

SOCIOTECHNICAL TRANSITIONS AND MULTILEVEL PERSPECTIVE: A Literature Review

GABRIELA ALMEIDA MARCON NORA
UNIVERSIDADE DO VALE DO ITAJAÍ (UNIVALI)

ANETE ALBERTON
UNIVERSIDADE DO VALE DO ITAJAÍ (UNIVALI)

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1. Introduction

Societies are facing persistent socio-environmental challenges. The objectives of sustainable development (SDGs) outlined in the Agenda 2030 elucidate the dimensions of these challenges and their global nature. An unprecedented economic, social, and technological transformation is needed to confront this reality. The theory of sociotechnical transition emerged as a conceptual framework in search of examining and understanding changes towards sustainability (Geels, 2004; Markard et al., 2012; Lachman, 2013; Forbord & Hansen, 2020). As social issues became more complex, there was a need to expand the exclusively technological perspective to a socio-technical view and there is a growing interest in systems transitions and innovation due to promote environmental efficiency (Geels, 2005a; Geels & Kemp, 2007). The theory assumes that social functions such as urban mobility, electronic communication, water supply, food, energy, and housing are provided by a set of relevant entities, namely technologies, companies, supply chains, infrastructure, markets, and regulations, collectively called the sociotechnical system (Geels, 2002; Sorrel, 2015). Social functions are, therefore, fulfilled by these sociotechnical systems, consisting of a set of aligned elements, for example, artifacts, knowledge, markets, regulation, infrastructure, maintenance networks and supply networks (Geels, 2005a). Over the years, with the alignment and co-evolution of the relevant entities and the practices developed, they acquire mutual dependence and became resistant to change (Geels, 2002; Geels, 2004; Geels, 2012).

The main source of stability in these systems would be the existence of rules, norms, expectations, and shared beliefs that guide the behavior of the different actors within the system - called the socio-technical regime. The socio-technical regime, in turn, is characterized by these intangible and underlying structures, for example, engineering beliefs, heuristics, practical rules, routines, standardized ways of doing things, policy paradigms, visions, cultural significance, promises and social actions (Geels, 2002; Forbord & Hansen, 2020). Transitions in a sociotechnical system cannot be confused with the substitution of technologies alone. When it comes to transitions, there is not just one line of thought to be followed. There are multiple dimensions, such as geographic or spatial, global structures, justice and power, agency conflicts (Coenen et al., 2012; Truffer & Coenen, 2012; Binz et al., 2014). Graham & Thrift (2007), when dealing with maintenance and repair services as a vital source of variation, improvisation, and innovation, emphasize, for example, the importance of the subjectivity, ingenuity and human work involved in these processes.

Mapping the relevant intellectual territory to specify a research question is an essential step to deepen the studies and expand the frontier of knowledge. In this sense, this paper aims to explore the state of the literature about sociotechnical transitions and MLP, trying to trace an evolution of the existing studies and characterize the multilevel perspective as framework to further analysis. From there, it will be possible to validate the framework and outline future perspectives on the theme.

2. Theoretical Framework: Overview of the multi-level perspective on sociotechnical transitions

The concept of “transition” was first coined by Alex de Tocqueville in the 19th century. Since then, the term has been used by several fields of science, and, in the 90s, introduced in sociotechnical research (Lachman, 2013). In the words of Geels & Schot (2007, p. 399/400): “The sociotechnical regime is an extended version of the technological regime of Nelson and Winter (1982), which referred to shared cognitive routines in the engineering community and explained the standardized development to the along technological trajectories”. The evolution

of studies on sociotechnical transitions and their characteristics are addressed by Köhler et al. (2019). According to Köhler et al. (2019), research on socio-technical transitions can be subdivided into nine themes or directions, which address their different aspects. The referred directions are: (i) Understanding transitions; (ii) Politics and power in transitions; (iii) Governing transitions; (iv) Civil Society, culture, and social movements; (v) Business and industries in sustainability transitions; (vi) Transitions in practice and everyday life; (vii) Geography of transitions: Spaces, scales, and places; (viii) Ethical aspects of transitions: Distribution, justice, poverty; (ix) Reflections on methodologies for transitions research.

