Towards a stage model of regional industrial path transformation

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**ABSTRACT**

The recent debate on innovation-based structural change in Evolutionary Economic Geography is characterised by a strong focus on the rise of new industrial paths. This paper seeks to shift attention and cast light on radical innovation activities occurring within existing paths without necessarily leading to their dissolution. Departing from a systemic perspective of path development we propose a stage model of path transformation. We outline how radical change becomes initiated, reinforced and finally consolidated in established industrial paths. Particular attention is devoted to the ways in which actors – influenced by ‘the past’ and driven by visions and expectations (that is, ‘the future’) – exert agency to stimulate asset modification processes that are assumed to underpin path transformation and the reconfiguration of the wider support structures. The framework is applied to the analysis of the automotive industry in West Sweden, which is currently transforming towards the development of self-driving cars.

**KEYWORDS**

Path transformation; evolutionary economic geography; stage model; assets; agency

1. Introduction

The rise of Evolutionary Economic Geography (EEG) has led to a renewed interest in the mechanisms and processes of innovation-based development of industrial paths.\textsuperscript{1} The debate is characterised by a dichotomy between on-going, gradual change driven by incremental innovations leading to minor adjustments of existing paths on the one hand and radical change triggered by disruptive innovations believed to underpin the rise of new paths on the other hand. The past few years have witnessed a shift of attention towards the latter (MacKinnon et al. 2019).

This paper seeks to provide a more nuanced view, focusing attention on how radical transformation activities may take place within mature regional industrial paths. We argue that radical innovations can happen ‘on the path’ and do not necessarily lead to its dissolution. We scrutinise the unfolding of the transformation of an industrial path and its wider regional set-up (that is, the regional support structures) over time. We contend

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\textsuperscript{1}Drawing on the definition of a newly created path (Binz, Truffer, and Coenen 2016, 177), an existing path can be defined as ‘a set of functionally related firms and supportive actors and institutions that are established and legitimized […]’.

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that due to the disruptive nature of radical innovation, one can hardly assume such transformations to be linear and abrupt but rather to be complex and long-term processes, featuring a transition from pre-transformation to transformation activities. It is argued that transformation activities, that is, activities and practices that deviate from those dominant in the past (pre-transformation activities), are manifested in distinct forms of asset modification processes. The aim of this paper is to contribute to a more thorough understanding of how such transformation activities become initiated, intensified and finally consolidated.

To address this question we draw on systemic conceptualisations of path development and propose a stage model of path transformation. In the next section we will provide a critical review of EEG accounts of regional industrial path development. In section 3 we draw on broader conceptualisations of regional industrial change and outline our conceptual model. It centre stages the nature of asset modification processes that underpin the transformation of mature industrial paths (and the wider support structures they are embedded in) and explicates how multiple actors and their agency – influenced by the past and driven by future prospects – engage in radical ‘on path’ changes. We explicate how these processes differ between three stages of path transformation, that is, the initiation stage, the acceleration stage, and the consolidation stage. Section 4 applies the stage model to the empirical case of the automotive industry in West Sweden, which is currently undergoing major change processes triggered by the advent of self-driving cars. Our empirical findings largely confirm our conceptual arguments but also reveal some ‘deviations’ that require further research. Finally, section 5 concludes.

2. Regional industrial path development: EEG perspectives

Innovation and adaptation processes are place-dependent phenomena (Martin 2010). Evolutionary Economic Geography (EEG) explains the current state of affairs from history, placing emphasis on assets, skills and competencies developed in the past, which influence present and future choices (Martin 2010; Martin and Sunley 2006). These essential ideas underpin the notion of ‘path dependence’.

At the core of EEG thinking is the duality of continuity and change in regional industrial evolution. Continuity in an evolving system is understood as on-going, gradual change in order to respond to constant competitive pressures (Martin 2010). EEG understands this form of steady adaptation as the norm, while also acknowledging the possible occurrence of events that may trigger radical discontinuities. This dichotomy, however, is problematic. It suggests that gradual change is happening ‘on the path’ (Martin 2010), while radical change results either in path dissolution or in the creation of new paths. In this article we maintain that radical innovation activities may also occur within mature industrial paths and institutional settings. We refer to such processes as ‘path transformation’, that is, radical, innovation-based forms of path development, where an established path and the regional support structures it is embedded in are undergoing major change.

EEG has significantly enhanced understanding of how regional structural change unfolds over time. However, recent contributions have highlighted several shortcomings of EEG models. First, EEG portrays path development as a firm-driven process, neglecting the importance of other actors such as universities (Vallance 2016) and policy makers
(Dawley 2014). Second, there is a strong focus on the redeployment of technological and skill assets. Other assets such as institutional endowments (MacKinnon et al. 2019; Maskell and Malmberg 1999) tend to be overlooked. Further, recent work suggests that it is not only the re-use of existing assets that matters. Since established innovation systems are often poorly equipped to support radical change, creation of new assets and the destruction of old constraining ones are vitally important. One also needs to acknowledge that such asset modification processes may be contested. Innovation-based change might lead to intra-path and inter-path conflicts and competition over scarce assets (Frangenheim, Tripl, and Chlebna 2020). Third, EEG offers substantial insights into how ‘the past’ influences structural change but has thus far done little to incorporate the role of ‘the future’ in the form of visions and expectations into analyses of path development (Hassink, Isaksen, and Tripl 2019). From a sociological perspective, future prospects are a vital driver for engagement and agency of actors (Emirbayer and Mische 1998).

Recent work has begun to integrate the insights outlined above into a systemic perspective of path development (Tripl et al. 2020), arguing that the rise of new and the renewal of existing paths require substantial asset modification processes. Redeployment of existing assets, creation of new assets and destruction of old constraining assets are said to reflect reconfiguration processes of (multiscalar) innovation systems and are seen as brought about by firm-level and system-level agency.

In order to better understand how such processes take place in mature industries facing radical change, we propose a stage model of path transformation and examine the ways in which multiple actors engage in asset modification throughout the process of path transformation.

