. However, in the more than 10 years since the programme stopped receiving public funding, private actors have generally not facilitated new symbioses between companies. The fact that it was government-funded alleviated some of the inherent skepticism that businesses had about working together since they recognised that it was overseen by an impartial authority.

The challenge for companies has been to find commercial viability to the symbiosis model as the waste exchange was free for customers and recipients, which helped drive the IS model. A problem faced by

businesses and local authorities is that much of the waste is not being monitored as there is no obligation to do so, which prevents symbiosis based on an understanding of the industrial diversity of the area and its materials to determine the possibilities for symbiosis. Although there have been cases where companies have continued to promote IS and have made it a strategic element in their business model. Markets such as biodiesel production developed through NISP have seen an opportunity and have grown because of this.

So far, nothing has come forward to fill the void when the government money runs out. This, according to interviewees, proposes a new vision of IS in which the context should be based on the diversity of materials over any geographical distance. Given externalities such as Brexit and Covid-19, local authorities see IS as a cost-effective way forward. Currently, authorities are once more interested in facilitating IS as they see it as an opportunity to accelerate a regenerative economy that supports local economies. Nevertheless, interviewees argue that there is a need for staff on the ground to talk to businesses and connect with different points in the value chain to realise symbiosis. Another problem that has been highlighted in the interviews has been the slow pace at which environmental regulations are not evolving at the same pace as technological innovations.

Moreover, the industrial landscape has changed and many elements that were successful in the past may not be successful if they were to be implemented again as the industrial ecosystem evolves according to the interviewees. Yet, the companies consulted agree that the future of sustainable industries will only move forward if they make business sense and are supported in their early stages by government intervention through incentives such as public procurement or subsidies, otherwise, their momentum in a 2.0 program is unlikely. But, due to the lack of continuity in the programme, expert knowledge will be less because of the retirement of the people involved in the development and evolution of the program. Though, it has been mentioned that social innovations must be part of the model to gain social acceptance from different parties and that they must have greater consumer involvement to push for more sustainable modes of production.

At this early stage of the transition, it appears that the very elements that brought the creation of symbiosis to life are the elements that are impeding a long-term vision of transition (**Figure** 3). A commitment sustained solely by a commercial objective has meant that a lack of support and continuity of public policy, especially funding, can be seen as the elements that have not allowed the initial vision to continue in this part of the transition. This is reflected in the fact that only two types of stakeholders are defined: a) those who finance initiatives that facilitate the symbiosis and generate the regulatory framework, represented by local and national governments, and b) the stakeholders who receive the money to carry out the implementation of the IS programmes, represented by companies and business associations. Other authors such as Rincón-Moreno et al., (2021) and Hein et al., (2017) have

highlighted the same problem and the need to include another group of stakeholders that collaborate in the achievement of the IS. In that sense, authors such as Ghinoi et al., (2020) have created a wider group of stakeholders that can help consolidate the transition and support the already established roles of companies and governments. Stakeholders who play a less economically driven role could serve as trusted third parties as coordinating functions must be maintained to achieve the required continuous increase in network performance. However, the commercial viability of the projects should be considered relevant.