The basic theoretical references in the field of transition studies for sustainability are the Multilevel Perspective (MLP), the Technological Innovation System (TIS) approach, Niche Strategy Management (SNM) and Transition Management (TM) (Markard et al., 2012). All of them adopt a systemic perspective to capture the coevolutionary complexity of the main phenomena, such as path dependence and non-linear dynamics. As mentioned, when addressing socio-technical transitions, relevant interdependent and co-evolutionary entities combine to form economically significant and geographically extensive systems that, over time, become increasingly stable and resistant to substantial changes (Rip & Kemp, 1998; Uhrun, 2000; Geels, 2002). The transition processes cannot be entirely foreseen, and it is admitted that they are only partially planned (Geels & Schot, 2007; Forbord & Hansen, 2020). MLP is a prominent approach on sociotechnical transitions characterized as a proposition of how the interaction between various analytical levels can influence the system's development process. It theorizes sociotechnical change as a process of niche innovations competing with incumbent regimes (Levidow & Upham, 2017). This perspective, in an explorative, and flexible way, usually portrays a chosen topic, development or historical action and the elements and interactions connected to it (Geels, 2004; Geels & Schot 2007; Geels, 2007; Vähäkari et al., 2020). Geels (2004) proposes that change should not be seen only from the point of view of those who produce it, but also of users, as it aims to satisfy social demands. The system, according to the author, does not work autonomously, but from the exchange between the actors, the environment, and the artifacts. The MLP expands a unit of analysis of technological products for socio-technical systems that provide social functions such as energy, food, water, urban mobility, housing, transportation, etc.

As a framework, MLP, specially, aims to understand the nature, characteristics, and modes of operation of socio-technical systems; its sources of inertia; the conditions under which it changes; the processes through which transitions to different systems occur; and the conditions under which systems are effectively transformed (Geels, 2004; Geels; Schot, 2007; Markard et al., 2012; Turnheim; Geels, 2013; Sorrell, 2015; Kivimaa; Kern, 2016; Geels et al., 2017). Considering that systems consist of an interdependent and co-evolutionary mix of technologies, supply chains, infrastructure, markets, regulations, user practices and cultural meanings and that transitions come about through dynamic processes, MLP suggests that those processes should be analyzed within and between three different levels, which are: (i) the micro or niche-innovations level; (ii) sociotechnical regimes and (iii) exogenous context or sociotechnical landscape (Geels, 2002; Geels, 2018).

The first level consists in small networks of actors supporting novelties based on co-construction, expectations, and visions. These niches influence the environment and suffer external influence. Radical innovation is assumed to emerge in this micro or niche level (Geels, 2002; Geels & Schot, 2007). Radical innovations emerge from the technological niches, it implies not only the emergency of new knowledge and products, but also new communities, networks and institutional rules (Van de Ven, 1993; Geels et al., 2008). These novelties are, at first, unstable and with low performance, which is why the micro-level acts as incubation room, protecting novelties from mainstream market selection. The emergence of these novelties in the so-called protected spaces or incubation rooms, free from mainstream market selection, is

important to foster changes that may enable a wider sociotechnical transition (Kemp et al., 1998; Geels & Schot, 2007; Kivimaa, 2014). This process requires major changes in culture and behavior as well as support for new institutional priorities (Köhler et al., 2020). The sociotechnical regime, on the other hand, represents institutional structures. Existing elements become aligned making it dynamically stable in a dominant design, consistent with path dependence and incremental changes. The third level is the exogenous environment. Landscape developments put pressure on existing regime, opening opportunities for niche-innovations (Geels, 2007; Raven et al., 2016; Geels, 2018). According to Geels & Schot (2007), empirical levels do not necessarily correspond to analytical levels of the MLP. The analyst should demarcate the empirical level object of analysis and, later, operationalize the MLP.

3. Methods

First, it is required to define what is intended to be accomplished and, later, to describe the findings. Systematic review is an important method for summarizing evidence with precision and reliability. The aim of this study is to explore the state of the literature about sociotechnical transitions for sustainability and characterize the multilevel perspective as framework to the analysis. Therefore, research descriptors were: Sociotechnical Transitions and Multilevel Perspective. The search term to cover the investigated terms as follows: ("sociotechnical transitions" OR "sociotechnical systems" OR "sustainability transitions" OR "energy transitions") AND ("MLP" OR "multilevel perspective" OR "multi-level perspective").

Due to the relevance to the area and availability of indexed journals, the ISI, Science Direct, Emerald, Willey and Scopus databases were searched (Mongeon & Paul-Hus, 2016), considering only papers published in peer-reviewed journals. Peer-reviewed journal articles tend to demonstrate a more consistent degree of quality than other types of documents (Zheng & Kouwenberg, 2019). The PRISMA recommendation (*Preferred Reporting Items for Systematic reviews and Meta-Analyse*) was adapted in this study (Moher et al., 2010). This method specifies four steps to be followed and reported when identifying and extracting information for a literature review, namely: identification, selection, eligibility, and inclusion. Santos and D'Antone (2014) inclusion and exclusion steps and criteria were also considered.

The first stage aimed to identify a set of articles related to the theme. A raw database composed of 990 articles was identified, not all of them aligned with the research theme. No time cut was applied in the search. With the EndNote X7 software, analyzes were performed and duplicate documents were excluded. The retrieved data includes author, names and affiliations, article title, keywords and abstract. Then, documents with incomplete metadata were evaluated and excluded. Documents other than English were excluded. Other twenty-five documents were recruited by snowballing, which is a method of tracking the references of references (Greenhalgh & Peacock, 2005).

