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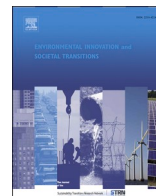
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Research article

Disrupting transitions: Qualitatively modelling the impact of Covid-19 on UK food and mobility provision

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ABSTRACT

The 2020 Covid-19 pandemic provides an empirical testing ground for assessing the impact of critical events on societal transitions. Such events are typically seen as exogenous to the transition process, an assumption which is investigated in this paper. Using a qualitative system dynamics modelling approach we conceptualize transition pathways as sets of interacting sequences of events. This enables the analysis of event sequences that constitute the evolving pandemic as impacting on those pathways. We apply this approach to the provision of (auto)mobility and food in the UK. This shows the way in which the pandemic has had a differential effect on ongoing transitions in both systems, sometimes slowing them down, and sometimes accelerating them. In addition, it reveals how it has established new transition pathways. The empirical work further shows how qualitative modelling with system dynamics facilitates an explicit and systematic comparative analysis of transition case studies.

1. Introduction

The Covid-19 pandemic has led to substantial short-term changes in social practices, especially since March 2020, when national lockdowns proliferated worldwide (ECDC, 2020). Routines of office work, food provision and leisure were suspended, altered, or replaced with new routines. These changes fed into public debate on strategies for dealing with the impact of the pandemic. Such strategies sought to build on changed practices to capture benefits such as reduced air emissions and increased wellbeing among parts of the population. During this period scenarios and proposals for 'green' recovery mechanisms were articulated (i.e. EU, 2020), signalling that the pandemic is a critical event providing the impetus for an overarching transition to a radically different society.

Such articulations neglect that in many sectors, transitions were ongoing when the Covid-19 pandemic started. In the UK sectors of mobility and food provision emergent and centrally guided initiatives were well underway. The national food strategy sought to establish a sustainable and healthy diet for UK citizens, while the electrification of personal mobility was seen as key towards reducing UK carbon emissions (Dumbleby, 2020). This raises the question of how the pandemic, and the societal response to it, affects ongoing transitions (Milev and Al-Habaibeh, 2020; Gov.uk, 2020a). We might expect them to stall as disrupted economic activity extends into

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the innovative niches which form the kernel of transitions. Current niches might be weakened when critical resources are depleted to sustain current systems. Alternatively, overarching initiatives for a 'green' recovery might strengthen existing initiatives, embedding them in a wider favourable trend. The impact of Covid-19 as a critical event is thus in need of an analysis that disentangles potentially counteracting effects.

In this paper we conceptualize the pandemic as a disruption of ongoing transition processes or pathways (Geels and Schot, 2007). The aim is twofold. First, we theorize the disruption of transitions in terms of critical events that accelerate, retard, or shift ongoing transition pathways. Secondly, we provide an initial empirical test of these ideas into two UK systems of provision that have been dominated by identifiable socio-technical regimes for decades.

Our research questions are:

- 1 What are the intersecting sequences of events that constitute transition pathways in two UK systems of provision, and how does an ongoing critical event such as Covid-19 affect these pathways?
- 2 How can we meaningfully assess the change in socio-technical systems as a result of Covid-19?

As critical events continue to have an effect years after they occur (as with the 2008 financial crisis (Van den Bergh, 2013)), we develop an approach that can be used while the critical event we are interested in is still ongoing (i.e. the event has a long duration). We use system dynamics methodology which allows us to conceptualise critical events as endogenous to the socio-technical system (Richardson, 2011) and is generally well-suited to capture the endogenous dynamics nature of transition processes (Papachristos, 2014; 2018; 2019; Kohler et al., 2018; Holtz et al., 2015; Papachristos and Struben, 2019). In doing so we extend prior work on sociotechnical system transitions and Covid-19 that has used system dynamics in various ways (Bradley et al., 2020; Sahin et al., 2020; Struben, 2020; Papachristos and Adamides, 2016; Papachristos, 2011). This approach also allows us to improve on the way in which case studies are used in transition research (Köhler et al., 2019).

The explanatory approach of transition research and the MLP is based on process theory (Geels and Schot, 2010; Geels 2002), and looking for patterns in sequences of events (Pettigrew, 1997; Abbott, 2001; Langley, 2007). In this mode of theorising, a case description has to include and demonstrate the logic that drives the observed temporal progressions (Van de Ven, 1992). In the context of transition research, transition narratives need to trace and include event sequences and their conjuncture within, and between, MLP levels (Geels, 2011).

Replying to criticism on the lack of methodological consistency (Genus and Coles, 2008), case studies in transitions research require improvement (Köhler et al., 2018) to catalyze the comparative analysis of transition cases and allow the inference of general transition insights (Smith et al., 2010). The use of system dynamics methodology (Sterman, 2000) and causal loop diagrams (CLD) in particular, is one way to systematically analyse transition cases (Papachristos, 2018; 2019). The application to transition research embraces the open-ended character of the MLP that is one of its strengths (Geels, 2011). Explicit representation of the causal connections in narrative sequences with the use of CLDs will enable replication and critique of the inferences made in a way that is difficult to achieve with a purely narrative representation of transition cases (Griffin, 1993).

In section 2 we provide our conceptual view on how critical events affect transitions. Section 3 presents our methodology for analysing transition pathways, the way they are affected by shocks, as well as our approach for assessing altered system pathways. Section 4 presents the two cases. Section 5 presents the comparative analysis for the two sectors. Section 6 concludes.

2. Critical events and disruption of existing transition pathways

Conceptually we draw on transition theory as a set of established theoretical ideas that has been tested extensively using empirical case studies (Köhler et al. 2019). Transition theory posits that changes in sociotechnical systems result from the interrelationship of two modes: change and stability. Key in this process of change are so-called strategic niches: the social sites where configurations of sociotechnical system elements alternative to the existing regime are constructed and tested (Smith and Raven, 2012). Sociotechnical change is conceptualised in terms of regime changes in the social and technical parts of the system that co-evolve and bring about alternate periods of relative stability and periods of major change.

Critical events and system boundary

The established view on sociotechnical transitions conceives of events such as a pandemic as part of the metaphorical 'landscape' in which sociotechnical change unfolds: an evolving structural context which affects transitions, but is itself not immediately affected by those transitions. Van Driel and Schot (2005) categorise landscape elements in levels of duration of change: almost unchanging, long-term changes, and rapid external shocks.

The common denominator in this theorising is to **externalise** critical events from the socio-technical system in transition. This makes sense for critical events whose causes are outside the boundary of the socio-technical system under study. If this condition is not fulfilled, then labelling these events as external is misleading, especially when the event has a long duration, as is the case with Covid-19. We thus propose to investigate more precisely how critical events affect socio-technical transitions, working within the constructivist perspective of transition theory (Geels, 2010; 2011). A pandemic is not a neutral and objective phenomenon, but is collectively defined and shaped (Romme, 2020). It therefore needs to be drawn inside the system boundary, to conceptualise how it interacts with niche and regime dynamics.

The pandemic is not only an exogenous shock that merely disrupts an ongoing transition. It is not the opposite either, where transition dynamics as a response to the pandemic contribute to landscape changes. Instead, an exogenous shock is mediated to become a partially endogenous phenomenon within spatial and temporal confines. The pandemic is likely to become an inherent

Table 1
Transition pathways specified as sequences of events.