3. Towards a stage model of path transformation

This section provides a more detailed account of key elements of recent broader conceptualisations of path development, which have begun to complement established EEG perspectives (section 3.1). Building on these insights, we outline how path transformation may unfold through three phases (section 3.2).

3.1. Setting the scene: key factors brought forward in recent conceptualisations of path development

The idea that historically grown structures set the possibilities for socio-economic actors in the present is at the core of evolutionary thinking: previous choices and activities influence subsequent ones (Martin and Sunley 2006, 409). The regional asset base is seen to reflect previous rounds of path development and serves as a platform for future ones (MacKinnon et al. 2019; Tripl et al. 2020). In this regard, different types of assets constituting the regional asset base have been identified (MacKinnon et al. 2019; Maskell and Malmberg 1999): natural assets (resources), infrastructural and material assets, industrial assets (technological and firm-based competences), human assets (skills and knowledge), and institutional endowments (rules, routines and norms). Furthermore, financial assets must not be neglected. More often than not, mobilising
financial resources is of crucial importance to modify infrastructural, industrial, human and other types of assets.

Natural resources (such as sources of energy supply) and infrastructural assets (digital as well as material ones) form the often-overlooked basis for economic activity. Industrial assets refer to the competences, routines and networks of firms. They are a core focus of conventional EEG perspectives and seen as the driver of economic evolution. Human assets not only imply the regional labour force and their skills, but also knowledge created in research organisations and higher education institutes (Vallance 2016). Institutional assets, which constitute ‘the way of doing things’ also matter. They range from formal institutions such as laws and regulations to informal ones like common norms, values and trust and thus also reflect social capital within regions (see for instance Westlund and Kobayashi 2013). One the one hand, such historically grown place-specific endowments provide stability for socio-economic actors. On the other hand, they tend to favour the old over the new and thus might hamper new path development (Zukauskaite, Tripll, and Plechero 2017). Industrial change is therefore often contingent on institutional change (Boschma et al. 2017).

Regional industrial path development and transformation will only unfold if local (and non-local) actors harness and valorise the regional asset base (MacKinnon et al. 2019). In contrast to firm-centred views prevailing in conventional EEG models, systemic perspectives of path development (Tödtling and Tripll 2013) suggest adopting a multi-actor approach. In line with this view, our framework appreciates the role played by non-firm actors such as universities or research institutes (Vallance 2016), policy actors, support organisations, intermediaries (Dawley 2014), and so on. These actors may fuel path transformation by pursuing system level changes. This calls for consideration of what is called system level agency2 (Isaksen and Jakobsen 2017) in addition to firm level agency.

The main difference between those two types of agency lies in their field and scope of influence (Hassink, Isaksen, and Tripll 2019). While firm level agency is mainly concerned with changes within a firm or organisation, system level agency is geared towards broader regional adaptations and based on actions to transform regional innovation systems to better support industrial change (Isaksen and Jakobsen 2017), e.g. by establishing research institutes to develop new knowledge, creating protected space for transformation activities or contributing to legitimisation of a new technology (Binz, Truffer, and Coenen 2016). Path transformation thus requires both firm level and system level agency. The latter is particularly important for modifying infrastructural, human and institutional assets.

Yet, to understand the complexity of agency, one has to grasp it in its inter-temporality: agency refers to the ‘capacity to contextualise past habits and future projects within the contingencies of the moment’ (Emirbayer and Mische 1998, 963). While our model acknowledges the habitual aspect of agency through the relation between the regional asset base (involving routines, norms etc.) and actors, we particularly highlight the role of visions and expectations in moving the process towards path transformation forward. By so doing, we complement the prevailing focus of EEG models on how the past influences path development by explicitly recognising the role of the future in shaping transformation activities. Steen (2016) highlights the generative power of the future in path development. Accordingly, socio-
economic actors can be understood as strategic entities that pursue goals and undertake activities to achieve them. Actors’ visions and expectations thus contribute to the mobilisation of resources, experimentation efforts, network activities and so on (Steen 2016).

Visions can be individual or collective in nature. While contested visions might be a source of conflict and a barrier to change, shared visions provide orientation and directionality for actors (Wanzenböck et al. 2019). Future prospects are a matter of continuous re-evaluation and they change over time. The emergence of joint expectations often takes time, requires efforts by system level agents (Sotarauta 2009) and benefits from geographical proximity (Steen 2016).

3.1.1. Path transformation through asset modification

Due to its radical nature, path transformation comes with profound alterations of historically grown regional structures, implying a modification of the regional asset base (MacKinnon et al. 2019). As Maskell and Malmberg (1999, 10) point out, regional assets can be ‘modified or reconstructed by the deliberate and purposeful action of individuals and groups within or outside the area’. Accordingly, actors – influenced by the past and driven by future prospects (Emirbayer and Mische 1998) – are engaging in asset modification, using different strategies throughout the path transformation process. Recent contributions distinguish between various types of asset modification, including the recombination of existing assets, creation of new assets and the destruction of old assets (Trippl et al. 2020). While each of these types is vital for change, we claim that their relative importance is changing throughout the unfolding of regional industrial path transformation.

Different strategies of asset modification are key not only to alterations within the industry but also to create a supportive environment for path transformation. This is because established asset configurations support and stabilise pre-transformation activities. Put differently, they are often well aligned to existing paths and are thus poorly equipped to provide the capabilities, infrastructure, or institutional settings necessary for disruptive innovations and radical shifts to unfold (Tödtling and Trippl 2013). Such processes might involve conflicts of interests. They are thus often controversial and might be contested.

Finally, path transformation per definition represents a radical, innovation-based form of alterations of well-established paths and regional support structures. Yet, such change processes are also shaped by national or even global dependencies, influences and events (Martin 2010; Simmie and Martin 2010). How shifting non-local conditions are affecting the development of a certain place depends on local characteristics. Accordingly, these two influences are not mutually exclusive: while one has to acknowledge the multi-scalar nature and geographical complexity of regional economic evolution, some regions still remain better suited than others to deal with extra-regional pressures.