Given our research question, it was considered that peer-reviewed journal articles tend to demonstrate a more consistent degree of quality than other types of documents (Zheng & Kouwenberg, 2019). Documents that despite the filter established in the databases themselves, were not research papers, but book chapters or conference papers, were also excluded. After, from 809 documents, those whose titles or keywords did not align the descriptors of the research were excluded. As inclusion criterion, it was considered mandatory that the content of the article articulate both axes of the research (sociotechnical transitions and MLP). Of the remaining papers, all abstracts were read. Methodological choices tend to consider the researcher's subjective views, which is not a devaluation if they are justified (Ensslin et al., 2010). Due to the researcher's line of study, the content analysis of the abstracts considered research that could contribute to the understanding of energy transitions, even if performed in other sectors. A portfolio of 65 papers was selected for basic analysis and qualitative synthesis. It is necessary to consider that the inclusion and exclusion process is not devoid of the researcher's subjectivity,

despite the objective criteria adopted in the initial phases. Figure 1, below, illustrates this research process:

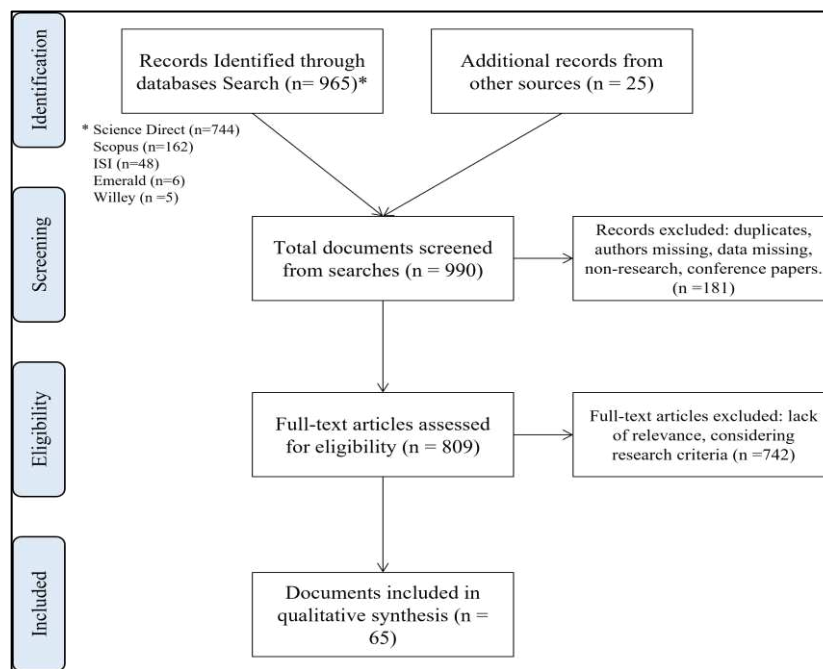


Figure 1- Research Steps from PRISMA flow diagram.
Source: The authors (2021).

Descriptive data analysis relied on quantitative approach for topographical and bibliometric analysis. Descriptive statistics were employed in Excel to generate a series of graphs and tables intended to identify patterns and frequency. As for the citation analysis, considering the scope of the research reached more than one database, Google Scholar data was used – since, due to its coverage, it is a valuable source for analysis in applied social sciences (Prins et al., 2016; Martín-Martín et al, 2018; Nora et al., 2021). It was examined the number of times a given document in the review portfolio has been cited by other documents located on scientific databases. The collection of citation’s numbers was carried out in April 2021. Since citations are accepted as means to establish scholarly impact, it was performed to help identify influential authors, papers, and journals. In general, it is considered well referenced an article cited more than fifty times (Greenwood & Meyer, 2008; Santos & D’Antone, 2014). Another aspect in this analysis is the year of publication. A recently published article with several mentions in the literature deserves to be highlighted. Critical synthesis is one of the review methods most widely adopted in applied social science research (Zhang et al., 2019; Zheng & Kouwenberg, 2019; Tranfield et al., 2003). The last step was to read 65 articles thoroughly and extract the data corresponding to the research questions, understanding the data, synthesizing conceptualizations, and their interrelations.

4. Descriptive Analysis

These articles come from a wide variety of sources, which points to the interdisciplinary nature of this subject. The variety of keywords that will be explored, as well as the analysis of citations for the journals, indicates how the network of relevant literature is developed. The underlining of this section is on answering the following questions: Which journals publish the topic most? What are the main research areas of the journals? Where are the corresponding authors? What are the main interests (keyword analysis) of these studies? How are these works cited in the literature? What is the main methodological approach?