Causal Loop	Causal loop variables	Strengthening +/- weakening -	Concise narrative representing causal loop
P0: Causal loops in the reproduction pathway			
S1	enactment of regime practices → ⁺ profit to incumbents → ⁺ regime-supportive investment → ⁺ enactment of regime practices	+	<i>The continued enactment of regime practices generates profit for incumbent producers, which they use to invest in a way that supports continued enactment of regime practices</i>
S2	enactment of regime practices → ⁺ profit to incumbents → ⁺ resources for market control → ⁻ change of rules → ⁻ enactment of regime practices	+	<i>The continued enactment of regime practices generates profit for incumbent producers, which can be used as a resource to control markets, including the prevention of rule changes that would lead to a reduced enactment of regime practices</i>
S3	enactment of regime practices → ⁺ legitimacy of regime → ⁻ change of rules → ⁻ enactment of regime practices	+	<i>The enactment of regime practices supports the legitimacy of the regime, which reduces the chance that rules are changed in a way that makes enactment of regime practices more difficult</i>
P1: Causal loops in the transformation pathway			
S4	enactment of regime practices → ⁻ enactment of new practices → ⁻ enactment of regime practices	+	<i>The enactment of regime practices precludes the enactment of new practices, which would reduce the enactment of regime practices</i>
S5	profit to incumbents → ⁺ niche-supportive investment → ⁺ enactment of new practices → ⁺ profit to incumbents	+	<i>Profit generated by incumbents is used to invest in a way that supports niches controlled by incumbents. This leads to the enactment of new practices which generates profit for incumbents</i>
S6	profit to incumbents → ⁺ niche-supportive investment → ⁺ available infrastructure for enactment of new practices → ⁺ enactment of new practices → ⁺ profit to incumbents	+	<i>Profit generated by incumbents is used to invest in niche infrastructure. This supports the enactment of new practices which generates profit for incumbents</i>
S7	profit to incumbents → ⁺ search for new practices → ⁺ actor enrolment → ⁺ enactment of new practices → ⁺ profit to incumbents	+	<i>Profit generated by incumbents provides resources for the search for new practices. This search induces actors to enrol in new practices, leading to enactment of new practices which generates profit for incumbents</i>
S8	profit to incumbents → ⁺ niche-supportive investment → ⁺ resources for rule change → ⁺ change of rules → ⁻ enactment of regime practices → ⁺ profit to incumbents	+	<i>Profit generated by incumbents is used to support the niche, providing resource for rule changes favourable to the niche. The resulting changes in rules leads to enactment of new practices which generates profit for incumbents</i>
S9	legitimacy of regime → ⁻ emergent need for new practices → ⁺ search for new practices → ⁺ enrolment → ⁺ enactment of new niche practices → ⁻ legitimacy of regime	+	<i>Reduced regime legitimacy feeds the emergent need for new practices, which instigates a search for new practices. This leads to enrolment in new practices which reduces regime legitimacy</i>
P2: Causal loops in the de-alignment and re-alignment pathway			
S1-S3	See above	+	
S10	legitimacy of regime → ⁻ emergent need for new practices → ⁺ search for new practices → ⁺ enrolment → ⁺ enactment of new practices → ⁻ enactment of regime practices → ⁺ legitimacy of regime	+	<i>Reduced regime legitimacy feeds the emergent need for new practices, which instigates a search for new practices. This leads to enrolment in and then enactment of new practices. This reduces enactment of regime practices, further reducing regime legitimacy</i>
S11	Actor enrolment → ⁺ enactment of new niche practices → ⁺ actor enrolment	+	<i>Actor enrolment in new practices leads to enactment of new practices, which stimulates further actor enrolment</i>
S12	enactment of new niche practices → ⁺ profit to niche actors → ⁺ niche-supportive investment → ⁺ enactment of new niche practices	+	<i>Enactment of new practices generates profit for niche actors which they invest to further support the niche. This facilitates further enactment of new practices</i>
S13	enactment of new niche practices → ⁺ profit to niche actors → ⁺ niche-supportive investment → ⁺ infrastructure for new practices → ⁺ enactment of new niche practices	+	<i>Enactment of new practices generates profit for niche actors which they invest to further support the niche by creating infrastructure. This facilitates further enactment of new practices</i>
S14	enactment of new niche practices → ⁺ profit to niche actors → ⁺ niche-supportive investment → ⁺ resources for rule change → ⁺ change of rules → ⁺ enactment of new niche practices	+	<i>Enactment of new practices generates profit for niche actors which they use as a resource for rule changes favourable to the niche. These rule changes facilitate further enactment of new practices</i>
S15	enactment of new niche practices → ⁺ profit to niche actors → ⁺ niche-supportive investment → ⁺ resources for rule change → ⁺ change of rules → ⁻ enactment of regime practices → ⁻ enactment of new niche practices	+	<i>Enactment of new practices generates profit for niche actors which they use as a resource for rule changes favourable to the niche. These rule changes reduce the enactment of regime practices which facilitates further enactment of new practices</i>
P3: Causal loop diagram in the technological substitution pathway			
S1-S4	See above	+	
S10-S15	See above	+	
P4: Causal loop diagram in the Reconfiguration pathway			
S1-S15	See above	+	
P5: Causal loop diagram 'disruptive change', a sequence of transition pathways			
S1-S15	See above	+	

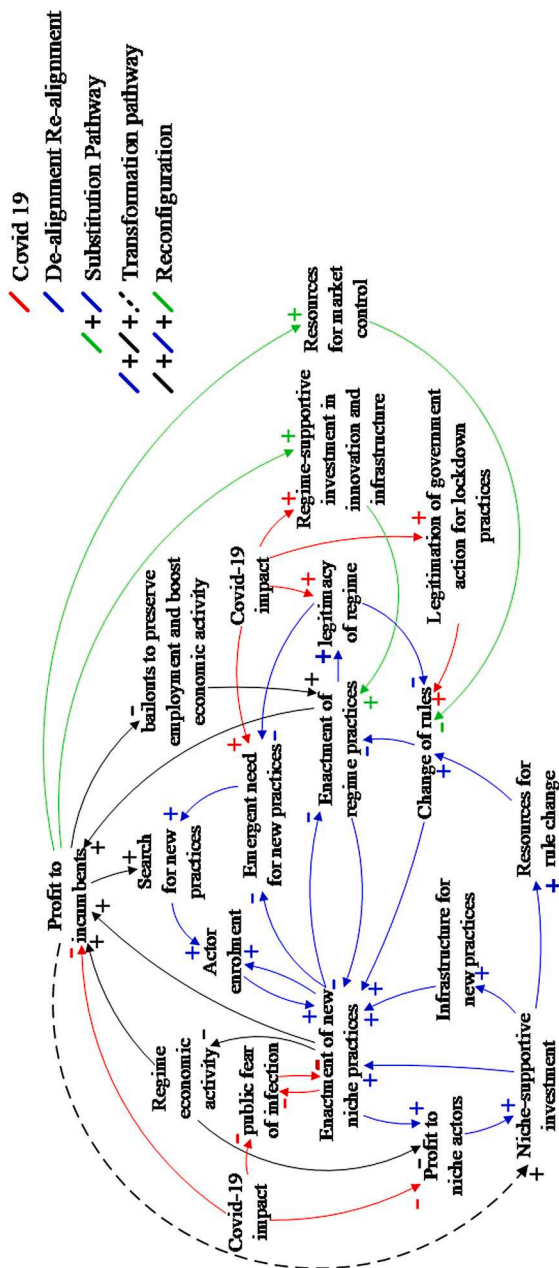


Fig. 1. Interaction of sequences of events as a causal loop diagram (CLD).

feature of our systems that will endogenously drive transition dynamics further. The endogenous view on critical events has two building blocks:

- A Transition pathways viewed as interacting sequences of events, documented in narratives and represented in causal loop diagrams;
- B Sequences of events triggered by a pandemic which potentially interact with the event sequences constituting transition pathways.

(A) Transition pathways as sequences of events

The dynamics between niche and regime, influenced by ‘external change’ have been formulated as ideal types in transition pathways typologies (Geels and Schot, 2007; Smith et al., 2005; Papachristos et al., 2013). We deepen the Geels and Schot typology by identifying key variables in the socio-technical system and their system interrelationships, which lead to a visualisation of the key dynamics of each pathway in a causal loop diagram (CLD; see Annex 1). Each CLD in the Annex summarises the interplay between key sequences of events that constitute a pathway. As these diagrams are complex in showing interrelated sequences of event, Table 1 provides individual event sequences in their formal shape and as a concise narrative. In Tables and diagrams the signs follow CLD conventions: with an arrow connecting A to B, a plus sign means that when A decreases/increases, B will decrease/increase as well; a minus sign means that when A increases B will decrease and vice versa.

The table reveals a considerable overlap in the event sequences of the theorised transition pathways. Consequently, a simple listing of the presence/absence of sequences is insufficient to determine what transition pathway actually occurs. Additional interpretive steps are required.

(B) Event sequences that result from a pandemic critical event

To understand the pandemic as an endogenous part of the system we represent Covid-19 and its effects as a set of additional event sequences. The way in which these sequences interact systemically is summarized in Fig. 1. Table 2 below describes the additional sequences of events, in three categories:

Responses to minimize health impacts of the pandemic – Sequences S16-S17 are causal loops showing how the number of infections induces a response including the enactment of new practices. New practices can be ones that already were present in niches before the critical event took place or be newly emergent practices consequential from the event.

Economic impacts on regimes and niches – Sequences S18 and S19, in combination with the previously defined sequence S14, specify causal loops where the critical event changes the balance of regime and niche practices which affects the profits reaped from the enactment of regime practices.

General economic impacts – Sequences S20-S22 capture the general economic consequences of the pandemic.

Table 2
The impact of Covid-19 on transition pathways specified as sequences of events.