Agency can be defined as deliberate and purposive actions or interventions by actors in order to produce particular effects (Emirbayer and Mische 1998; Sotarauta and Suvinen 2018).
3.2. The unfolding of industrial path transformation

The key factors discussed above, that is, historically grown structures, number and connections of relevant actors, the role visions play for their agency and the resulting asset modification processes can be expected to vary between early and later phases of industrial reorientation. To capture these dynamics, we suggest a stage model of path transformation, distinguishing between three phases, namely, initiation stage, acceleration stage, and consolidation stage.3

Stage models of economic development are popular within the economic geography and regional science literature. Amongst other concepts,4 cluster life cycles have received the most attention (Menzel and Fornahl 2010; Fornahl and Hassink 2017) in recent years. This literature seeks to move beyond overly static perspectives on clusters and conceptualises their evolution in different phases from emergence and growth to maturity and decline. This sequence is either explained through the industrial life cycle (where a cluster’s evolution is strongly connected to the development of its overarching technological-industrial orientation), or through agglomeration effects, which themselves are believed to have a life cycle (Martin and Sunley 2011).

Cluster life cycle approaches differ from the model suggested in this paper in various ways. They put focus on the whole lifespan (from emergence to decline) of a clustered industry. In contrast, our model casts light on mature industries and pays attention to a particular phase of their evolution, namely their transformation based on radical innovations. Additionally, the cluster life cycle approach gives limited appreciation to the wider regional environment and (non-firm-level) agency (Trippl et al. 2015). These dimensions are at the heart of the approach outlined in this paper.

Yet, there are similarities. As with all conceptualisations based on the notion of stages, our model might evoke ideas of linearity or universality. However, rather than implying deterministic claims, the transformation stages outlined in this paper point to ideal-type processes. Stage models in general are searching for commonalities rather than differences (Markard 2018) and should be seen as ‘a heuristic device to organize empirical cases [...] without denying the indeterminate outcome of the process’ (Frenken, Cefis, and Stam 2015, 15). Therefore, we acknowledge the possibility of failure at any stage of transformation. Moreover, some key processes may lag behind or outpace others and thereby deviate from the ‘typical’ (Markard 2018). Additionally, external shocks or newly emerging problems or opportunities might lead to setbacks or leaps forward.

3.2.1. Initiation stage

The initiation stage is usually enabled by new possibilities or emerging pressures. Path transformation might be initiated by disruptive events taking place within or outside the region, like crisis, the emergence of new competitors, market shifts or radical innovations (Martin 2010; Simmie and Martin 2010). Such discontinuities challenge historically grown structures.

In this phase, many actors are still focusing on their established fields of action (or what we call ‘pre-transformation activities’), while only a small number of first movers engage in early experimentation (Foray 2014). Path transformation is often initiated by
innovative entrepreneurs who deviate from existing products and processes (Garud and Peter 2001) and exploit emerging opportunities. Early movers may be large corporations or agile start-ups. Early transformation activities may also be induced or supported by system-level actors. Knowledge generated in universities or new policy incentives may be sources of path transformation (Sotarauta and Suvinen 2018).

We assume expectations and visions to be ambiguous in the initiation stage. Pioneers of change seek to exploit emerging opportunities. Driven by strong beliefs in the innovation, they find themselves in ‘early sense-making processes’. However, radical innovations that challenge dominant paradigms are characterised by great uncertainty. There is no clear vision of what the outcome might actually be. This leaves many actors in an observant state (Sotarauta and Mustikkamäki 2015).

Many assets – like technological competencies or favourable regulations – do not preexist for completely new solutions (like self-driving cars, which are in focus in the empirical part of this article). There are strong reasons to assume that in the initiation stage pioneers of change do not only engage in redeploying and recombining existing assets but also in creating new ones.

In the initiation stage, it is only few knowledgeable non-firm actors who create the necessary regional assets (e.g. educational programmes, fitting regulations and norms, etc.) They often have to work around institutionalised logics of highly aligned structures (Sotarauta and Mustikkamäki 2015).

### 3.2.2. Acceleration stage

In the acceleration stage, transformation activities experience intensification. Opportunities created in the initiation stage are increasingly utilised. Newly established structures serve as a foundation to build upon. The process towards transformation gains momentum due to reinforcing effects. Yet, many assets are still ‘locked-in’ and oriented towards pre-transformation activities, resulting in a ‘co-existence’ of old and new structures within the industry and the support system.

The spreading of economic knowledge demonstrates future opportunities to a larger number of actors (Foray 2014). Thus, in this phase more and more incumbents are following the early movers. They are reorienting their activities, longing to complement or exploit opportunities created by the pioneers of change (Simmie 2012). At the same time, the number of spin-offs and start-ups might increase as well. Similarly, a growing number of system-level actors are expected to engage in asset modification endeavours.

Moving beyond the initial stage of path transformation requires collective belief formation (Sotarauta and Mustikkamäki 2015). This is a challenging issue. There are often conflicting opinions about the route towards path transformation. Therefore, system-level agency is expected to play a key role in this stage, contributing to setting the agenda and thereby creating a joint vision by bringing together different actors, resolving conflicts and shaping interpretations (Sotarauta 2009).

Despite varying expectations, we assume that reorientation of existing assets gains momentum in the acceleration phase due to the growing recognition of promising future
prospects. An important question is how to unlock assets in use or to ‘import’ the necessary knowledge and other resources from elsewhere. This can either take place within organisations (e.g. in-house innovation, recruitment of skilled labour) or by acquisition of assets (e.g. mergers and acquisitions) and collaboration with other actors. Established organisations may unlock and reorient existing assets and recombine these with new (related) ones (Boschma et al. 2017). This might enable incumbents to regain their competitive edge.

Additionally, in the acceleration phase a broader set of regional assets (including complementary infrastructural, human and institutional assets) is being shaped. A growing number and variety of actors is undertaking efforts to deliberately reconfigure support structures (Trippl et al. 2020). System-level actors can for instance facilitate the reorientation of activities within research labs or provide the needed infrastructure. Organisations and institutions are formed that represent the views and goals of new actors or of reorienting incumbents. At the same time, regional assets oriented towards pre-transformation activities are increasingly questioned due to their incompatibility with newly emerging structures.