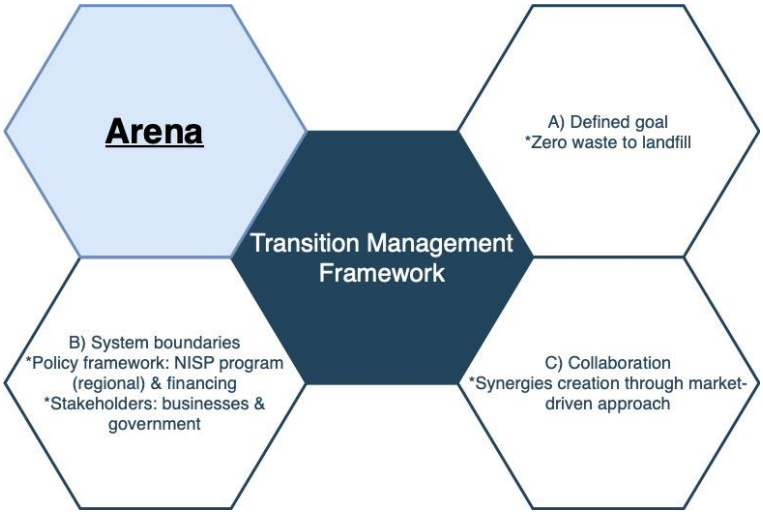

Figure 3 *Transition Arena analysis*

Transition agenda

The second component of the TM framework is called Agenda. The agenda is built on a shared awareness of the problem's persistence, the need for a transition or drastic change, and a set of guiding principles for the envisioned transition. The emphasis here is on linking the long- and short-term, as well as anchoring new visionary visions in agendas, programs, and potential regulations. Furthermore, the transition agenda is reflected in changes to institutional structures and framework circumstances, such as new governance structures that promote cooperation and self-organization, new alliances, or new finance possibilities. The agenda has a special function in TM by serving as a "compass" for the "search and learning process" that lies ahead (**Figure** 4). Throughout the innovation process, government agencies play a significant role (Frantzeskaki, 2022; Kumar, 2021; Peterson, Baker, Aggarwal, Boyer, & Chan, 2022).

Building on the industries present in the region, this “compass” involves energy supply, manufacturing, and agriculture activities and carries out waste-to-resource exchanges in a network that provides bio-based developments in the energy sector and optimises material and energy flows, including waste The public and private drive to implement waste-to-resource innovations in the bioenergy industry made the

Humber region ideal to contribute to innovation progress towards IS between agriculture, waste aggregators, biodiesel production, and construction, all of which have a wide range of inputs and outputs, were determined to be extremely central, along with the port, a critical link in supply chains, and industries that cycle materials from waste product to resource (Penn et al., 2014).

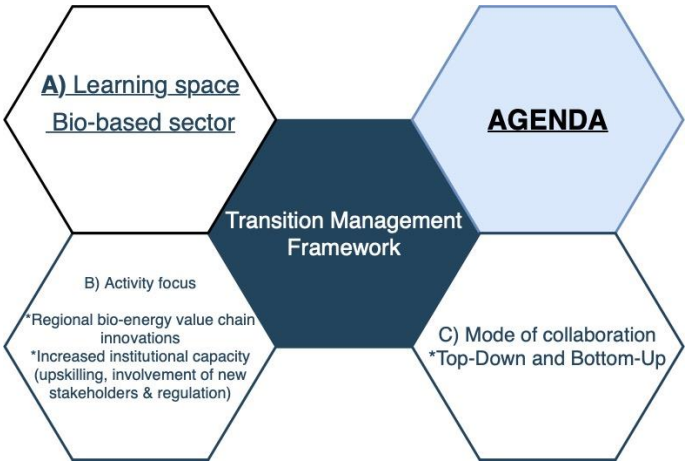

Figure 4 *Transition Agenda Analysis*

However, since 2012, the governance network in the Humber region has diminished due to funding cuts in a context wherein a lack of strong policies on environmental regulation and climate change adaptation weakened the governance capability to play an active part in the regional network. Currently, the regional governance system has a limited capacity to participate in planned collaborations and operationalise national government objectives and plans. Nowadays, local entities are trying to re-enforce IS through the CE strategy proposed for the region. The role of regional government in terms of planning and environmental licenses, as well as luring investment, appears to be underscored (Velenturf, A. 2016).

Some local authorities believe that their role should be more associated with building capacity to support companies to seek opportunities among themselves. Flexible progressive participatory frameworks in which companies and regulatory agencies co-produce plans for the implementation of regulatory objectives have been used in for example the water sector (Breman, Pleijte, Ouboter, & Buijs, 2008) and could also be used for waste-to-resource developments. Velenturf, A.(2016) suggests that regional governance actors should devote resources to attracting expert knowledge on both technical and social aspects of biowaste-to-resource innovation, as well as training regional governance officers in emerging technologies, to increase regional capacity.

This increase in institutional capacity has been referred to by interviewees as an additional issue to the financing of IS initiatives, making them crucial actors through strong government policies that comply with the execution of value-creating IS and promote collaboration through intermediary stakeholders.

However, stakeholders such as the research institutions (RI) consider that there is a need to obtain facilitation services, for small and medium-sized enterprises to amplify the benefits of adopting a IS through innovative waste solutions. It has also been argued by the interviewees that it is the existing stakeholders in symbiotic relationships that should secure funding through local enterprise partnerships because they can access regional development funds supported by local consultancy services that bridge the gap between companies. According to interviewees, the role of the facilitator or a trusted partner who should be a third party is mentioned as a crucial component in the development of IS by seeking to bring together and target companies with similar waste streams to achieve synergies aided by established digital solutions and a waste database. It has also been mentioned that this role should be composed of local people who build trusting relationships between the parties. One of the roles that this new stakeholder should play is to know in real time the volumes, quality, and reliability of waste collection to build confidence in the supply chain.