4.1 Journals

The sixty-five articles in this selected portfolio come from nineteen different journals, of which thirteen are published by Elsevier. To assess the impact of journals in the portfolio, SCImago H Index was used. It provides unrestricted access, is based on a larger source journal database, and focuses on the quality of citations that a journal receives by other journals, rather than the absolute number (Falagas et al., 2008). Table 1 shows the six most redundant journals in the selected portfolio, classified by the largest number of documents in the sample.

Documents in portfolio	Journal	H Index (SCImago)	Publisher & Coverage	Country	Main Areas
17	Research Policy	224	Elsevier/ 1971-2020	Netherlands	Business, Management and Accounting, Decision Sciences, Engineering
12	Technological Forecasting and Social Change	103	Elsevier/ 1970-2020	EUA	Business, Management and Accounting, Psychology
6	Energy Research & Social Science	49	Elsevier/ 2014-2020	United Kingdom	Energy, Social Sciences
5	Energy Policy	197	Elsevier/ 1973-2020	United Kingdom	Energy, Environmental Science
5	Technology Analysis & Strategic Management	64	Elsevier/ 1989-2020	United Kingdom	Business, Management and Accounting, Decision Sciences
5	Environmental Innovation and Societal Transitions	42	Elsevier/ 2011-2020	Netherlands	Energy, Environmental Science, Social Sciences
3	Journal of Cleaner Production	173	Elsevier/ 1993-2020	Netherlands	Business, Management and Accounting, Energy, Engineering, Environmental Science

Table 1 - Most Redundant Journals in the Selected Portfolio

Source: Research data (2021).

As seen, the main areas of prominent journals are Business Management and Social Sciences, but in many cases the areas appear combined with others, demonstrating the interdisciplinary nature of the topic. Table 2 presents the seven most influential journals publishing sociotechnical transitions and MLP, ranked by their H Index.

H Index (SCImago)	Journal	Publisher	Documents in Portfolio
1124	Science	American Association for the Advancement of Science	1
258	Renewable and Sustainable Energy Reviews	Elsevier	1
224	Research Policy	Elsevier	17
197	Energy Policy	Elsevier	5
173	Journal of Cleaner Production	Elsevier	3
138	Progress in Human Geography	SAGE Publications	1
121	Technovation	Elsevier	1

Table 2 - Most Influential Journals by H Index

Source: Research data (2021).

As for the geographic distribution of journals, the portfolio features four countries, namely: Finland, the United Kingdom, the Netherlands, and the United States. Of these, the United Kingdom and the Netherlands stand out. Nine journals represented in these results are from United Kingdom. Research Policy is a journal from the Netherlands that has 17 documents in this research portfolio. Also, Technological Forecasting and Social Change, a US journal, has 12 documents in the portfolio. Evolution of this research literature was further analyzed in terms of the longitudinal progression of annual publication volume.

4.2 Geographic Distribution of Corresponding Authors

Corresponding authors in this selected portfolio are from sixteen different countries. Most of the corresponding authors are from Europe. In twenty-nine of the sixty-five articles the corresponding author is from the United Kingdom. It is necessary to consider that some authors

are redundant in the portfolio, however the indicator highlights the development of research in this region. Also, worth mentioning are The Netherlands and Germany, as in both cases six articles have the corresponding author of a researcher from the country. Switzerland then stands out with four articles.

4.3 Influential Authors and Papers

Twenty-four of the sixty-five articles that make up the analyzed portfolio have only one author. Nine of them have two authors, eighteen have three and six have four or more authors. Frank W. Geels stands out as an author in twenty-five articles in the selected portfolio, ten of which are among the fifteen most cited in the portfolio and two among the most cited published in the last five years. The authorship is individual in sixteen of the twenty-five mentioned articles. The twenty-three most cited articles in the selection represent 90% of the citations in the entire portfolio. It is noteworthy that there are nine articles with more than 50 citations within 5 years of publication, which demonstrates the current and the great academic interest in the topic. Table 3 shows the fifteen most cited articles, its authors, and journals.

Citations	Title	Year	Author	Journal
5976	Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study.	2002	Geels, F. W.	Research Policy
4692	Typology of sociotechnical transition pathways	2007	Geels, F. W. & Schot J.	Research Policy
3906	From sectoral systems of innovation to socio-technical systems.	2004	Geels, F. W.	Research Policy
2459	Sustainability transitions: An emerging field of research and its prospects	2012	Markard, J.; Raven, & Truffer, B.	Research Policy
2255	The multi-level perspective on sustainability transitions: Responses to seven criticisms.	2011	Geels, F. W.	Environmental Innovation and Societal Transitions
1868	Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy	2008	Schot J & Geels, F. W.	Technology Analysis & Strategic Management
1713	Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges.	2010	Smith, A.; Vob, J.P. & Grin J.	Research Policy
1583	Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective	2010	Geels, F. W.	Research Policy
1390	Technological innovation systems and the multi-level perspective: towards an integrated framework.	2008	Markard, J. & Truffer, B.	Research Policy
1096	Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective	2014	Geels, F. W.	Theory, Culture & Society
1008	Toward a spatial perspective on sustainability transitions.	2012	Coenen, L.; Benneworth, P. & Truffer, B.	Research Policy
983	Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective	2005	Geels, F. W.	Technological Forecasting and Social Change
935	Translating Sustainabilities between Green Niches and Socio-Technical Regimes	2007	Smith, A.	Technology Analysis & Strategic Management
916	The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930)	2006	Geels, F. W.	Technology Analysis & Strategic Management
911	The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960–2004)	2007	Verbong, G. & Geels, F. W.	Energy Policy