Causal Loop	Causal loop variables	Strengthening +/ weakening -	concise narrative representing causal loop
Responses to minimise health impacts			
S16	Covid-19 impact → ⁺ legitimization of government action for lockdown practices → ⁺ change of rules → ⁺ enactment of new practices → ⁻ Covid-19 infections → ⁺ Covid-19 impact	-	<i>The impact of Covid-19 raises the public fear for infection which increases legitimacy of government-induced lockdown practices. This result in change of rules which affects the enrolment in new practices that lowers the number of C19 infections</i>
S17	enactment of new niche practices → ⁻ public fear of infection → ⁺ enactment of new niche practices	-	<i>Enactment of new practices reduces the public fear of infection, which leads to reduced enactment of new practices</i>
Economic impacts on regimes and niches			
S18	Covid-19 impact → ⁺ legitimization of government action for lockdown practices → ⁺ change of rules → ⁺ enactment of new niche practices → ⁻ profit to incumbents → ⁺ regime supportive investment → ⁺ enactment of regime practices	(not a loop)	<i>The impact of Covid-19 increases the legitimacy of government action to induce lockdown practices. This leads to changes of rules which lead to the enactment of new practices which reduces profits to incumbents. These have less resources for regime supportive investment, leading to reduces enactment of regime practices</i>
S19	Covid-19 impact → ⁺ enactment of new niche practices → ⁻ profit to incumbents → ⁺ resources for market control → ⁺ change of rules	(not a loop)	<i>The impact of Covid-19 leads to the enactment of new practices which reduces profit to incumbents, who then have less resources for market control which leads to a change of rules</i>
S14	See previous table		
General economic impacts			
S20	enactment of new niche practices → ⁻ regime economic activity → ⁺ profit to incumbents → ⁺ regime supportive investment → ⁺ enactment of regime practices → ⁻ enactment of regime practices	+	<i>Enactment of new practices reduces regime economic activity which reduces the profit to incumbents. This reduces resources available for regime supportive investment which reduces enactment of regime practices. This advances the enactment of new practices</i>
S21	enactment of new niche practices → ⁺ profit to niche actors → ⁺ niche supportive investment → ⁺ enactment of new niche practices	+	<i>Enactment of new practices increases the profit to niche actors. This increases resources available for niche supportive investment which advances the enactment of new practices</i>
S22	enactment of new niche practices → ⁻ regime economic activity → ⁺ profit to incumbents → ⁻ bailouts to preserve employment and boost economic activity → ⁺ enactment of regime practices	-	<i>Enactment of new practices reduces regime economic activity which reduces the profit to incumbents. This invites bailouts to incumbents to support regime activity, i.e. enactment of regime practices</i>

These sequences include variables that also occur in the sequences which make up the transition pathways (Table 2). These shared variables indicate where the pandemic influences transition pathways. The complete set of event sequences (S1-S22) and their interrelations provides our conceptualisation of the pandemic as endogenic to sociotechnical transitions. Figure 1 combines the separate CLDs in the Annex; individual transition pathways can be identified as combinations of coloured arrows (for instance, the substitution pathway is constituted by the variables connected by solid blue and solid green arrows). The sequences related to Covid-19 (S16-S22) are indicated by red arrows.

Fig. 1 is used to assess the effect of Covid-19 on ongoing transitions in food and automobility provision in UK. In general, we expect Covid-19 to have one of the following impacts on a specific domain represented by S1-S15:

- A **Accelerate a transition pathway:** the ongoing transition pathway speeds up, as negative loops are counteracted, and positive loops are strengthened and/or added.
- B **Retard a transition pathway:** the ongoing transition pathway slows down, as negative loops are added and /or strengthened that counteract positive loops.
- C **Shift a transition pathway:** the type of pathway that characterises the domain changes, as loops are added creating a different basic dynamic. For instance, Technological substitution and de- and re-alignment differ in the presence/absence of S1 and S2. If Covid-19 acts to add or subtract those loops, then the type of pathway changes.

Together, the sets of sequences presented in Tables 1 and 2 provide the basis for a systematic methodology which allows an empirical exploration of how a critical event of long duration interacts with regime-niche dynamics.

3. A Methodology for analysing disruption of transition pathways

Building on the above representation of transition pathways and Covid-19 sequences our empirical approach consists of the following steps:

- A Delineate the focal systems of provision based on the purpose of analysis. A system of provision comprises all activities required to fulfil a particular need of members of a society (Geels et al., 2015). In such systems, there are typically several transitions ongoing; as a result, the empirical unit of study can become vast. We therefore used Vayda's (1983) method of progressive contextualisation as a main guide, choosing an initial phenomenon of interest, around which a first boundary is drawn based on prior knowledge and preliminary investigation. Through iteratively collecting and analysing data, events outside the initial boundary are included until satisfactory understanding has been achieved.
- B Articulate transitions as perceived by system participants. This step includes both ongoing transitions, as well as the transitions that system actors were publicly considering as the pandemic was unfolding.
- C Collect data on the systems and their dynamics. Extensive empirical data was obtained through so-called longitudinal field immersion (Wells and Nieuwenhuis 2017). Active immersion in a system of provision has allowed us to identify, access and interpret historical data in both empirical domains. Data for the impacts of the Covid-19 pandemic was collected during the first wave (February – June 2020). Data triangulation data was used where possible to increase validity (Jick, 1979; Johnson et al., 2017). We focused on: (1) data showing how *individual variables* in the model perform over time, using reliable and accepted sources (ONS, OECD, IGD etc.), and (2) data on *links between variables*. Such links represent an underlying structure and can be evidenced by academic literature.
- D Identify for each system of provision sequences of events from the CLDs, and construct a narrative of sequences and their intersections.
- E Interpret the set of sequences for each system, identify current transition pathways using the template CLDs.
- F Analyse how transition pathways were disrupted. This requires impact indicators for the critical event. For socio-technical transitions an indicator should document the speed and comprehensiveness with which an existing socio-technical regime is being displaced. In our conceptual framework this displacement is defined as the increased enactment of new practices, combined with decreased enactment of regime practices. Proxies for these include the establishment of infrastructure and increased sales of artefacts necessary for the enactment of new practices.

In the case of 'guided' transitions, such as transitions with specific sustainability objectives, additional indicators can provide insight into the attainment level of objectives. While important, their relevance relies on the realism of assumptions about how the substitution of regime practices by new practices leads to attaining sustainability objectives. If these assumptions are unrealistic, or when unintended consequences occur (for instance because of rebound effects which lead users of energy saving lamps to leave them on longer than normal lamps), then additional indicators are not useful.

With guided transitions, the additional indicators are thus dependent on the objective envisioned with displacing a given socio-technical regime. We adopt the following indicators for:

- the acceleration or slowing down of a given transition, based on the objectives that these transitions are perceived to serve.
- the emergence of new objectives as a result of the critical event. This needs to be reflected in the assessment of the changes that occur in the system of provision that is studied.

Change in both generic and sustainability indicators needs to be interpreted with caution. Observed changes in indicators in themselves are not evidence that the change is the result of the critical event. For that we need evidence for a compelling causal narrative, i.e. sequences of events that link the critical event to the observed change. In this paper these are the sequences presented in Table 2.

4. Covid-19 and its implications for the transition of UK food and mobility provision

We present the results on UK food and automobility provision in Sections 4.1. and 4.2. using the structure below (which follows the methodological steps above):

- (1) boundary statement for the system of provision under study (step A)
- (2) ongoing transitions before Covid-19 emerged (first part step B)
- (3) system participant articulation of transitions they envision to come out of the pandemic (second part step B)
- (4) narrative describing system dynamics during the pandemic (based on iteration of steps C and D)
- (5) analysis of system dynamics in terms of our analytical framework (based on steps E and F).

We chose these empirical domains as they show evidence of ongoing transitions, and have evidently been affected by the pandemic. In the descriptive text we included analytical markers indicating sequences (such as “S1” indicating that the preceding part of the narrative is interpreted as evidence for the occurrence of (building blocks of) sequence 1 (following the numbering in Tables 1 and 2). At the end of each case section we present a Table (3 and 4 respectively) which concisely presents the complete sequences that characterise the system, before and during Covid, adding crucial detail of idiosyncrasies.

4.1. Mobility provision (focused on automobility)

(1) Statement of system boundary

As is noted in the methodology, the approach taken to delineate an empirical system is one of progressive contextualisation (following Vayda (1983) and Markard and Truffer (2008)). Automobility is the dominant feature of the contemporary personal mobility system of provision. Hence, we ‘build out’ our understanding of the UK mobility system of provision starting from automobility. However, it is clear that the extent of automobility is then circumscribed by a) decisions over whether to be mobile or not and b) opportunities available through other modes of transportation. Understanding the process of automobility transition therefore necessarily must embrace other modes of achieving mobility via active travel or public transport or, even, finding alternatives to physical mobility.

(2) Ongoing transitions in mobility provision: electrification, sharing, autonomy, and digitalisation

Previously, automobility was strongly embedded as the core regime practice. There is long-run evidence of preference for the car (DfT, 2020a), car ownership and licence holding in households (DfT, 2020b,c). Road transport dominated public infrastructure investment, while the industry enjoyed strong new car sales (albeit cyclical, see DfT, 2020d), and R&D support. The SMMT estimated that the UK automotive sector was worth £202bn GVA to the economy (in 2017). The stock of cars (DfT, 2020e) grew in GB from 2.01 million (1951) to 30.49 million (2019). [S1; S2]. The regime enjoyed strong legitimacy. [S3].

Given our focus on automobility in terms of ongoing transitions, there are two developments to consider. First, the transition to more sustainable mobility in the form of battery electric vehicles. Second, and in contradistinction, the transition to reduced automobility (substitution via either reduced ‘need’ for physical mobility or via the uptake of other modes). The notion of virtual mobility summarises all alternative means of achieving the same ends. So, this can include video conferencing and online meetings, but also for example online shopping. Immobility is the absolute form, where people are no longer mobile; whereas less or reduced mobility refers to fewer trips and / or shorter trips. Immobility remains relevant because it manifests the socially-constructed character of the ‘need’ for mobility, which in turn underpins the significance of automobility as the dominant feature of the mobility regime.