Unfortunately, this role is not defined as it has not been funded by the government for the last 10 years. Although it has been stated in the literature that enterprises in an IS can self-organise, as has been the case in the Humber region, as one of the ways in which symbiotic relationships can be developed (Yazan, Romano, Albino, Fraccascia, & Giannoccaro, 2016), in the ca. 10 years without government support, these symbioses have generally not materialised. To overcome this problem, Velenturf (2016) mentions that governance in the Humber region should be focused on: a) improving regulatory 'landscape' integration and flexibility across government departments; b) improving connections between national and regional government organisations, as well as within the Humber region; and c) investing in regional governance actors' knowledge, skills, and operational capacity.

On a similar note, Velenturf (2017) argued that actors who serve as network brokers for industrial symbiosis should be better understood due to their commercial interests in resource synergies. Incentives have played an important role but clearly IS has been lagging without a facilitator to link top-down policy targets with bottom-up processes. (Velenturf, A. 2016). Regarding transition theory, transition brokers can improve regional change processes, build alliances, help generate the required preconditions, and launch meaningful circular projects as an intermediary, impartial players without being regarded as working in their self-interest. They function as a conduit between businesses and other necessary parties to help prepare, negotiate, and seal a circular contract, as well as scale up and mainstream these activities (Cramer, 2020c).

Transition experiments

Transition experiments refer to day-to-day activities such as innovative experiments in which spaces for experimentation and collaboration can be created, how and which actor networks can be mobilized, and what action policies and strategies can be recommended to bring about change (Kumar, 2021; Peterson et al., 2021). An experiment is a multi-actor approach, which means that the local government is also one of the participants. Transition experiments provide new avenues for proactive engagement with actor role shifts, both deliberate and unintended (Dóci et al., 2022).

As mentioned in the previous sections, funding for NISP has stopped and no government initiatives on symbiosis have been promoted for approximately 10 years in England. However, some initiatives continued because a) there was a clear commercial incentive to pursue them and b) there were defined collaboration roles among the various stakeholders that made symbiosis possible. Table 3 recaps the types of experiments developed by the different stakeholders and those in which they have been indirectly involved. The following list of experiments (Table 3) is not intended to be an exhaustive list of all the IS projects underway in the Humber region, but as many of the interviewees are still closely linked to the original program either directly or indirectly, their responses reveal a snapshot of what the transition has been and what it could become.

Companies and government entities stand out as the type of stakeholders that have led the highest percentage of transition experiments (90.32%) in the region. The experiments that have been promoted most by the companies have been related to partnerships in the chemical and manufacturing sectors such as cooperation to carry out projects or to establish a cooperation framework that allows synergies to be implemented. Also, pilot projects in sectors such as bioenergy that serve as examples to be scalable or demonstration projects in the glass industry that can be useful in the cement industry are among the symbiosis projects that are in the works.

Table 3 *Transition experiments in the Humber region*

		Chemical	**Industry-wide**	**Manufacturing**	**Renewable Energy**	**Services**
Businesses	Innovation project	1.6%			1.6%	
	Landfill diversion					1.6%
	Methodology					1.6%
	Partnerships	3.2%		6.5%	1.6%	
	Pilot project		1.6%	3.2%		3.2%
	Procurement			1.6%		

	Remanufacturing project			1.6%		
	Reports					1.6%
	Research project			8.1%		1.6%
	Technological innovation	1.6%			3.2%	
	Training					1.6%
	Waste characterisation			1.6%	1.6%	1.6%
	Waste market	1.6%		3.2%		
	Waste recovery project	3.2%	3.2%		1.6%	
	Workshops					1.6%
Business associations	Grants		1.6%			
Local administration	Economic incentive scheme	1.6%				
	Grants		1.6%			3.2%
	Partnerships		1.6%			4.8%
	Procurement		1.6%			
	Reports		1.6%			
	Research project			1.6%		
	Training		3.2%			
	Waste recovery project					1.6%
	Workshops		1.6%			
Research institutions	Partnerships		1.6%			
	Pilot project		1.6%			
	Technological innovation		1.6%			
	Waste characterisation		1.6%			
	Waste market		1.6%			

Other types of experiments that have been mentioned are research projects, mostly carried out by universities or consortia of research centres. Typically, these types of experiments seek to find potential uses for certain materials that can be recirculated within the business fabric. Typically, the experiments were developed on a laboratory scale to test the feasibility of these wastes having a better use than being sent to the landfill, without yet considering whether they have any commercial applicability. On the other hand, the experiments that refer to waste recovery projects allude to materials that already have sufficient volume to have commercial scalability. Thus, using the methods already established in companies, new alternatives are emerging for waste management such as obtaining biofuels from food waste or obtaining 'green chemicals' in the lime industry.