The intensification of path transformation activities may come with particular challenges. They might result from growing requirements the old regional structures cannot meet or from competition over scarce assets. The former may lead to conflicting ideas concerning the direction of change (varying expectations) or legislative difficulties (testing, insurance, regulations, risk-management, etc.), the latter to inter-path conflicts (competition over skilled labour, funding, public attention, etc.) (Frangenheim, Trippl, and Chlebna 2020) or problems related to the behaviour of consumers (acceptance, demand, etc.).

3.2.3. Consolidation stage

In this stage, the reorientation of a broad variety of assets cumulates and ultimately leads to a broader shift of regional structures. New activities are increasingly replacing old ones, thereby revealing assets no longer needed or unable to reorient.

More and more actors depart from pre-transformation activities. Eventually reaching the necessary critical mass marks an important point of discontinuity (Simmie 2012). Reinforcing effects, i.e. increasing returns and positive externalities, gain further momentum. In this phase firms commercialise the new knowledge (Simmie, Sternberg, and Carpenter 2014) and abandon old structures. Not only firms but also the majority of system level actors are focusing on transformation activities and new practices.

The belief formation in the consolidation stage is ultimately resulting in a ‘collective [...] understanding of what might be at stake’ (Sotarauta and Mustikkamäki 2015, 353). Formation of joint visions and widely shared expectations are believed to intensify substantially in the consolidation phase. This can be expected to influence asset modification processes. The creation of novel and the reorientation of existing assets might still matter but these processes do not represent the entire picture: For the process towards path transformation to ultimately consolidate, destruction of old constraining assets and destabilisation of structures suppressing change (Kivimaa and Kern 2016) are necessary. Destruction is particularly relevant in later phases when alternative innovations have already gained momentum (Kivimaa and Kern 2016). Accordingly, firm-level and system-level actors alike are believed to intensify their efforts to remove constraining
structures. This leads to a further adaptation of regional structures, which facilitate new activities and positive lock-in effects (Martin and Sunley 2006). The majority of regional assets are reoriented towards the new activities. In the consolidation phase the ‘old rules of the game’ are disregarded or adopted and the new ones are aligned and institutionalised.

Destroying, altering or de-aligning constraining assets does not come without frictions. For firm-level actors it can be an expensive procedure due to sunk costs. Closures of those unable to adapt are likely to be observed. There are also obstacles to activities by system-level actors such as incumbents’ interests, strong networks and rigid formal and informal institutions. Destructing constraining assets is often politically controversial (Kivimaa and Kern 2016). Therefore, the challenges in this stage are often intra-path or intra-regional in nature. Dismantling old structures requires disruptive activities by actors from different domains.  

To summarise, our model unravels radical ‘on path’ transformations by distinguishing between three stages of development, each of them coming with specific conditions (‘past and future’) that drive actors’ agency and result in different processes of asset modification (Figure 1).

![Figure 1](image_url)

**Figure 1.** Path transformation and development of key dimensions throughout the stages according to the model.
3.2.4. Analytical dimensions

To distinguish between the different stages of transformation, we propose to use different analytical indicators for the key dimensions underlying the model, that is, actors and their actions, the development of visions and expectations, and changes in the regional asset base.

Actors and their activities capture the relative degree of activity associated with transformation activities in contrast to pre-transformation activities. Indicators can thus be the number of actors engaging in transformation activities, the extent of research and entrepreneurial activities in transformation areas and changes in the size of networks (Markard 2018). We expect the ratio between pre-transformation and transformation activities measured through these indicators to change significantly throughout the stages (quantitatively and qualitatively), where the latter initially represent only niche activities, then grow to a comparable size to pre-transformation activities (co-existence) and finally become the main field of action within the path.

Visions and expectations as ‘wishful enactments of a desired future’ (Borup et al. 2006, 286) are a generative force (resources, commitment, and actions). They can help to bridge boundaries and are crucial for legitimising future technological situations and capabilities (Steen 2016). While elusive, the materialisation of visions and expectations in form of artefacts or actions throughout the stages can be used as a measure (Borup et al. 2006). Indicators can be the number and content of respective newspaper articles or relevant conferences, the formation of associations or other organisations committed to a certain future goal or early regulations associated with transformation activities. We expect ambiguous and often contested prospects in initial stages that continuously develop into more consolidated expectations over time.

Finally, structural changes point to alterations of the historically grown regional asset base. To distinguish between phases, we suggest using the different modes of asset modification, that is, asset creation, redeployment and destruction. We argue that their relative importance varies between different phases of transformation. Asset creation is expected to play a pivotal role in the initiation stage, redeployment in the acceleration stage and destruction in the consolidation stage. Indicators will depend on the type of asset under consideration. For industrial assets, modifications from the firm level should be considered, e.g. in form of the redistribution of financial and other resources (such as labour, investments) between pre-transformation and transformation activities or the dismantling of pre-transformation areas in later stages. Changes within universities and research institutes (e.g. new curricula, financial assets mobilised for new R&D programmes) or training courses within firms indicate the modification of human assets. Alterations of institutional endowments can be seen in adjustments of regulations to fit transformation activities, changes in user acceptance or the abolishing of old regulations. Lastly, infrastructural asset modification is reflected in the establishment or alteration of digital as well as material infrastructure to boost transformation activities (e.g. test sites) or in the dismantling of old infrastructural elements.

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5Focusing on the policy domain, Kivimaa and Kern (2016) identify four ways to destabilise existing systems, namely control policies (e.g. taxes and regulations), significant changes in regime rules (major changes in legislation), reduced support for dominant regime technologies (e.g. withdrawing subsidies) and changes in social networks through replacement of key actors (e.g. in policy advisory councils).
As many of these analytical dimensions are hard to capture with quantitative approaches, this paper argues for more qualitative research designs in EEG (see also Hassink, Isaksen, and Trippl 2019). What is more, it is crucial to understand the description of both the phases as well as the indicators as mid-stage characteristics, where differences between the stages are most pronounced. Furthermore, as with similar conceptualisations, it is hardly possible to define clear-cut thresholds to identify transitions from one phase to another, as shifts between stages might be rather smooth (Markard 2018).