Prior to the pandemic several event sequences indicated a transition. In addition to contestation over e.g. air quality concerns and the emergence of new mobility providers such as UBER [S9], ownership of electric cars was growing slightly [S5] (see DfT, 2020f). Initial investments had been made in public charging points, and incentives were available for both cars and domestic / workplace charge points [S6; S7]. As of 1 April 2020, there were 17,947 public electric vehicle charging devices available in the UK. Since 2015, the number of public charging devices has grown by 402%, (see DfT, 2020g,h). Average distances travelled had reduced over time, and total trip numbers per annum were static (DfT, 2020i). In 2018 a joint R&D fund of £1bn was announced for low carbon vehicles, and £246 m for battery electric vehicles R&D along with £250 m for connected and autonomous vehicles. [S4-S9 evident to a modest degree].

Transitional change was largely being managed by the automotive industry through institutions such as the Automotive Council, the LCVP, and the SMMT. The government policy document of 2018 (The road to zero) established ‘ambitions’ rather than binding targets, for the share of zero emission vehicles in new car sales by 2030 (Rhodes, 2019).

(3) articulations of possible scenarios of system actors post Covid-19 Statements by system actors, people with a view on possible futures

The automotive industry in the EU and in the UK sought support for new car sales as part of emerging economic stimulus packages. Support measures varied widely on a country-by-country basis. Responses supportive of transition have included a varied mixture of purchase support for new and / or used battery electric cars, charger installation support, scrappage incentives, retrofit support and fiscal support. An interesting feature therefore is that COVID-19 responses have exposed distinctly national prerogatives rather than a

unanimous pan-EU position. Alternatively, there was stronger support for ‘green growth’ packages, with variable inclusion of support for electric cars across the EU. In the UK and elsewhere there was support for ‘active travel’ solutions (McKinsey, 2020) and reducing the demand for mobility in general (e.g. via remote working). This is evidenced by articulations from industry representatives:

“A strong new car market supports a healthy economy and as Britain starts to plan for recovery, we need car retail to be in the vanguard...Safely restarting this most critical sector and revitalising what will, inevitably, be subdued demand will be key to unlocking manufacturing and accelerating the UK’s economic regeneration.” (SMMT Chief Executive, Mike Hawes, 05/05/20 [UK])

Policy makers should:

“Firstly, to take concrete measures to avoid irreversible and fundamental damage to the sector with a permanent loss of jobs, capacity, innovation and research capability. Secondly, Europe should prepare to stimulate the recovery of our sector, which will be a key contributor to the accelerated recovery of the European economy at large.” (Eric-Mark Huitema, ACEA Director General, 20/03/20 [EU])

Industry was not unanimous:

“I believe that after coronavirus it would be naive to expect everything to return to normal – to think that consumers will come back into showrooms asking for petrol or diesel cars.” Volvo Cars CEO, Håkan Samuelsson, 15/05/20.

Many critics argued against relaxing carbon emissions reductions rules:

“Governments must ensure workers throughout car supply chains remain employed, but this is not the time to roll back Europe’s cornerstone emissions rules, such as the CO₂ targets for cars, vans and trucks.” Julia Poliscanova, director of clean vehicles and mobility at T&E, 22/04/20.

While high-level political support for active travel showed a new direction in mobility thinking:

“From helping people get fit and healthy and lowering their risk of illness, to improving air quality and cutting congestion, cycling and walking have a huge role to play in tackling some of the biggest health and environmental challenges that we face. [...] That’s why now is the time to shift gears and press ahead with our biggest and boldest plans yet to boost active travel – so that everyone can feel the transformative benefits of cycling.” (Boris Johnson, Prime Minister, 28/07/20).

(4) identification of relevant sequences of events seen to be emerging as a result of Covid-19

Mobility was key to the spread of Covid-19 and for strategies of containment thereafter [S10]. The UK automotive / automobility industry attempted without success to place cars at the core of the recovery process [S21]. The ensuing ‘lockdown’ period and subsequent austerity in the face of the need for economic recovery packages resulted in a re-ordering of priorities [S21].

The industry suffered a large reduction in new car sales, while many established travel patterns collapsed. New car sales fell by 97.3% in April 2020 compared with April 2019. Data from EVvolumes.com showed electric vehicle sales to the end of 2019 were up 24% compared with 2018 (PHEVs and BEVs) to reach a 3.2% market share. During the first half of 2020 the market share of electric vehicles grew rapidly. As of May, year-to-date 2020 EV sales accounted for a 7.2% share, and more than doubled in absolute volumes as the market overall was at 51% of the equivalent period in 2019 (SMMT, 2020). In the first three months of 2020, 1436 more BEV charge point devices were available in total, increasing by 9%. Rapid devices also increased by 283, up 10% on the previous quarter. The number of battery electric cars registered for the first time in 2020 Q1 more than tripled (+203%) compared to 2019 Q1 [S21]. Investments in public charge points were brought forward for BEVs [S13].

Google Analytics data shows that compared with the baseline trips fell to retail and recreation (-78%); pharmacies and grocery (-37%); parks (-10%); transit points (-64%); and workplaces (-48%), see Google (2020). Significant behavioural changes regarding mobility followed with the lockdown, some of which are expected to be either enduring for a long time, or effectively permanent [S11; S21]. These changes, underpinned by fear of infection, have acted to support government legitimacy on the lockdown policies [S16] to include remote working, curtailed public events, festivals, and gatherings, and reduced international travel, notably flying. Thus, there was a much stronger challenge to the enactment of regime practices and to the legitimacy of the regime, undermining profitability for incumbents and stimulating the search for new practices [S7].

London Cycling Campaign has advocated a series of steps from short-term response to long-term strategy (LCC, 2020). Cities such as Oakland (US), Bogota, Berlin and Vancouver have allocated lanes on multi-lane roads for pedestrian and cycle use (McKinsey, 2020). Often these measures are ‘temporary’, but they may become permanent [S19]. Pressure groups such as Clean Air for London have argued that the opportunity to retain clean air should not be lost, and traffic levels should be permanently lower [S19]. A Yougov survey across Europe showed strong support for car-free city centres, more bicycle lanes, and a greater emphasis on active travel (Dornier, 2020). The UK government introduced new measures such as monitoring and fines for motorists that park in cycle lanes, improved cycle lane design standards, and funding to support bicycle repairs.¹

In February 2020 it was announced that £5 billion would be available for bus and cycle links, but the emphasis was on buses. In May 2020, the emphasis changed to £2 billion on a ‘new era of cycling and walking’. Emergency bike lanes were established; trials on electric scooters brought forward [S12; S013].

The experienced benefits of reduced automobility, both in the UK and more widely, has resulted in reduced legitimacy for the regime [S10] (see He et al., 2020; Holder, 2020). While profitability for incumbents has collapsed in the short term, those of niche

¹ Also note that the ‘People’s Assembly’ advocated much stronger anti-car measures than the government has so far adopted.

actors (Tesla) have been growing [S12; S13].

While some countries adopted an approach of strongly accelerating the transition to the electrification of automobility, that has not been the case in the UK. Rather, the emphasis has been on active travel, and reducing the ‘need’ to travel [S17]. However, the pandemic also resulted in an erosion of trust in public transport and shared transport, and in this respect the space available for automobility was not closed [S18]. A survey report in April 2020 by Auto Trader claimed that 48% of existing public transport users would be less likely to do so once the pandemic had passed, and 68% of young people (16–24 years old) thought so (Auto Trader, 2020). In addition, over half (56%) of individuals that had a driving licence but did not have a car thought that Covid19 would now make them consider owning a car [S18].²

The economic consequences of the pandemic are expected to have significant repercussions on mobility and the legitimacy of the prevailing regime [S20]. The Bank of England estimates that the effect of the recession will be equivalent to each household losing £9000 per annum. Consumer confidence indices (e.g. CEIC, 2020) show that March and April 2020 had large reductions. Unemployment is expected to double to 8% by 2021 while reduced job security will constrain the demand for large credit-financed purchases. Overall, there expected to be a reduction in demand for new cars, but short-term reductions in car use may be offset to some extent by changes in travel mode away from public transport [S18; S20].

(5) Analysis and assessment

Table 3 summarizes the event sequences that were observed in the UK mobility system.

Table 3. Event sequences identified in the UK automobility system

Looking first at the system before the critical event the set of event sequences is consistent with the *transformation pathway*. Since Covid-19 pathway changes have taken three forms:

- a **Acceleration of the transformation pathway** – as noted above, petrol and diesel car sales declined while the absolute number and share of electric cars increased. Use of public transport also declined, while virtual mobility increased;
- b **De-stabilisation of the reproduction pathway** – rapid sales declines and the use of factory closures caused stress throughout the existing incumbent regime including retail, petrol stations, and maintenance;
- c **Parallel emergence of a new (different) transformation pathway** – a new transformation pathway centred on active travel by bicycle and walking, along with micro-mobility in the form of electric bikes and electric scooters (including sharing schemes).

An *assessment* of the transition in terms of the generic indicator of displacement of regime practices is complicated. The moves towards electrification, autonomous driving, and vehicle sharing potentially offer sustainability benefits, but they also have actual or potential disbenefits (Axsen and Sovacool, 2019). The balance between substitutional effects and those that are complementary or additional is highly variable depending upon multiple factors. Prior to Covid-19 at least some substitutional effect was anticipated to reduce total automobility (VMT or vehicle miles travelled). The focus of policy for sustainable mobility was on electric powertrain to reduce carbon emissions, but with a long-term perspective that did not envisage full electrification of cars until 2050, and with insubstantial support for active travel. However, in mid-2020 the UK Government published a new policy proposal (DfT, 2020) that identified six priority areas:

- Accelerating a shift towards public and active transport
- Decarbonising road vehicles
- Decarbonising how our goods and services reach us
- Solutions for emissions reductions based on specific locations
- The UK as a hub for green technology and innovation
- Reducing carbon in a global economy

This stance was mirrored by mainstream lobby groups such as The Campaign for Better Transport (CfBT, 2020) which argued for:

- A world-leading public transport network with improved connectivity
- 100 per cent zero-emission road transport and railway
- Permanent improvements to sustain greater levels of walking and cycling
- Changes to the way transport is paid for, including new means to raise revenue.