Table 3 - Influential Papers and Authors ranked by citation number.

Source: Research data (2021).

One indication of impact, as previously mentioned, is citation numbers. Most papers are considered relevant if they are cited more than 50 times and their life span of influence is usually brief (Greenwood & Meyer, 2008). Table 4 shows nine recent articles, within less than five years of publication, with significant number of citations.

Title	Year	Author	Journal	Citations
Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions.	2016	Kivimaa, P. & Kern, F.	Research Policy	564

The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014)	2016	Geels, F. W. et al.	Research Policy	519
An agenda for sustainability transitions research: State of the art	2019	Köhler et al.	Environmental Innovation and Societal Transitions	492
Sociotechnical transitions for deep decarbonization	2017	Geels, F. W. et al.	Science	386
Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective	2018	Geels, F. W.	Energy Research & Social Sciences	200
Socio-technical transitions and policy change – Advocacy coalitions in Swiss energy policy	2016	Markard, J.; Suter, M. & Ingold, K.	Environmental Innovation and Societal Transitions	200
Business models as drivers of the low carbon power system transition: a multi-level perspective	2016	Wainstein, M.E. & Bumpus, A.G.	Journal of Cleaner Production	125
Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective	2019	Geels, F. W.	Current Opinion in Environmental Sustainability	92

Table 4 - Most cited articles within five years of publication.

Source: Research data (2021).

We highlight Kivimaa & Kern (2016), with 564 citations, published in the “Research Policy”. The authors argue that sociotechnical transitions imply not only the development of disruptive innovations, but also policies aimed at broader change in sociotechnical systems. They propose that ideally policy mixes for transitions should include elements of "creative destruction", involving both policies aimed at "creating" the new and "destabilizing" the old. According to Kivimaa & Kern (2016), the main idea of the MLP is that transitions come about through interactions between three different levels and that top-down landscape pressures, however bottom-up developments of several emerging niches may lead to the destabilization of incumbent regimes. They point out that the existing academic literature on sociotechnical transitions to sustainability recognizes that governing transitions is a political project in which the direction of travel and means are often highly contested (Kivimaa & Kern, 2016). It is as well worth mentioning the article by Köhler et al (2019) with 492 citations, accepted in January 2019 and published in the journal "Environmental Innovation and Societal Transitions". The authors provide an extensive review and an updated research agenda for the field of sociotechnical transitions, classified into nine principal themes.

4.4 Keywords

In the selected portfolio, 299 keywords were raised, among which 24 terms are redundant. Among the keywords in which there was co-occurrence, the term multi-level perspective was redundant in 28 articles in the portfolio, with spelling variations (multi-level perspective, multilevel-perspective or multilevel perspective). Analyzing the co-occurrence of keywords there is a great centrality of themes related to sustainability in transition studies, and, especially, also due to the search terms, to energy. The verified terms corroborate the adherence of the selected articles to the research axes and descriptors.

4.5 Methodological Approach

Regarding methodological approach, qualitative research stands out in the portfolio, as 57% of papers used this approach. Among the other articles, 5% used mixed methods and 37% theoretical. The search presented only one quantitative article (Hirt et al., 2021), which will be better addressed in the literature discussion. There was a strong trend towards the adoption of qualitative research methods, with emphasis on investigative strategy of content analysis, discourse analysis, case study (e. g.: Levidow & Upham, 2017; Lee et. al, 2020); multiple case study (e.g.: Marx et al., 2015) and documentary longitudinal case studies (e.g.: Geels, 2007; Geels, 2009; Jørgensen, 2012; Geels, 2016; Roberts & Geels, 2019; Wilkinson et. al, 2020). Some combine qualitative and quantitative approach (Köhler et. al, 2020; Geels et al., 2020).

Also, many theoretical articles were found (e.g.: Geels & Schot, 2007; Geels, 2011; Markard et al., 2012; Köhler et al., 2019; Batinge et al., 2019). This vast presence of theoretical articles in prominent journals may indicate the academic perception of the need to deepen transition's theory.