4. Empirical case: self-driving cars in West Sweden

To illustrate our conceptual arguments and to provide additional insights into the stages of path transformation, we apply our framework to the empirical case of the automotive industry in West Sweden, which is currently undergoing disruptive changes due to the advent of self-driving cars. In other words, we use a case study methodology to complement the conceptual discussion, identifying a ‘paradigmatic case’ (Flyvbjerg 2006) of path transformation that serves to illustrate, and potentially challenge, the assumptions made in the conceptual discussion.

The data collection took place in two steps. First, a document study was performed, in which newspaper articles, newsletters, reports, PR material, financial information, legal documents, and policy documents were reviewed. The document study served to identify relevant interview partners and as a starting point for the narrative explored in the interviews. It also helped to contextualise findings from the interviews. Second, semi-structured interviews with key actors were conducted. In total, 23 respondents were interviewed between March 2017 and May 2018. All interviews were transcribed and coded, using categories derived from the analytical framework (Saldaña 2015). Interviews were conducted until a state of (albeit temporally contingent) ‘data saturation’ (Glaser and Strauss 2017) had been reached. Previous studies of path development have highlighted the potential downsides of studying processes in hindsight, when outcomes have been materialised (Steen 2016). By studying an ongoing process, we aim to provide nuances to the complexities involved in path transformation, being aware of the difficulties involved with identifying critical events and narratives as they are happening.

The roots of the automotive industry in West Sweden date back to the beginning of the 20th century. Today the region is home to firms from all parts of the value chain, ranging from OEMs such as Volvo Cars and Volvo AB (trucks), to global suppliers such as Autoliv, smaller suppliers, automotive technology firms and consultants. The automotive industry is supported by a strong regional innovation system, endowed with knowledge providers such as Chalmers University, innovation support organisations and other intermediaries. The automotive industry in West Sweden is known for its competence in safety technology. From the introduction of three-point safety belts in the 1960s, to the invention of side-impact airbags by Autoliv in the 1990s, safety technology has been one

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6However, as expectations tend to follow a certain temporal pattering in form of early hype, later disappointment and finally more grounded views (in particular in capital-intensive sectors to attract attention of sponsors and to protect niche activities in early stages) (Borup et al. 2006), the absolute number of such artefacts or actions is often not sufficient to distinguish between transformation stages. Thus, a content analysis and additional qualitative and ‘prospective’ data (Steen 2016) are often necessary.
of the industry’s competitive edges. During the beginning of the 2000s, one could observe a reorientation of the regional innovation system from ‘passive’ to ‘active’ safety features, that is, technologically sophisticated features intended to help avoiding accidents rather than just reducing the damage when accidents occur (James et al. 2016). In 2009, Google announced that they would establish a unit to develop self-driving cars. In our empirical material, this has been highlighted as the ‘global trigger’ for path transformation in the car industry. In the following sections, we outline how this process has unfolded over time in the automotive industry of West Sweden.

The first signs of path transformation in West Sweden that could be discerned in the empirical material are statements by Volvo executives in newspaper articles about SDCs and the Google project, which aimed at downplaying the radicalness of what Google had recently introduced as ‘SDC technology’. They highlighted a close relation between SDCs and pre-transformation activities and existing assets (such as ongoing R&D activities and technological competence related to active safety). For example, the appointed ‘technical leader for active safety functions’ at Volvo Cars expressed in a press release from 2009 that:

‘[some autonomous driving features] require no hocus-pocus technology [...] Instead, the focus is on adapting existing technology.’ (SP 2009).

The beginning of the initiation stage can be identified as the time when the first transformation activities started to emerge, with a subsequent increase of activity among regional actors. For additional robustness, we have analysed the number of hits in Swedish newspaper articles for terms capturing articles about Volvo and self-driving car activities. After appearing in a handful of articles per year in the beginning of the 2010s, the number of articles increased in 2012. This finding is also confirmed by our interviews, pointing to the period immediately after 2012 as the beginning of the transformation process.

4.1. **Initiation stage**

4.1.1. **Actor base**

While the initiation stage did not come with major changes to the regional actor base, our document analysis and interviews point to the establishment of the ‘Drive Me’ consortium as a key event. The consortium was initiated by Volvo Cars and initially involved the Swedish Transport Agency, the Swedish Transport Administration, the City of Gothenburg and Lindholmen Science Park (a regional support organisation). While the size of the regional actor base remained more or less constant, the Drive Me consortium represented a first step towards establishing a network around issues related to SDCs, including both regional and national actors.

4.1.2. **Visions**

Early transformation activities focused extensively on vision development and sense-making activities. One can observe a rapid increase of articles during the period 2012 (79 results) – 2015 (850 results), indicating how visions and expectations are materialised in the public discussion. This is exemplified also through the establishment of a newsletter about self-driving technology (edited by a regional research institute) in 2013, which was highlighted by public actor interview partners as an important source of information.
At the same time, our empirical analysis shows that one of the key tasks for regional actors was to ‘translate’ visions of SDCs prevailing in the media to expectations about future development that would fit the regional setting. Through a content analysis of newspaper articles from the time, it is possible to observe a shift in how public sector actors, such as the local city planning authority, were envisioning alternative solutions to the future of urban mobility. Public actors quickly adopted the idea of SDCs as part of a broader strategy for mobility system transition. Among automotive actors, transformation activities in the initiation stage included both plans to turn existing safety technology into autonomous features, and to create visions for how future technological development could unfold. This could been seen as a type of ‘catch-all’ strategy, demonstrating various potential benefits of SDCs.