In both cases, sustainability mobility is defined with a clear focus on decarbonisation and on greater emphasis on both public transport and active travel. Hence policy for sustainable mobility will seek to reverse the losses (of users and revenues) in public transport. The removal of private ownership of public transport provision is under discussion (Lawhon and McCreary, 2020), for example in Wales, as are measures such as the Universal Basic Income as an approach to diffusing the ‘jobs versus environment’ dichotomy. Leading academic research suggests that actual sustainable mobility outcomes will be contested and diverse (Sovacool et al., 2019), but are also likely to include shared and automated electric mobility (Manders et al., 2020). These activities are likely to create new markets and new business opportunities, countering the economic decline of ‘old’ mobility practices (Deloitte, 2019).

² Lacking data on impact on car sharing, hire, etc.

Table 3
Sequences identified in the (auto)mobility system.

Sequence #	Ongoing transition	Covid-19 impact
1	Strongly embedded regime practices → normal profits → regime-supportive investments	Significant decrease in regime practices → lower regime profitability → reduced investment → reduced enactment of regime practices
2	Strong enactment of regime practices → normal profits → alternative modes excluded by not changing rules	Significant decrease in regime practices → lower regime profitability → less resources for market control → more scope for regime adverse rule changes
3	Enactment of regime practices → regime legitimacy → low incentive to change rules or regime practices → slow transition to electrification	Significant reduction in enactment of regime practices → decreased regime legitimacy → more scope for regime adverse rule changes → allowing micro-mobility → reduction in the enactment of regime practices. Parallel reduction in public transport modes.
4	Enactment of regime practices → little scope for new practices → reinforced existing regime practices	Reduced enactment of regime practices → growing enactment of active travel and remote working → Reduced enactment of regime practices
5	Normal profitability → some niche supportive investment → enactment of new practices	Falling profit to incumbents → neutral on niche-supportive investment → enactment of new practices without profits to incumbents
6	Normal profitability → some niche supportive investment and new infrastructure → enactment of new practices	Falling profit to incumbents → experienced need for new practices investment (no extra incentives for BEVs) including the available infrastructure for enactment of new practices (steady policy on charge points) → enactment of new practices without profit to incumbents
7	Normal profitability → some experimentation in enactment of new practices and enrolment → thence enactment of new practices	Falling profit to incumbents → search for new practices → enrolment in new practices → increased enactment of new practices without profit to incumbents
8	Brexit → normal profitability → experimentation in niche supportive investment → substantive rule change reduced by political support for automotive industry interests, while enactment of regime practices had stagnated and profits to incumbents had started falling	Falling profit to incumbents → niche-supportive investment focused on other modes (e-scooters and e-bikes) → resources for rule change (making e-scooters legal on the road, creating new bike lanes) → undermined enactment of regime practices → lower profit to incumbents (including e.g. car dealerships)
9	Issues around air quality and CO ₂ emissions → reduced regime legitimacy → emergent need for new practices → enactment of new practices that generally were supportive of the regime	Lockdown → challenges regime legitimacy, but also significant impacts on competing modes (trains, buses) or complementary demand modes (air travel, ship cruises) → experienced need for new practices → search for new practices → some enrolment and enactment of new practices → reduced regime legitimacy
10	Issues around air quality and CO ₂ emissions → reduced regime legitimacy → emergent need for new practices → enactment of new practices that generally were supportive of the regime → slightly reduced enactment of regime practices	Reduced regime legitimacy → emergent need for new practices → search for new practices → increased enrolment/enactment of active travel, remote working, and EVs) → declining enactment of regime practices driving declining legitimacy of the regime (public transport also suffered from falling legitimacy, while informal surveys suggested an increased appetite for automobility)
11	enrolment → enactment of new practices (EVs; car sharing; micro-mobility) → further enrolment	stronger enrolment → enactment of new practices (including active travel, which may be temporary) → further enrolment
12	enactment of new practices → increased profits to new entrants (Tesla; UBER; micro mobility) → niche-supportive investment → enactment of new practices	[insufficient evidence to link increased enactment to profit for niche actors; some niche practices such as car sharing and ride hailing have declined significantly]
13	enactment of new practices increased profits to new entrants (Tesla; UBER; micro-mobility) → niche-supportive investment → available infrastructure for new practices → enactment of new practices	new infrastructure mostly as (temporary) cycle lane provision; some acceleration in charge point provision for EVs → enactment of new practices
14	enactment of new practices → increased profits to new entrants (Tesla; UBER; micro-mobility) → resources for rule changes (car-free and zero emissions zones) → increased enactment of new practices	Rule change → enactment of new practices, but related to political / policy initiative at the highest level to link increased active travel with improved health outcomes and hence better resilience to the pandemic, rather than niche profitability
15	enactment of new practices → increased profits to new entrants (Tesla; UBER; micro-mobility) → resources for rule changes (car-free and zero emissions zones) → enactment of new practices → regime practices unaffected (except for Brexit impacts)	[insufficient evidence for this sequence; link from enactment to niche profits has not been shown]
16	[no evidence to support this sequence]	Covid-19 infections → public fear of infection → emergent need for new practices → legitimacy of government action (lockdown practices) → reduced mobility in general
17	[no evidence to support this sequence]	enactment of new practices → reduced the public fear of infection → sustains enactment of new practices → reduced rate of infection → enactment of new practices
18	[no evidence to support this sequence]	Covid-19 infections → increased legitimization of government action (lockdown practices) → change of rules → enactment of new practices → reduced incumbent profitability → lower regime supportive investment reduced enactment of regime practices
19	[no evidence to support this sequence]	Enactment of new practices → reduced incumbent profitability → less resources for market control → less regime supportive investment → less enactment of regime practices
20	Brexit decision → enactment of new (trading) practices → some breakdown of regime firms (e.g. closure of Honda assembly plant)	enactment of new practices, but accompanied by decline in economic activity → lower GDP → accelerated breakdown of regime firms or

(continued on next page)

Table 3 (continued)

Sequence #	Ongoing transition	Covid-19 impact
21	[no evidence for this sequence]	reduced profitability) → reduce regime supportive investment → the enactment of regime practices
22	[no evidence for this sequence]	enactment of new practices, but accompanied by decline in economic activity → partial breakdown of niche firms (e.g. UBER); nevertheless growth in niche supportive investment → enactment of niche practices enactment of new practices, but accompanied by decline in economic activity → lower GDP → accelerated breakdown of regime firms or reduced profitability). No strong evidence for bailouts to preserve employment and boost economic activity and therefore the enactment of regime practices

4.2. Food provision

(1) Statement of system boundary

The system under consideration is the UK-based food supply from production to consumption, with food retailers as crucial intermediaries. If we delineate the system in this way, we need to be aware of the fact that the UK imports almost half of its food with thirty percent coming from the EU and ten to fifteen percent from developing economies; this employs complex supply chains that are vulnerable to disruptions (Lee and Rammohan, 2017). Some UK supply chains are also reliant on EU seasonal labour with UK agriculture employing approximately 70,000 seasonal workers (Defra, 2018). Using our approach of progressive contextualisation, we will bring in this international embeddedness where relevant. To further focus our empirical attention within this vast system we look at key transitions as perceived by system actors.

(2) Description of ongoing transitions: Brexit, healthy diet, eating out

Before Covid-19 food supply by both grocery retail and the non-domestic food sector (hospitality, food to go) was strongly embedded as core regime practices [S1; S2]. Food is the largest manufacturing sector in the UK with 6.3% of GVA worth £120 billion employing 3.98 m people (Defra, 2020). The UK's grocery food retail sector is one of the world's most concentrated with four leading supermarkets (Tesco's, Sainsbury's, Asda and Morrison's) accounting for 70% of total grocery sales (Garnett et al., 2020). According to Hasnain et al. (2020), grocery retailing is worth £30.3 billion to the UK economy with out-of-home catering worth £36.4 billion. Also, online sales via grocery retailers was static at 7% of total sales (Mintel, 2020).

There was sizeable contestation regarding the legitimacy of food supply related to problems of human and planetary health [S3-S6, S10, S14]. Poor diet in the UK leads to 1 in 7 deaths in Britain every year (Bhunno and Poppy, 2019), accounting for £6.1 billion of annual NHS spend (around 9% of budget). 46% of food and drink advertising spend goes on confectionery, sweet, savory snacks and soft drinks, only 2.5% on fruit and vegetables (Houses of Lords, 2020) [S11]. Almost 23% of children are overweight or obese when they start primary school (NHS, 2019a). Obesity-related hospital admissions increased by 86% in 4 years (NHS, 2019b). Many voluntary initiatives were introduced across the food industry, but were still falling short in meeting dietary recommendations. UK citizens eat the most processed food in Europe (Euromonitor, 2018).