5. Literature Discussion

This study emphasizes socio-technical transitions, contextualizes the issue of sustainable development, and aims to characterize MLP as an analytical framework. The 65 papers, considering the research axes defined in this article, all mention the framework of the multilevel perspective for their analysis of sociotechnical transitions. The review covers more than twenty-five years of transitions studies. The idea is to structure the research discussion according to its direction. By synthesizing those articles, analyzing the main concepts and their interrelationships, this section gives answer to the research question.

5.1 Critical Synthesis

Different terms and concepts are used in the literature to signify and objectify what sociotechnical transition is. Going through these definitions, we identified that Sociotechnical transitions are multidimensional, multi-actor, long-term and coevolutionary processes, characterized by path dependency, resistance to change, uncertainties and disagreements between incumbent and new actors. Technology, in a way, is a tool in the transition process. A new technology is often seen as something from outside. It is necessary for a transition in the regime level to activate its adaptive capacity to receive new technologies, responding to pressures that may affect it (Rip & Kempt, 1998; Jacobsson & Johnson, 2000; Unruh, 2000; Berkhout, 2002; Geels, 2002; Geels, 2005a; Smith et al., 2005; Geels, 2005b; Smith, 2007).

The systemic dimension of transitions and the struggle between stability and change are central to the MLP, characterized by the interface of different degrees of structuring (Köhler et al., 2019). As a framework to analyze transitions, MLP brings different visions of interactions between its three levels. Some state transitions occur when the coevolutionary dynamics at these three levels connect and reinforce each other (Geels, 2006b) and others examine process by which niches and regimes interact and are interdependent, considering translations between niches and regimes (Smith, 2007). Besides, some studies emphasize niche-empowerment to adjust existing regimes (Smith & Raven, 2012; Raven et al., 2016); interactions between multiple regimes (Geels, 2007), and active resistance to transitions (Geels, 2014). MLP also supports the assertion that sustainable development is leading to a reassessment of innovation and technological change (Smith et al, 2010) and allows addressing duration and acceleration of sustainability transitions (Kanger, 2021). In this sense, the multilevel perspective was used to explore contexts, processes, policies, institutions, and interactions that affect the adoption of microgrid (Ajaz & Bernell, 2021).

There is, moreover, the use of the multilevel perspective to support the discussion of clashes between different political views on the transition process, the pressure of the actors for the adoption of one or the other path and the role of the intermediary actors in this process of rupture or adjustment of the regime (Kivimaa, 2014; Hess, 2016; Stirling, 2014; Turnheim & Nykvist, 2019). In addition, MPL upholds the study of cooperation between incumbents and new entrants (Geels et al., 2016). The structural rules are restrictive, informing the legitimacy of the acts, and simultaneously create an environment of trust and predictability that allows the development of actions (Geels, 2004; Geels, 2006). Geels & Schot (2007) bring the theory of structuring by Giddens (1984) to explain the role of actors in the structure of rules that they reproduce through their actions. Actors are passive followers of rules and, at the same time, active creators of rules.

It is possible to state that the first generation of studies was focused on emerging innovations and the resistance of established structures to changes in the sociotechnical regime.

Unruh (2002), for example, states that the institutional technocratic complex generates blockages (or lock-ins) to changes in the system. Geels (2002) brings concepts and insights from evolutionary economics and technology studies to transition studies. This resulted in a MLP for technological transitions, in which two views of evolution are combined, namely: (i) evolution as a process of variation, selection and retention, (ii) evolution as a process of unfolding and reconfiguration. When innovation enters the markets, the actors of the current regime defend themselves and invest in improvements – so-called by Geels & Schot (2007) the “sailing ship effect”. Market competition and power struggles influence competition between incumbents and new entrants. If innovation replaces the old technology, it leads to indirect effects and broader changes in the sociotechnical regime (Geels & Schot, 2007; Geels et al., 2008). Geels & Schot (2007) argue that, although it does not always show in case studies, agency is always present in the MLP, because its levels provide different degrees and kinds of structuration to local practices. The MLP is normally a global model that maps the entire transition process, which is the reason why it may not emphasize each actor, but it allows to analyst to expand the look to the actors, considering that the connection amongst processes at different levels is made by them in their cognitions and activities. The dynamic of MLP is not mechanical, it is socially constructed by different groups that pressure, negotiate and form coalitions. With its attention on the interactions among niches, regimes, and landscape, the MLP perspective provides narrative explanations in terms of patterns that result from interactions (Geels & Schot, 2007).