On top of that, the experiments carried out by governmental entities are related to partnerships, which makes sense given their role of being a key participant in the transition. This type of experiment is focused on achieving regional economic development through this type of governmental strategy and as a stakeholder that guarantees collaboration between companies. Thus, it is also understandable that if governments are involved in partnership issues, they will be involved in experiments such as grants, since one of its main roles is the money, it invests in different initiatives aimed at impacting the greatest number of organisations to create synergies.

Similarly, experiments such as training through support programs for companies and increasing the capabilities and skills of the workforce in industries such as the turbine blade manufacturing plant in Hull stand out. The experiments shown here demonstrate how local governments and businesses have been the major promoters of experiments. As the objective of any transition is to bring together those stakeholders who can enable the transition, having only two major stakeholder groups would suggest that they are not yet mobilising the necessary actors for this stage to bring about change.

Therefore, to understand how the experiments are being mobilised among the different stakeholders, a comparison of the experiments carried out with and without cooperation across actor types is made. Table 4 shows that research institutions have the highest percentage of cooperation with companies. As shown in Table 3, these types of experiments are more related to research projects with possible industrial application. Likewise, business associations collaborate exclusively with local governmental agents. This is explained by the reason for the existence of the business associations, which serve as a bridge to funnel local funds to businesses.

Table 4 *Collaboration between stakeholders*

	Businesses	**Business associations**	**Local administration**	**Research institutions**	**No cooperation**
Businesses	34%	10%	5%	15%	37%

Business associations	0%	0%	100%	0%	0%
Local administration	40%	27%	13%	7%	13%
Research institutions	80%	0%	0%	20%	0%

Likewise, 34% of businesses collaborate with other businesses, while 37% of the experiments in IS are conducted without any cooperation between different type of actors. As could be expected in the absence of an overarching facilitator, the experiments currently being conducted in the Humber region are fragmented and without much multi-stakeholder traction. Transition experiments (**Figure** 5) identify areas for experimentation and cooperation, how and which actor networks can be mobilised, and what initiative policies and strategies can be recommended to effect change (Frantzeskaki, Hölscher, Bach, & Avelino, 2018).

As an iterative process that can be executed in parallel, the TM framework could suggest that from the transition of arenas, the goals set for the region could be rethought to create a transition with a broader multi-stakeholder group that would allow for joint goals to be set. It is a simple but effective activity that can be used as a jumping off point for learning and to demonstrate a visible action that is accessible, encourages debates and discussions that change people's thoughts and perceptions, and can be adopted and owned by the community (Peterson et al., 2021). This in turn would result in experiments that show a higher percentage of collaboration between the different stakeholders and would ensure a more effective transition.