Poor dietary health is compounded by increasing UK food poverty. Between April 2018 and March 2019, the Trussell Trust's network of food banks distributed 1.6 million food parcels, a 26-fold increase on 2010 (Power et al., 2020; Trussell Trust, 2019a). The Food and Agriculture Organization of the UN estimated in 2018 that around 2.2 million people in the UK are severely food insecure (i. e. with limited access to food, due to a lack of money or other resources) [S10, S14, S15]. In addition, the UK food system is responsible for problems with environmental degradation. GHG emissions from UK agriculture were estimated to cost the UK £3.1 billion per annum (Defra, 2020). Soil degradation costs an estimated £0.9bn - £1.4bn per year (Defra, 2020). Furthermore, regarding UK biodiversity 41% of species in the UK are declining [S10, S11].

There was some evidence of industry voluntary transition with retailers responding to the fourfold increase in the number of UK vegans (Twine, 2018) by launching new vegan food ranges [S5-S8]. Furthermore, several retailers launched sustainability initiatives in partnership with NGOs e.g. Tesco-WWF partnership to halve the environmental impact of food shopping (WWF, 2020) [S4-S9]. The National Farmers Union made a public commitment to net zero GHG emissions by 2040 (Waters, 2020). There was also the emergence of food hubs to aggregate and localise food supply, plus the growth of urban indoor vertical farming enterprises (Edmondson et al. 2020; Guzman and Reynolds 2019) [S12-S15]. These efforts were complemented by £46.5 million UKRI and UK Government research funding in the Transform the Food Systems Programme, recognizing the failure of business as usual [S4, S12]. However, according to the House of Lords, the food industry and the UK Government have failed to take the necessary action (House of Lords, 2020). Many Government proposals to impose restrictions on the marketing, advertising and price promotion of less healthy foods have so far failed to progress beyond consultation stage [S2].

A further change in the landscape was EU Exit at the end of December 2020, leading actors across the food supply chain to assess their dependency on EU suppliers and markets for products. Grocery retailers had been making contingency for a no-deal Brexit by working on contingency plans including diversifying supply from new sources (Glottz, 2019).

(3) Articulations of possible scenarios of system actors post Covid-19 Statements by system actors, people with a view on possible futures (Wake-up Call).

Those suffering from obesity are twice as likely to die from Covid-19 (Tan et al. 2020). According to the House of Lords select

Table 4
Food system table of sequences.

Sequence	Ongoing transition	Covid-19 impact
1	Strongly embedded regime practices → normal profits → regime-supportive investments → regime practices	Significant selective growth in regime practices: high in grocery supermarket regime practices, decline in hospitality and food service sectors → selective profits → selective regime supportive investments
2	Strong enactment of regime practices → normal profits → new practices excluded by (not changing) rules	Increased profits → increased investment in online supply infrastructure and provision, combined with increased donations to food aid providers
3	Enactment of regime practices → strong regime legitimacy → low incentive to change rules or regime practices	Regime private actor actions → increased regime legitimacy
4	Enactment of regime practices → little scope for new practices → reinforced existing regime practices	This sequence is undermined by increased enactment of new practices: home cooking due to remote working); fears of Covid-19 increase interest in healthy diet, exercise and home cooking to boost immune systems; increase in online shopping due to fear of infections in busy supermarket environments
5	Incumbent profit → beginning voluntary industry transition to niche supportive investment and new practices (vegan diet, sustainable (net-zero) food production)	incumbent profit → regime-based investments (on-line provision, redesign of store footfall, new queuing and cashless systems). Out of home (not necessarily based in profit) invests in new practices: table service only, closely monitored numbers, takeaway provision and screen partitions and cashless systems. Also, regime actors engage in B2C localised supply of food produce and investment in new collaborations and donations to alleviate rising food poverty due to the pandemic
6	Incumbent profits → some experimentation in niche supportive investment and new infrastructure → enactment of new practices; not always profitable for incumbents e.g. food donations to charities	grocery profits → significant donations to tackle food poverty
7	Normal profitability → some experimentation → enrolment/enactment of new practices and enrolment. Brexit negotiations → diversifying supply by groceries, changing product specifications, forward contracting, extra warehousing etc.	Increased costs to grocery incumbents (hygiene, less footfall) → search for new practices (e.g. online) → enrolment/enactment in new practices → profits to incumbents
8	Normal profits to grocery retailers → niche supportive investment (sustainability partnerships). Other regime actors also invested in niche infrastructure (National Farmers committing to net zero, food hubs localising supply, vertical farming)	Reduced turnover hospitality sector → search for new practices (take out, delivery collaborations) → incumbent profits (at lower level) Enactment of new practices (increased local shopping → increased investment in new practices (vertical farming equipment, hydroponics, establishment of localised supply chains)
9	Various negative impacts of regime practices (obesity, GHG emissions) → regime legitimacy → perceived need for new practices	Sequence triggered by negative impacts temporized, but still intact
10	Various negative impacts of regime practices (obesity, GHG emissions) → reduced regime legitimacy → need for new practices → enrolment/enactment of new practices (smart farming, alternative proteins)	Reduced legitimacy of livestock regime → need for new practices → enactment of new practices (sales of fresh vegetables and fruit) → reduced enactment of regime practices (fast food outlets)
11	Brexit → new Environmental Land Management Scheme incentivizes sustainable farming → enrolment/enactment in new practices (regenerative farming, regime to cut GHG emissions)	EU Exit coupled with Covid-19 impact → new trade deals e.g. with US might lower environmental standards
12	enactment of new practices → increased profits to niche actors → limited supportive investment feeding into enrolment/enactment	[insufficient evidence to support this sequence]
13	enactment of new practices → increased profits to niche actors (e.g. Regenerative Farmers, Food Hubs etc.) → niche-supportive investment and available infrastructure for new practices	Enactment of new practices (e.g. direct purchasing from farmers, vertical hydroponic approaches) → investment in supporting infrastructure → enactment of new practices
14	Enactment of new practices → profits to new entrants → some voluntary rule changes (environmental stewardship incentives, premiums for organic production) → enactment of new practices	Enactment of new practices → profit used to advocate rule change on unhealthy produce
15	Additional to niche investment, UKRI and UK Government provide research funding of £46.5 million pound (Transform the Food Systems Research Programme)	Enactment of new practices → profit to some niche actors → investment in new direct B2C supply chains → enactment of new practices
16	[no evidence to support this sequence]	Covid-19 infections → public fear of infection → legitimization of government action (lockdown) → emergent need for new shopping practices → enactment of new practices (mainly in relation to groceries; reduced food to go)
17	[no evidence to support this sequence]	enactment of new practices → reduced public fear of infection → increased enactment of new practices (online provision, direct purchasing from farmers)
18	[no evidence to support this sequence]	Covid-19 infections → public fear of infection → legitimization of government action (lockdown) → emergent need for new practices (related to unhealthy diet → unclear impact of rule changes
19	[no evidence to support this sequence]	Covid-19 infections → new rules (UK Obesity Strategy 'Better Health Campaign' in part to 'beat Covid-19') → some evidence for changed practices
20	Brexit → repatriation of rules (25-year Environment plan and associated new Environmental Land Management scheme as a 'Green EU Exit'; New Agricultural bill)	Enactment of new practices → profit to regime actors (grocery sector) but falling profit to others (on the go food, hospitality) → breakdown of

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Table 4 (continued)

Sequence	Ongoing transition	Covid-19 impact
21	[no evidence to support this sequence]	some regime firms → investment in regime-based infrastructure for new practices Enactment of new practices → growth in niche supportive investment → further enactment of new practices
22	[no evidence to support this sequence]	[no evidence to support this sequence]

committee (2020) chaired by Lord Krebs,

“The Covid-19 crisis should serve as an urgent wake up call to the Government. People should be able to access not only enough food, but also the food that they need to stay healthy. [...] We hope one of the outcomes of Covid-19 and the rise in home cooking is move away from our reliance on processed food”.

Dave Lewis outgoing CEO of Tesco said recently,

“...the problems facing the UK food system cannot be left to the market. We need not simple incremental change, but heavy-duty food systems transformational change. The sort of change that means we all have to bring our expertise together and work in a very different way”.

Andrew Opie of the British Retail consortium said,

“It’s thanks to the food industry that the UK has remained resilient during the Covid-19 pandemic. We have shown what is possible in labelling, reformulation, removal of trans fats and healthier promotions. We just need universal application of those and support from government in the Covid-19 recovery period”.

These narratives demonstrate an appetite for a shift in transition towards rule changes for a healthier diet. In addition, they appear to call for strong government.

(4) Identification of relevant sequences of events seen to be emerging as a result of Covid-19

Home cooking has been boosted by lockdown and shutdown of the eating-out sector [S21, more in-home leisure and work time, and the positive connotations these activities enjoy with both economising and healthiness. The UK grocery sector has experienced unprecedented sales growth (Kantar World Panel, 2020) with double digit growth every week [S1-S2]. To support grocery retailers during the pandemic the UK government also provided business rate relief enhancing their profits further [S1, S2] (Fresh Talk Daily, 2020). 45% of adults reported doing more home cooking [S5-S6], within which scratch cooking has been the main focus (Kantar World Panel, 2020). The sector saw a 25% increase in fresh fruit and vegetable sales and increases in organic category sales of fresh produce [S17]. In fact, UK supermarket Tesco reports the best sales of fruit and vegetables this century (Fruitnet, 2021). There has also been an increase in alternative business models that take fresh produce direct from farmer to consumer [S13, S14] leading to a 111% increase in demand for UK fruit and vegetable box schemes (Wheeler, 2020).