The second generation comes with an emphasis on accelerating sociotechnical changes. At its heart is innovation. There is a need for the development of new industries, fundamental transformations in existing sectors and long-term vision (Smith, 2007; Markard & Truffer, 2008; Markard et al., 2009; Smith et al., 2010). The literature has evolved over the years. The perspective of institutional theory was incorporated into transition studies and made it possible to explore how actors can influence the movement towards sustainable development, developing and nurturing alternative technological interventions designed to mitigate poverty and social exclusion, promote decarbonization and prevent harmful effects of climate change, for example (Lawhon & Murphy, 2012; Geels et al., 2016; Geels et al., 2017). Fuenfschilling & Truffer (2014) work from a MLP in the light of Institutional Theory, considering the organizational field as an environment of institutional processes and sharing systems of common meaning. In this context, the social structures that guide actions in the field of organizational interaction can be regulatory (formal laws and standards), normative (rules of conduct, moral values) or cognitive-cultural (beliefs, understandings, interpretation). The authors use institutional logic to characterize the content of various structural elements present in a sociotechnical system, tracking conflicts and contradictions between them. They state that the effective occurrence of the transition presupposes a process of institutionalization of change (Markard et al., 2012; Fuenfschilling & Truffer, 2014).

In the last ten years, studies have emerged that point out potential weaknesses and suggest adjustments to the MLP framework. Sorrel (2018), for example, identifies and assesses the explicit and implicit philosophical assumptions underlying the MLP. These include assumptions about the nature of reality (ontology), the status of statements about that reality (epistemology) and the appropriate choice of research methods. The paper assesses the consistency of these assumptions with the philosophical tradition of critical realism and uses it to highlight several potential MLP weaknesses. It concludes, though, that the flexibility of MLP provides room for proposing an alternative and critical realistic interpretation of sociotechnical systems. The next generation of studies focus on the great challenges faced today. Wainstein & Bumpus (2016), for example, adopt MLP to explain actor dynamics in the energy transition lock-in. Other studies also congregate sustainable development challenges and sustainability transitions with the MLP (Coenen et al., 2012; Kivimaa & Kern, 2016; Vähäkari et al., 2020;

Pilloni et al., 2020; Zwartkruis et al., 2020). Coenen et al. (2012) brings about the geographic unevenness of transition processes. Authors demonstrate concern about the lack of attention for the spatial dimensions of sustainability transitions in most studies and argues that there are two interrelated problems, which are institutional embeddedness of sociotechnical development processes within specific territorial spaces, and an explicit multi-scalar conception of sociotechnical trajectories.

Kivimaa & Kern (2016) argue that an area in which policy combinations are particularly important is the field of sustainability transitions. The paper recognizes that transitions imply policies that aim at a broader change in sociotechnical systems. It proposes that these policy combinations for transitions include elements of "creative destruction", involving both policies aimed at "creating" the new and "destabilizing" the old, as articulated by the MLP. Also, develops new analytical framework, including the two dimensions of policy combination ('creation' and 'destruction'), broadening the approach to the functions of the technological innovation system. Recently, Geels (2020) states that the MLP is indeed a prominent framework for understanding socio-technical transitions, but its micro-foundations have remained underdeveloped. It seeks to develop the theoretical micro-foundations of MLP, which are rooted in the Social Construction of Technology, in evolutionary economics and in neo-institutional theory. It analytically reviews the three theories, focusing on: (1) the relevance of each theory to the transitions and MLP, (2) the conceptualization of the agency theory, (3) the criticisms of each theory and subsequent conceptual elaborations (which set the stage) for potential crossings between them). It articulates a multidimensional model of agency, which provides a relational and procedural conceptualization of the continuous trajectories in which the actors are inserted. It is because sociotechnical transitions are evolutionary processes and, more than that, are interpretative and socio-cultural processes.

Vähäkari et al. (2020), pursuing to advance on the frontier of knowledge, suggests a key framework to link sustainability studies and MLP. Authors propose that there are various co-benefits in creating convergence between the two fields of study and assert that MLP framework gives a structure on the systemic dynamics in societal change providing methods to construct alternative pathways to societal transitions, contributing to a better understanding of the dynamics of change for more sustainable futures. Also connecting sustainability transitions and MLP, Pilloni et al. (2020) use the framework to in-depth examination into drivers and barriers to biogas technology. The authors introduce the social niche concept, which plays the role of the agency that embodies individuals' level and bridges social practices to the regime.

In a similar path, Zwartkruis et al. (2020) combine three perspectives to study the role of agricultural nature conservation in the Dutch land use domain for achieving internationally agreed climate and biodiversity targets, which are Multilevel Perspective (MLP), Initiative Based Learning (IBL) and Integrated Assessment Modelling (IAM). The MLP role in this framework is to provide insight into the extent in which agricultural nature conservation has affected or changed the existing nature and agricultural regimes.