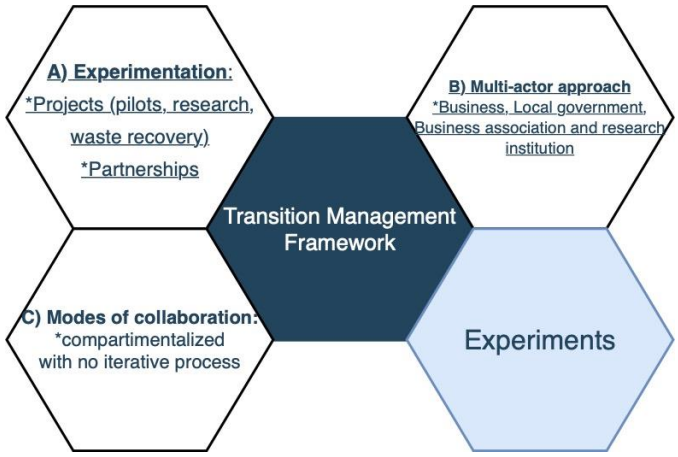

***Figure 5** Transition experiment analysis*

Transition monitoring

Monitoring is an important aspect of the transition process. This level should not be segregated from the others (arenas, agenda, experiments) because it is an intrinsic part of governance processes and should feed into activities at the other three levels (Wittmayer, Steenbergen, Frantzeskaki, & Bach, 2018). Monitoring, assessing and learning from the transition experiments, as well as revising the vision, agenda, and coalitions, are all part of this phase (Frantzeskaki, 2022). It also assists actors in continually adjusting their aims and behaviours by understanding and accounting for changes at all levels. Short- and long-term monitoring and evaluation are crucial in the last step of this iterative cycle to measure the effectiveness of the transition process, which then feeds back into further adoption and development, influencing the larger landscape dimension (Kumar, 2021). Adaptations can be made in the desired direction of the system, in different experiments, or the transition agenda based on monitoring insights (Peterson et al., 2021).

Table 5 *Suggested monitoring indicators by interviewees*

Stakeholders	Sector	Monitoring
Businesses	Services	Tonnage moved of waste
Business associations	Services	Carbon emissions Waste diverted from landfill
Local administration	Industry-wide	Number of new products designed

In this part of the analysis of the transition in the Humber region, monitoring and evaluating are based on the lessons learned from the experiments, followed by any necessary adjustments to the vision or agenda (Dóci et al., 2022). Therefore, once funding for the program stopped, there was no further evaluation of previous processes or experiments that would allow changes to be made to the agenda or arena.

However, in this study, stakeholders have been asked about the monitoring indicators (Table 5) that they propose or have used to evaluate the progress of the experiments. Monitoring indicators suggested or used by stakeholders such as LCA or carbon emissions tracking could be used in a cross-cutting manner if they were to become part of the transition evaluation. As there is a disconnect between the experiments and the rest of the stages of the transition as they were not conceived from the beginning, adjustments to the agenda and vision do not seem to have been impacted (**Figure** 6).

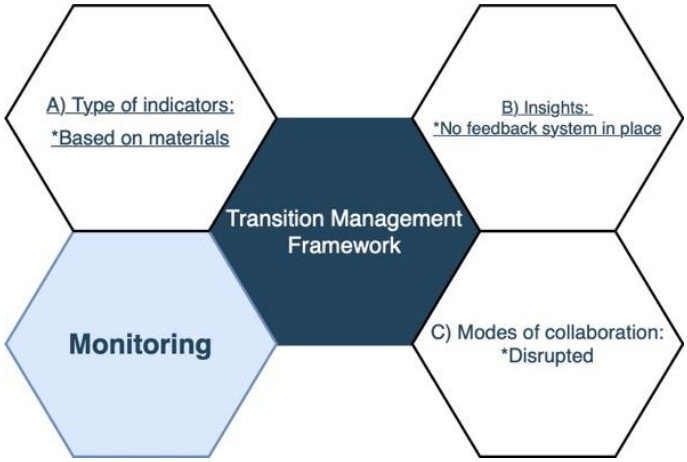

Figure 6 *Transition monitoring analysis*

Conclusions

This study has aimed to integrate and use concepts and learning from the emerging area of TM to systematically investigate how to move from a linear system to a more sustainable mode of production. The concepts of the TM framework have been applied to analyse IS in the Humber region. The four cycles of the TM framework have been used to analyse the emergence, decline, and re-emergence processes that have taken place in the region. It could be argued that under the lens of the transition arenas, goals, boundaries, and collaborations were crucial for its initial success. But issues such as more funding and the commitment of more stakeholders to participate in the visioning process could help strengthen the transition.

Key to the process could be the integration of more stakeholders that fulfil the role of brokers, with a less commercial profile and a more social nature that engages more actors and offers trusting and long-lasting relationships. In the last parts of the framework (Experiments and Monitoring) there have been many projects in a symbiosis that have sometimes been consolidated but have not been evaluated to generate and/or evidence substantial changes towards a transition.

As can be seen, the IS programme in the region was a success as long as funding lasted for an independent third-party facilitator, and for government agents to have capacity to collaborate on these initiatives. The activities initially implemented are still relevant if a transition using the TM framework were to be considered. The opportunities offered by an iterative process such as the TM framework would lead to a more solid foundation in the region to ensure and accelerate the transition to a cleaner and more efficient industrial system. It is expected that these findings might subsequently be extended to other locations to improve industries in developed economies, and to help prevent emerging economies from becoming entrenched in unsustainable management as industrial outputs increase.

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