With fears of Covid-19 there is an increasing interest in healthy diet, exercise and home cooking to boost immune systems [S17, S18-S22]. The IGD report that during the pandemic 51% of people in the UK have consumed more fruit and vegetables. However, despite the increase to 3.4 portions of fruit and vegetables a day this is still below the UK dietary guidelines of 5 portions per day (IGD, 2020). To support this increase consumption of fresh fruit and vegetables the UK Government in July 2020 announced a new Obesity Strategy ‘Better Health’ to lose weight and beat Covid-19 (DoHSC, 2020) which involved rule changes to advertising unhealthy food and drink before the 9pm children’s watershed [S9-S11, S16, S17, S19, S20]. This appears to signal a shift in transition with stronger government intervention with new rules for the food industry.

The Covid-19 outbreak also sparked a rapid increase (IGD, 2021a) in usage of online purchasing thanks to the dramatic shift among consumers from in-store to online in response to the lockdown mandate and aversion to busy public spaces [S19]. A sizeable 34% of adults said that they had increased the amount of online shopping they were doing as of April 23 2020 (Kantar World Panel, 2020). While some of the demand prompted by the outbreak will ebb, some will bring lasting growth for online sales [S3-S4] and scale-up by the grocery sector e.g., Tesco online sales nearly 50% up [S7]; Waitrose opening third fulfilment centre.

Increase in Inequalities

A YouGov survey commissioned in partnership with the Food, Farming and Countryside Commission (FFCC), showed 1.5 million people in the UK reporting that they’d gone a whole day without eating since the lockdown came into effect, and 7.1 million say they’ve had to reduce or skip meals. Rising unemployment is predicted in 2020/2021 with 1 in 3 people actually better off during Covid-19 period, thereby increasing disparity [S18]. In fact, UK food insecurity has doubled in 2020 (Ipsos Mori, 2020).

Shopping Local

After the Covid-19 outbreak 28% of adults report shopping more from local businesses, which is corroborated by Kantar data (Lee, 2020) [S19]. This reflected necessity, with supermarkets struggled to meet demand early on, as well as a desire to support small local businesses, with an invigorated community spirit during the crisis. The solidarity and appreciation for small, local businesses may prove to be a lasting legacy [S11-S15] (IGD, 2021b). Localism trend comprises niche adaptations such as increased orders for indoor vertical farming equipment (at scale), app-based provision and Local Food Hubs direct supplying to consumers.

(5) Analysis and assessment

Table 4 summarizes the event sequences that were observed in the UK mobility system.

Table 3. Event sequences identified in the UK food system

The event sequences observed prior to the pandemic are consistent with the *reconfiguration pathway*. The critical event of Covid-

19 and the sequences of events it has given rise to have had the following effect:

- a **Strengthening of the sequences associated with reproduction of the regime** – despite initial disruption to supply chains the grocery retail regime has been strengthened by the pandemic. This has enabled significant investments in online infrastructure, indoor vertical farming and in store safety. Several niches have emerged focused on adaptation of the out of home sector such as vegetable box schemes.
- b **Acceleration of a desire to see healthy diets** – increase because of poor UK dietary health being exposed by the pandemic. More cooking from scratch with fresh produce and also government intervention with the new Obesity Strategy launched in July 2020. This provided new legislation to curb the advertising of unhealthy products to young people. Furthermore, UK Department of Health and Social Care (DHSC) launched on February 11th, 2021 a new white paper giving Ministers new powers to intervene in the UK food system on food labelling and advertising restrictions on unhealthy foods (DHSC, 2021).
- c **Emergence of a new reconfiguration pathway** - the shift to local retailers and food providers can be seen as a new pathway.
- d **Destabilisation of the non-residential food sector** which had grown significantly in the past 10-years to be larger than grocery retail.

An **assessment** of the transition due to Covid-19 shows a strengthening of the grocery supermarket regime giving them the resources from increased profits to invest in scaling up infrastructure to meet the growing demand for online retailing (Cummins et al., 2020). However, the non-residential sector has experienced significant decline showing the largest fall in pay of any sector with 8.8 million employees being furloughed under the UK Coronavirus job retention scheme (ONS, 2020). It is clear the shock of the Covid-19 pandemic has revealed the wicked problems in the prevailing food system of declining sustainability (human and planetary health). Shanks et al. (2020) voice their public health concerns regarding potential disruptions to food supplies due to ‘no-deal’ EU Exit. Obesity, driven by a food system that encourages consumption of cheap energy-dense food quickly emerged as a leading risk factor in Covid-19 mortality. The new UK government obesity strategy, and the increased fruit and vegetable consumption combined with increases in local supply demand demonstrate that Covid-19 could provide a trajectory towards a more sustainable food system.

We are now in the worst recession since the 1930s, in a second wave of Coronavirus and about to exit the EU with many parts of the

Table 5
Summary of key findings in the UK automobility and food systems.

ANALYSIS OF PATHWAYS		AUTOMOBILITY	FOOD
pre-covid-19 pathway		transformation	reconfiguration
Effect of Covid-19 on pathways	Accelerate	Transformation towards electrification’ Public statement (18/11/20) to reinforce shift to electrification. Ban on new pure ICE cars brought forward ten years to 2030.	Online purchase + home delivery has replaced shopping in physical stores. Nielsen reports a 14% increase in online grocery sales, which equates to an extra 600,000 households shopping for food online for the first time in the UK (Nielsen, 2020).
	Slow down	Observed in the shift back out of public transport towards cars; economic impact has constrained the ability of industry to support the electrification transition	All practices of eating out have been drastically reduced to temporary lockdown closures . Data suggests recovery of this sector will be slow. A quarter of the customers will only feel comfortable to patronize a sit-down restaurant when their communities’ ability to test, trace, and isolate Covid-19 cases is significantly improved (Gursoy and Chi, 2020).
	Shift	Emergence of a transition to active mobility, virtual mobility, in terms of enactment of practices and articulation in visions of post-Covid-19 society	Increase in home cooking and decrease in consumption of prepared meals as more people have time to cook. Poor diet identified as one of three top risks of death from Covid-19 and UK Government launches new Obesity Strategy on 27th July 2020.
aASSESSMENT OF OUTCOME INDICATORS			
Displacement of regime practices		Regime has been weakened	Grocery regime has been strengthened
Advancement of pre-Covid-19 transition outcomes		Electrification: accelerate sales of electric vehicles	healthy diet increased purchase of fresh fruit and vegetables as more people home cook. obesity levels continue to increase
		Autonomous driving: No specific outcome	EU exit concerns from various quarters about impact on fresh fruit and vegetable supply to the UK regarding port delays, price inflation.
		Carsharing: Reduced car sharing, taxis, etc.	Eating out: UK public concerned about eating out without proper track and trace system in place.
New transition outcomes		Active mobility: Increased cycling and walking	Shopping locally, convenience stores experience market growth
		Reduced user trust in public transport:	Home cooking: reduction in sales of prepared meals and increased consumption of fresh ingredients as more people cook from scratch at home.
		Major Reduction in trips with substitution by Virtual mobility; shopping delivery; home working	Significant increase in digital grocery shopping

food sector warning of inflationary pressure on the price of food (Choi et al., 2020). The new National Food Strategy launched its interim report in July 2020 recommending:

- A food security strategy for the UKs growing number of disadvantaged families to shore-up the diets of the most vulnerable children with healthy start vouchers to gain access to free fruit and vegetables
- Legislative restrictions on advertising unhealthy foods and associated fiscal measures
- Improved public sector recruitment of food and drink to promote healthy sustainable approaches
- Incentivise food sector disruptions that reduce the amount of foods that are high in fat, sugar and salt (HFSS).
- Empower consumers with honest nutritional labelling on all foods in retailing and non-residential catering.
- Incentivise farmers to increase soil health, biodiversity and reduce greenhouse gas emissions

5. Comparing systems of provision

Based on the insight provided in the individual systems of provision we can now compare them to see how the pandemic, as a critical event, led to sequences of events that affected ongoing transitions. Table 5 summarizes the main findings.

Regarding the *pre-Covid transition pathway* we find a difference, with mobility following a transformation pathway while the food system displays evidence of a reconfiguration pathway. This difference lies not so much in the presence or absence of sequences of events, but rather in the strength of (1) the sequences responsible for reproduction (S1-S3), which are weaker in the mobility system than in the food system, and (2) the extent to which alternatives to regime practices constitute a viable alternative to the regime, or are too weak to play that role. In automobility, there are indications in 2020 Q1 data (just pre-Covid-19) that the adoption of BEVs is accelerating. For that period there is no clear evidence of a change in the distribution of transport modes. In the food system, although problems of poor diet and obesity had been recognised before Covid-19, there is no evidence of an accelerating pace of change towards alternative systems such as organic products or regional food supply chains. These are stable, but a small proportion of the market.