4.1.3. Asset modification

Transformation activities in the initiation stage reflected a realignment of existing technology towards autonomous driving, rather than a divergence from the existing technological knowledge base. During the early stage, it is even possible to label SDC technology as a continuation of existing active safety development, drawing extensively on pre-transformation activities. As one interview partner put it:

‘I would say that it is a natural continuation of previous activities. It is not something that just suddenly comes from nowhere . . . We did the move from passive to active safety, this was a shift. Now, it has exploded in terms of application . . . but I still see it as a natural continuation.’ (Interview)

With respect to industrial assets, it was thus a matter of reusing and recombining assets aligned to pre-transformation activities, and ‘packaging’ active safety technology in SDC visions rather than creating entirely new ones. This process was backed by the strong support system centred around active safety technology, including financial support for transformation activities. The availability of funding for transformation activities was also influenced by the ‘hype’ around SDCs that was emerging in the media, through the materialisation of visions (see above).

Early transformation activities targeted other dimensions than technological knowledge. Examples include the creation of human assets such as novel knowledge about user behaviour, involving researchers active in disciplines such as ethnography and interaction design. Actors also engaged in demonstration activities intended to increase the legitimacy of SDCs, organised largely within the context of Drive Me. However, in interviews with firm representatives, it was expressed that organisational structures and established ways of working prevented incumbents from engaging in more experimental activities, which required more iterative, agile development processes. Even though transformation activities were performed by incumbent actors, firm-based competences and other industrial assets supported these activities only when they did not depart too far from the active safety segment.

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\(^7\)Searches were made by using the Swedish newspaper archive Mediearkivet Retriever, which covers virtually all Swedish printed and online news outlets and is searchable from the 1970s onward. We checked for the number of combined hits for [självkörande AND volvo] and [autonomy AND volvo]. Searches using other combinations of terms resulted in similar outcomes.
Asset modification thus focused on the re-deployment of existing assets, with the creation of new entirely new assets playing a less important role. For instance, research efforts within the active safety segment of the industry were ‘re-branded’ as SDC activities. Creation of new assets did thus not unfold at the same pace as the development of visions.

4.2. Acceleration stage

4.2.1. Actor base
One of the first signs of the path transformation processes gaining momentum was the expansion of the regional actor base. From initially taking place within the incumbent firms, small existing firms, newcomers and non-firm actors started to engage in transformation activities. For example, key players entered the Drive Me consortium. Chalmers University of Technology and Autoliv both joined in 2015, two years after the project was initiated. Furthermore, existing technology firms, both active in the automotive industry and in other regional industries such as IT, began to initiate international collaborations to strengthen their competences in the field. This took place in parallel to the emergence of new actors dedicated to SDC development. Partly in response to the need for more agile and fast-moving development processes, Volvo Cars and Autoliv decided to transfer their software development in active safety to a new joint venture, a spin-off named Zenuity. The new firm was announced in early 2017 and is the ‘flagship’ of autonomous technology and SDC development in the two incumbent firms’ portfolios. Another example is Veneeer (a spin-off of Autoliv) concerned with developing advanced electronics for active safety and autonomous driving. However, our interviews highlighted the fact that whilst spin-off processes from the large incumbent firms to some extent can help them become more flexible, they do not fully compensate for the weak entrepreneurial climate in the region. Interview partners in the automotive industry acknowledged the need for engaging more with small actors but lacked the means and experience to do so.

The intensification of transformation activities also led to inter-path conflicts. For example, the increased contact surfaces between the automotive industry and the IT industry did not only lead to opportunities for collaboration but also to competition over resources such as software specialists and regional funding. One interview expressed that:

For a while, a lot of people left [an IT firm located in the region] … for us. They were almost angry at us.’ (Interview with automotive firm representative)

4.2.2. Visions
Another indicator for the acceleration of the transformation process is reflected in a rapid increase in newspaper articles about Volvo and self-driving cars between 2015 and 2016 (from 850 to over 3,000 results), indicating an increased public awareness. Interviews taken and analysis of newsletters suggest that the number of conferences, workshops, seminars and other activities also increased substantially during the same time. Development of visions continued throughout the acceleration stage, reflecting an increased interest in what SDCs could mean for the region, both in terms of potentials
for economic development and in terms of providing opportunities and challenges for mobility systems and spatial planning. For example, in a press release from 2016 Volvo Cars communicated that SDCs ‘promises to free up congested roads, reduce pollution and allows drivers to use their time in their cars more valuably’. Similar statements can be found in local planning documents. Furthermore, a series of ‘co-creation workshops’ were organised at Lindholmen Science Park in which automotive actors and local planning officials met to discuss the potential benefits of SDCs.

However, while some core assumptions about the importance of SDCs for the future of West Sweden’s automotive industry were forming among regional actors, our interviews also point to a number of contested visions about the route and direction of SDC development. When the city of Gothenburg was working with long-term visions and planning perspectives involving SDCs, they deviated from the ‘car ownership norm’ prevailing in the automotive industry, anchoring their visions in possible trajectories in which new mobility services are introduced alongside autonomous technology. The existence of contested visions has not materialised into actual conflicts among actors but it is possible to observe a clear divide. Many system level actors perceive autonomous driving technology as an alternative to private car ownership, whilst automotive firms see it mainly as an addition to the existing car-based mobility paradigm.

Finally, our interviews point to a shift from perceiving SDCs as being part of the active safety segment of the automotive industry towards becoming an own field with a number of defining features. In terms of the materialisation of visions, this can be observed in the ways through which automotive actors started to highlight the importance of software development in their activities with regional support organisations such as Lindholmen Science Park and Chalmers University.