Mohamed et al. (2020) adopt MLP and address stakeholder's engagement and connection during transition processes. The paper combines the strength of global value chain (GVC) and national innovation system (NIS) using multi-level perspective (MLP) to create a new framework that could reveal the interconnections between the actors. The global system of innovation (GSI) framework is then introduced to point out the key players participating in the transition. In search, as well, of an expanded framework of analysis, Miremedi (2020) states that there is a clear difference between the literature of multilevel perspective with original focus in north Europe with reflexive governance, and the new literature which documents the sustainability transition in non-reflexive societies. The author supports the coupling of Multilevel Perspective and Causal Layered Analysis to find facts which, in his view, would have been hidden if the research were confined to the MLP. Despite criticism and

complementary approaches, is fair to argue that MLP remains as the most applied framework to address large-scale infrastructural sociotechnical change (Geels & Schot, 2007; Spinardi & Slayton, 2015; Roberts & Geels, 2019; Batinge et al., 2019).

5.2 Future Perspectives

MPL still permits addressing the arise of a new technology in a systemic and holistic manner (Batinge et al, 2019; Hirt et al., 2021). The level of analysis issue lingers on as an important line of research. It remains relatively unexplored in the scholarly literature how short-term changes at the micro level (or niche-innovation level), relate with a transformative long-term change in system level (Hodson et al, 2017; Ehnert et al., 2018; Köhler et al., 2019; Strambach & Pflitsch, 2020). Pilloni et al. (2020) assert the importance of exploring the role of social niches and niche strategic management in the transition studies in poor contexts. Working at the micro level contribute to transitions at the macro level (Köhler et al., 2019; Geels, 2020), which is a reason why the qualitative research can contribute to better understanding of sociotechnical transitions in contemporary times, performing case studies allowing to oppose both levels. Understanding conflicts between actors in different levels, and their interests, allows a better assessment of the conditions for the sociotechnical transitions to materialize. Transformative innovations are always under pressure from, and pressuring established institutions, while new actors are lobbying for alternative sociotechnical configurations. The social dimension, despite the manifest interdisciplinarity of the theme, has a limited emphasis on literature (Luchsinger, 2009; Lieu et al., 2020). MLP allows the combination of perspectives to broaden its outlook. It appears, therefore, that there is room for theoretical contribution from other fields in the social sciences, such as, for example, the aggregate of organizational theories (Farla et al., 2012; Geels, 2018). Besides, MLP can aggregate to the field of future studies, providing understanding of historical development processes (Hofman & Elzen, 2010; Vähäkari et al., 2020).

Quantitative methods are not usual in the field, so that only one article in this portfolio represented this approach (Hirt et al., 2021), although they may provide further support for regime description and differentiation in the future. Therefore, seems to be room for eventual scale development and linkage between MLP framework and quantitative statistical methods. Nevertheless, the qualitative approach remains prominent because it favors the addition of contextual richness, involving real-world actors, systems, and transitions, demonstrating who potentially gains or loses something when innovations arise and are implemented by elucidating the role of actors in the transition paths (Smith & Stirling, 2018). As transitions are nor random or linear, it is required to comprehend the context in which developments take place (Verbong & Geels, 2007; Markard et al., 2012), another reason why qualitative approach is preferred. As temporal framework expands, historical perspectives may allow depth in analysis. Especially regarding to the energy sector and transitions to renewable sources, economic and political struggles of key actors, such as state-owned companies, have a determining role in the transition paths (Markard, 2018). The critical synthesis in this article demonstrates a tendency to combine models and theories to account for the complexity of current sociotechnical transition studies (e.g.: Kivimaa & Kern, 2016; Miremadi, 2020; Vähäkari et al., 2020). As the MLP is usually a global model that does not specifically focus on the actors at each level of analysis (Geels & Schot, 2007), the aggregate of organizational theories, such as Stakeholders Theory, combined with the framework under consideration can reveal the important perspective of the actors involved in the process.

6. Conclusion

This paper provided an overview of existing research on sociotechnical transitions and MLP. As seen, there is a tendency to combine approaches for developing more complex frameworks, but without leaving out the multilevel perspective.

This trend of combining approaches for expanding the framework may demonstrate, on the one hand, an insufficiency of the classic MLP to face today's challenges or, on the other hand, an expansion of the scope of the framework to other research fields that were not initially thought about, a fact that would demonstrate the relevance and robustness of the model initially proposed. In addition, MLP is constantly changing, and seminal authors continue to research and add new nuances to the perspective. We believe that despite criticisms that can be made to MLP, it is still an important framework for transition studies, it is highly flexible, constantly evolving and, therefore, can be adapted to reason the complexity of the current reality.

Qualitative methods are the most used, since, in fact, they allow a deeper understanding of this interdisciplinary, complex, dynamic theme, which still requires further development of its fundamental concepts. This dynamic evolution of theory in recent times suggests that the constructs need to be clearer to support suitable quantitative studies. Regarding future studies, we suggest that theories of strategy and organizational theories could be brought to the field of sociotechnical transitions to, combined with MLP, provide a greater understanding of the relationships between the actors, the role of these actors and the conflicts of interest that impact the transition paths in different levels.

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