Looking at the *effect of Covid-19 on pathways*, both systems show effects in different directions: some ongoing transitions are accelerated while others slow down, and in both systems new transition pathways emerge, as summarized in Table 5.

Regarding the generic outcome indicator for a transition (displacement of regime practices) the two systems are radically different: while reproduction sequences are weakened in mobility, they are strengthened in food, leading to a differential effect on regime stability.

In automobility, the immediate effect is to destabilize both the automobility regime and the public transport systems (rail and bus). What is uncertain is the extent to which increased working from home and reduced household trips for shopping, leisure etc. may be a permanent change in mobility behaviour. There has also been a change in emphasis in government policy towards stronger support for cycling and walking than pre-Covid-19. Furthermore, there has been (so far) no large-scale government support for the automobile regime, either in terms of market support for fossil-fuelled car sales or in terms of support for retail sales or maintenance infrastructure. Support for retail sales and maintenance could be made compatible with BEVs, but the policy so far supports a change in direction of the transition.

In the food system, Covid-19 brought about at least three major changes in behaviour. The change to homeworking increased the amount of home cooking. This was reinforced by the restriction and closure of the eating out sector, leading to increased sales in the regime grocery sector. Simultaneously, homeworking together with restriction and closure of the entertainment sectors led to a major increase in online shopping. A further effect has been the increasing concern in the population for health issues, leading to an increase in sales of fruit and vegetables, organic foods and also locally produced foods. Another impact of Covid-19 has been an increase in food poverty.

There are two themes that are common to the automobility and food systems in the impacts of Covid-19. One is the reduction in personal mobility leading to a sudden major increase in the substitution of physical transport by online retail. The other is a sudden major increase in the importance placed on health, leading to an increase in active transport modes and a change towards 'healthier' and local food. We need to be cautious in overinterpreting the available data, as current evidence supports different future scenarios. One possible outcome is that in both systems ongoing pathways have been partially re-orientated towards health and, in consequence, there is convergence between the two systems of provision. The encouragement of active travel sought partly to alleviate short-term concerns with virus transmission, but also became part of a long-term concern to improve social health on the basis that a fitter population is better placed to resist the effects of the virus. In consequence, the reduced use of cars to visit restaurants or to go shopping for food, alongside increased active travel and home cooking, can be interpreted as a potential convergence of a food and mobility provision transition pathways around health. In macroeconomic terms, the shutdown of the eating out and leisure sectors may cause a long-term decline in the sector, thus reducing travel to leisure activities and demand for food for eating out. An alternative scenario draws on evidence from different contexts, including the UK (Jia et al. 2021; Robinson et al. 2021): the lockdown has led to a change in practices where people are more physically inactive, resulting in them gaining weight. If these practices are retained, the trend of increased obesity might be strengthened.

Several of the new practices are part of the response to the pandemic, such as home cooking and active travel. This means that they are fragile, in the sense that it is not clear how these pathways will continue once the sequences constituting the pandemic will weaken/disappear. Viewing niches as platforms for the development and enrolment into new practices, we can build on insights from Theories of Practice (Warde, 2005) to assess conditions under which these practices can be retained.

In automobility, new transition outcomes are constrained by structural dependence upon car use alongside embedded cultural dependency. The alternative outcomes of active travel and virtual mobility have weakened the regime, but distrust in public transport

has strengthened the regime.

6. Conclusions

We use a system dynamics approach to qualitatively model transition pathways in the UK food and automobility systems of provision. Our analytical ambition is to provide insight into the way in which an external event of long duration affects ongoing transitions. It could be argued that our timing to provide such insight is awkward; with the pandemic still ongoing, and the transitions studied still underway, we risk drawing premature conclusions. It is true that it is impossible to assess whether changes that we currently observe are inflection points in trends that in five or ten years can easily be labelled as a transition. The reason to nevertheless pursue this ambition is that to some extent, historical analysis is always transitory; with the passing of time perspectives on the past change, sometimes dramatically (Abbott, 2001). Also, our analysis does provide insights that are valuable, especially since we focus the analysis on how Covid-19, as a critical event of longer duration, affects ongoing transition pathways. The CLD analysis provides a structure for the collection and interpretation of empirical material. It enables us to interpret the empirical material to identify changes in transition dynamics in the two socio-technical systems as a result of changes in policy and behaviour arising through the Covid-19 pandemic (research question 2).

The cases of automobility and food provision showcase how an initially exogenous event becomes part of the system dynamics that constitute transition pathways. We can now draw conclusions on three distinct topics: (1) the need to make critical events endogenous to the analysis of socio-technical transitions, (2) insights specific to the ongoing transition in the provision of food and automobility in the UK, and (3) the usefulness of making transition pathways explicit as a causal loop diagram where recognizable sequences of events interact.

Critical events and the boundary between landscape and socio-technical system

Our exemplary cases clearly show how a critical event of a longer duration, such as Covid-19, generates sequences of events that become part of overall system dynamics that constitute transition pathways (research question 1). This has several effects. A key variable in our cases clearly is the income for incumbents generated because of regime practices being enacted, but other variables are important as well. In more general terms this means that critical events can change the strength of existing sequences of events. A clear example of this is the strengthening of regime reinforcing sequences in food provision, and a decrease of these sequences in the automobility system (see Table 5).

Secondly, in our cases we see the establishment of new niches which bring back past practices, such as active mobility and home cooking. These practices are an integral part of the response to the pandemic, providing evidence for how the critical event is endogenous to system dynamics.

Insights into our empirical cases

Our cases show evidence of how a critical event results in a variegated effect on existing transition pathways as well as the emergence of new pathways. As to changes in existing pathways, the combination of slowing down and acceleration is a direct result of the different ways in which existing transitions align with the societal response deemed necessary. The need to constrain infection rates ultimately requires reductions in social contact, which leads to changed practices of food and mobility provision. Buying food in local shops and using online platforms to deliver ingredients and meals is consequently accelerated. In contrast with the food system, mobility in general is reduced when social contact is reduced, in part countered by shifting from collective forms of mobility to personal mobility.

While we observed the emergence of new practices, we are careful to interpret these as full-blown transitions. With the pandemic ongoing we cannot definitively conclude which new pathways will persist. Nevertheless, there are indications that conditions for retaining changed practices over a longer period are fulfilled in specific cases such as more hours worked from home.

The case of Covid-19 also makes clear how governmental policy can create conditions for the rapid emergence of new transitions, such as active travel and home cooking. Covid-19 has increased the legitimacy of governmental intervention and the results provide evidence for its efficacy. This deserves further study as it is unclear to what extent such legitimacy can be retained over a longer period.

Methodological advances

The use of CLDs to explicitly define sequences of events enables transparent case descriptions and comparative analyses. Crucially, it facilitates the analysis of unfolding critical events and the way they interact with transition dynamics, showing how a critical event, and the societal response to it, becomes entangled with those dynamics. In terms of the MLP we would describe that as viewing the boundary between landscape and system as more permeable. Carefully inspecting the causal chains that constitute transition pathways, something which our method enables, produces an assessment of how a critical event can change the causal loops and therefore change the transition pathway.

In developing the CLDs we have made explicit how transition pathways consist of a limited number of sequences of events; the overlap of sequences across transition pathways indicates that the assessment is not only in identifying the presence or absence of a sequence, but also in the relative strength of sequences.

Our approach to the analysis of ongoing (possible) transitions can be extended to other cases; it thus responds to the call for case study methodologies for transitions that enable comparative analysis and can perhaps enable the development of general insights (Smith et al. 2010; Köhler et al. 2019). Our cases show how the methodology allows for a systematic disentangling of the sequences of events that make up transition pathways, and as such it enables theory-driven empirical comparative work.

Emerging insights on the impact of Covid-19 on the provision of mobility and food in other countries corroborate the need for such comparative work. For the provision of mobility, the responses by different countries to the COVID-19 pandemic have shown a combination of similar sequences of events (there has been some policy response in most cases), and distinct events unfolding.

Responses supportive of transition, which go further than the UK governmental support, have included a varied mixture of purchase support for new and/or used battery electric cars, charger installation support, scrappage incentives, retrofit support and fiscal support (see for example Mallet, 2020). An interesting feature therefore is that COVID-19 responses have exposed distinctly national prerogatives rather than a unanimous pan-EU position. In the provision of food, several countries show a profile of transitions that is similar to what we find in the UK.

Evidence on food provision in other countries likewise shows sequences of events which are similar to the UK, such as the growth of supermarket food sales, as top 20 global food retail markets reportedly grew on average by 8.8% due to COVID-19 (IGD, 2021a; Goddard, 2020). Also, the localism trend can be found outside the UK, for instance in (Cappelli and Cini, 2020; IGD 2021a). Also, worrying trends such as the rise in food insecurity is replicated in countries such as the USA (Nagata et al. 2020).

These individual observations should however be taken with caution; as our method advocates, they need to be seen in the context of the full set of sequences of events that make up transition pathways and dynamics resulting from Covid (Tables 1 and 2). Our main argument is that available and future evidence on the impact of Covid and similar events of long duration needs to be analysed from a systemic perspective.

Declaration of Competing Interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eist.2021.04.003.

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