### 4.2.3. Asset modification

Asset modification processes intensified during the acceleration stage. In terms of industrial assets, automotive actors went from reapplying existing active safety technology in the initiation stage to developing new dedicated SDC technology in the acceleration stage. One executive from Zenuity stated that:

‘We are continuously updating a gap-list describing what is missing in order to execute the strategy that we have [towards unsupervised driving]’ (Interview)

This involved both the creation of new assets and the ‘de-locking’ of assets aligned to existing paths. One prominent example of the latter is how Volvo Cars and Autoliv transferred all patents and other intellectual property rights related to active safety software to Zenuity (see above), in order for the new firm to be able to use them in new ways than would have been possible within incumbent structures. In one of our interviews with Zenuity, it was expressed that the separation from the incumbent firms gave them long-term stability that would not have been possible if being organised as a joint project within existing structures. Similarly, inter-path interactions, primarily between the regional automotive industry and the IT industry, are also indications of de-locking processes of regional assets and redirecting them to SDC activities. This is illustrated by intensified interactions between IT firms and automotive firms, both in terms of collaborations in projects and in terms of labour mobility from IT firms to the automotive industry.
Apart from industrial assets, the acceleration stage involved the modification also of human, institutional and infrastructural asset to an extent that could not be observed during the initiation stage. In terms of human assets, courses and education programmes at Chalmers University were increasingly adapted to reflect the increasing need for software developers and engineers trained specifically in autonomous technology. For instance, a new group focusing on vehicle engineering and autonomous systems was established, offering courses in the context of international master programmes at the university. In addition, a prestigious student ‘driverless car’ competition was introduced in 2016, promoting students to engage in projects related to self-driving technology.

The acceleration stage also included a strong focus on the modification of institutional assets. For example, transformation activities included the dismantling of old standards and modes of working in the automotive industry, illustrating the beginning of a full departure from pre-transformation activities. In one of our interviews with an executive at Volvo Cars, it was expressed that:

“we [had to] transform our product development principles to more agile teams, scale up all the teams and get them to collaborate. We talk about 400-500 teams that should collaborate in an agile framework.” (Interview with executive at Volvo Cars)

Furthermore, the acceleration stage was characterised by an intense engagement with the adaptation of formal laws and regulations shaping the context for product trials and experimentation activities. Firm actors engaged in system-level agency to dismantle legislative barriers, most notably through activities seeking to adapt regulations for SDC trials. For example, Volvo Cars provided inputs to an investigation at the national level, aimed at mapping the legal preconditions for automated transport in broad terms. After intense lobbying efforts from regional actors and several rounds of discussions, a special national regulation for SDC trials and routines for issuing permits was in place at the end of 2017.

Finally, the acceleration stage featured the modification of infrastructural assets. The maturing of SDC technology implies an ‘explosion in terms of testing and verification’ (Interview). Our empirical analysis demonstrates the importance of test infrastructure for supporting SDC development and attracting actors from other regions and countries to the region. In particular, test environments for road safety such as ‘Asta Zero’ (established in 2014) have been highlighted as crucial for testing and certifying SDC technology. According to interview partners, the establishment of Asta Zero was driven by regional interests, in particular Volvo Cars, who initially unsuccessfully lobbied for the construction of a test lane on a national highway between Gothenburg and the Volvo headquarters in Torslanda. Instead, they mobilised support for the establishment of a dedicated test facility in the region in collaboration with a nationally funded test-bed programme (Test Site Sweden) and secured funding from a range of different sources.

4.3. Consolidation stage

The ‘broad commercialisation’ of autonomous technology expected during the consolidation stage is yet to be observed in West Sweden (and elsewhere). The
commercialisation of new SDC technology is still taking place within the active safety segment of the industry, illustrating an interesting case of how new, potentially radical, technologies are introduced in ‘old’ market segments while waiting for new market possibilities to materialise. Industrial path transformation is thus ‘running ahead’ of the broader societal shift, as one can observe signs of consolidation in terms of the actor base, visions and asset modification.

4.3.1. Actor base
The number of actors involved in SDC activities has been growing continuously. Several dedicated SDC technology firms have emerged in the region, through spin-off and start-up processes and relocation from other regions. In addition, firms in other industries, most notably the IT industry, have diversified into SDC technology and inter-path acquisitions have taken place. This has been complemented by a continued engagement by actors from the public sector and regional support organisations.

4.3.2. Visions
Efforts concerned with belief formation have now consolidated to a shared understanding of SDCs as the future of the automotive industry in West Sweden. This is manifested in different ways. Autonomous driving has become an integral part of urban planning policies in Gothenburg and regional strategies refer to West Sweden as a ‘self-driving region’. As of summer 2019, regional politicians wrote a debate article in a major Swedish tabloid, arguing for the importance of SDCs for the future of the region, and announced a substantial regional investment to increase the competitiveness of the regional vehicle industry (Expressen 2019). Empirical evidence thus suggests a broad consensus among public actors about the importance of supporting SDC development.

In addition, regional firms operating in different industries are signalling their interest in different aspects of autonomous technology through investments, such as the establishment of an AI research centre, and acquisitions. However, our study also shows that there is still no established consensus about what SDCs will mean for society. The contested visions outlined in the acceleration stage still prevail. Actors’ decisions are based on different, sometimes incompatible, logics. An illustrative example is how the vision of reaching the more or less completely self-driving car is highlighted in the media and in discussions with public actors, while goals and strategies internal to the automotive firms are more oriented towards increasing the functionality of their existing cars, adding layers of self-driving features that will support the driver and car owner.

At the same time, our newspaper analysis indicates that the interest among journalists and the general public has shown signs of decline recently with around 30% fewer newspaper articles published in 2019 than in 2018. This should not be interpreted as an indication of a slow-down of transformation activities but rather indicates the consolidation of visions and expectations related to SDCs. While the ‘hype’ that was driving the initiation and acceleration stages has started to fade, transformation activities now relate to a broader set of objectives, such as digitalisation more broadly, and a shift towards software development and artificial intelligence as the competitive edge of the regional industry.
4.3.3. Asset modification
Some implications of the contradictions mentioned above can be observed in asset modification processes. Asset modification continues to target the re-deployment and re-orientation of existing regional assets, in combination with the creation of new assets. The destruction of old assets is however not as prominent as would be expected from the theoretical discussion. In some areas, existing assets still form barriers to full-scale transformation and whilst the empirical analysis shows early signs of how actors are acknowledging the need to destroy such assets, things are yet to take off on a broader scale. For example, several interview partners have highlighted how the main ‘product’ of the automotive industry is shifting from ‘cars’ towards ‘software’.

Our empirical analysis also indicates that there are still institutional assets preserving ‘old ways of doing things’. A case in point are old hierarchies and modes of working in the incumbent automotive firms. Our interview partners highlighted how platform-based development models among incumbent automotive firms need to shift towards more agile processes, inspired by how development projects are run in the software industry.

The most prominent signs of consolidation are instead found in the regional support structures emerging around SDCs. Throughout the acceleration stage, a number of support elements were introduced to deal with some of the challenges identified. Examples include organisations and initiatives promoting the attraction of extra-regional assets (like global start-ups and talent), as well as new research centres focused on technologies particularly important for SDC development such as AI and vehicle electronics. Our interviews also point to a consolidation of the funding system for R&D and innovation activities, now focused more explicitly on autonomous technology and AI. In addition, financial investments in the region by Geely, Volvo Cars Chinese owners, have increased substantially throughout the period of analysis and is a major factor for the dynamics of the path transformation process.

Also in terms of institutional endowments, the special regulations for SDC trials have been ‘tried out’ in practice. In 2018, Zenuity obtained a permit which allowed only trials with ‘hands on the wheel’ and banned automatic lane switching, followed by a permit with fewer restrictions in January 2019. The latest permit is, according to statements by Zenuity in the media, sufficient to perform the planned trials.

To summarise (Figure 2), as of the end of 2019, the path transformation process leading towards SDCs in West Sweden is still ongoing; some aspects have been consolidated while others remain fragmented and contested.

5. Conclusions
Over the past years, evolutionary economic geography (EEG) has contributed to our understanding of how and where industrial paths arise. In contrast, radical ‘on path’ changes have received limited attention and remain underexplored. In this paper we highlight the need to gain more insights into how such transformations of existing industries take place. We propose a stage model to cast light on the temporal pattern of change. Differentiating between three stages (initiation, acceleration and consolidation), we contribute to a more thorough understanding of how transformation activities within well-established paths unfold over time. Each stage in our model is believed to feature specific characteristics, pointing to the need to examine industrial restructuring from a process perspective.
Our approach is inspired by recent conceptualisations (MacKinnon et al. 2019, Trippl et al. 2020) seeking to capture a wider set of resources necessary for radical change to occur. Accordingly, different types of assets (natural, infrastructural, industrial, human, institutional) are seen as both the outcome of previous rounds of regional economic development and the platform for future ones. In line with other contributions (Trippl et al. 2020), this paper shows that fundamental change of mature industries involves substantial asset modification processes. Accordingly, actors from different domains - influenced by historically grown structures and future prospects - are engaging in deliberate and purposeful actions to alter the regional asset base. We claim that different asset modification processes, namely creation of new assets, redeployment of existing assets and destruction of constraining assets, differ in their relative importance depending on the stage of development.

Applying the conceptual model to the empirical case of West Sweden’s automotive industry has provided a number of insights. First, the case study confirms the crucial yet often overlooked ‘role of the future’ for path development processes (Hassink, Isaksen, and Trippl 2019). This paper therefore makes a strong case for incorporating the dimension of vision building and collective belief formation into analyses of innovation-based path development. Visions are a subject to continuous re-evaluation and development, yet they are not random. They reflect previous experiences, current processes and

<table>
<thead>
<tr>
<th>Regional asset base</th>
<th>Actors</th>
<th>Visions</th>
<th>Asset modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional asset base strongly developed in active-safety segment</td>
<td>Existing actors organize in the 'Drive Me' consortium to tackle SDC issues</td>
<td>'Adopting' the advent of SDCs for regional development strategies</td>
<td>Realignment of pre-existing (active safety) assets</td>
</tr>
<tr>
<td>Growing discrepancy bw. existing &amp; needed assets for SDCs become apparent</td>
<td>'Drive Me' growing, intensifying path inter-dependencies bw. the IT &amp; AM industries</td>
<td>Growing interest but also contestation around SDCs as a defining feature for West Sweden's future</td>
<td>Rapid intensification of modification processes, de-locking and creation</td>
</tr>
<tr>
<td>Industrial assets increasingly shift to software, support structures consolidating, regulations are adjusted</td>
<td>Actors involved in SDC activities growing continuously (spin-offs, diversification, ...)</td>
<td>SDCs seen as an integral part of West Sweden's AM industry, some contested expectations prevail</td>
<td>Asset destruction not yet as prominent as expected, but awareness that some existing assets preserve 'old ways' is growing</td>
</tr>
</tbody>
</table>

**Figure 2. Transformation of West Sweden's automotive industry (AM . . . automotive, IT . . . information technology, NIS . . . national innovation system). Source: Authors’ research.**
refer to actors’ assessment of the probability of certain scenarios playing out in a certain way (Steen 2016). As our empirical analysis shows, such visions can be contested but agenda setting activities by system level actors can serve as a guide through the long-term, complex processes of path transformation.

Second, our empirical analysis reveals some deviations from the development patterns proposed in the conceptual framework. Most notably, asset creation has not been that important in the initiation stage due to the already mature asset base in the active safety segment.

Third, as the transformation of West Sweden’s automotive industry is not yet consolidated and asset destruction processes are expected to take place in later stages of development, large-scale destabilising endeavours are yet to be observed. Thus, further research investigating the nature of asset destruction and de-alignment is required. Key questions may include: What role does power play in this regard? How do incumbents and other actors facilitate or prevent asset destruction or de-alignment? How can policies orchestrate and accelerate asset destruction (Kivimaa and Kern 2016) at different spatial scales?

Lastly, the empirical case proves the necessity to pay attention to inter-path relations (Frangenheim, Tripl, and Chlebna 2020). Path transformation in the automotive industry is facilitated by drawing on assets (skilled labour, working routines) from the IT industry in the region. This leads to both collaboration and competition between the two paths and creates strong path interdependences. More research is required to unravel how transformation activities in one industry affect and are affected by activities in other industries.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**Funding**

This work was supported by the Marianne and Marcus Wallenberg Foundation [grant number MMW 2016.0014].

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