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Abstract
The past years have witnessed a surge of academic interest into how new industrial paths are developed in regions. Transformation processes of existing regional industries have received less attention in recent work. We introduce the notion of 'path transformation' to describe a form of path development taking place within mature industries where both input and output factors are substantially altered and investigate how regional innovation systems are tackling challenges related to path transformation processes. Drawing on insights from the regional and technological innovation systems literatures, we develop an analytical framework that aims to elucidate the relation between path transformation and system reconfiguration. The framework suggests that regional system elements are layered or adapted to i) target the build-up of system functions regionally; ii) link up to system functions in other locations, and iii) transplant system functions from elsewhere to the region. The analytical framework is applied to an empirical case study of the transformation of the automotive industry in West Sweden towards self-driving cars. The empirical analysis provides support for the importance of the three types of system reconfiguration suggested by the framework, and emphasises the relevance of different types of resources. Furthermore, it highlights how actors tend to utilise previous networks and positions in global innovation systems rather than turning to the development of system functions regionally as the 'default option' of system reconfiguration.

Keywords: path transformation, system reconfiguration, self-driving cars, automotive industry

1 Introduction

Regions across the world are to an ever-increasing extent facing the pressure to react and adapt to a wide range of challenges related the rise of new competitors, accelerated technological development and fundamentally new market conditions. Dealing with these challenges is instrumental to maintain regional competiveness, jobs and economic growth. It is a crucial task of scholarly work to contribute with knowledge that can help regions to avoid the fates observed in 'old industrial areas'. In this paper, we do so by focusing on how regional industries and established innovation systems are undergoing transformation.

The past years have witnessed a renewed academic interest in regional industrial path development. Drawing on Evolutionary Economic Geography (EEG) models of regional structural change, many studies have sought to explain how new industries emerge in space through path creation, diversification or importation processes (Neffke et al., 2011; Dawley, 2014; Boschma, 2017; Isaksen and Trippl, 2017). Transformation processes of traditional industries have received less attention in recent conceptual and empirical work.

This paper introduces the notion of 'path transformation' to describe a form of path development where both input and output factors are altered, leading to substantial changes within an existing industry. Mature industries are often supported by a well-established regional innovation system (RIS), implying that system reconfiguration is a crucial part of path transformation. The aim of this paper is to contribute to the path development debate in economic geography by investigating both conceptually and empirically how RISs are tackling challenges related to path transformation processes. We combine insights from two strands of research, that is, the RIS and the Technological Innovation Systems (TIS) literatures, which both have elaborated on the link between innovation system changes and transformation processes of industries and technologies. We develop an analytical framework for understanding regional system reconfiguration, building on the idea that path transformation requires a set of system functions facilitating resource formation processes to be in place (Binz et al., 2016) and that regional system elements can be layered or adapted to 1) target the build-up of system functions regionally, 2) link up to system functions in other locations, and 3) transplant system functions from elsewhere to the region.

The analytical framework is used to investigate path transformation based on the development of Self-Driving Cars (SDCs) in the region of West Sweden, which comes with radical changes within the well-established regional automotive industry. Focusing on how system reconfiguration facilitates resource formation processes catering to new activities, we address the following research questions: how does system reconfiguration take place in the context of path transformation? Which types of system reconfiguration can be identified, through which mechanisms do they take place, and who are the actors involved?

The remainder of the paper is organised as follows. Section 2 provides a review the current literature on path development and develops an analytical framework for investigating system reconfiguration for path transformation, combining insights from RIS and TIS studies (section 2). This is followed by a methodological discussion and the presentation of the empirical case (section 3). Section 4 contains the empirical analysis. Finally, section 5 discusses the results and concludes.

2 Literature review and analytical framework

How new economic paths emerge and why some places are better positioned than others to nurture their further development are core questions of economic geography (Storper and Walker, 1989; Boschma and Frenken, 2006; Martin and Sunley, 2006; Martin, 2010). Evolutionary Economic Geography (EEG) portrays the development of new regional economic paths as an endogenous branching process, in which 'related' knowledge assets are combined and provide 'inputs' to new paths (Boschma and Frenken, 2011). However, recent work have questioned the narrow view of path development advocated by EEG scholars, pleading for broader conceptualisations to include institutional, social and cultural factors and take account of multi-actor and multi-scalar perspectives of the 'how and why' of path development (see Hassink et al., 2018; MacKinnon et al., 2018).

The literature has recently also been enriched by offering various more fine-grained typologies to distinguish between different types of path development (see Martin and Sunley, 2006; Tödtling and Trippl, 2013; Isaksen and Trippl, 2016; Grillitsch et al., 2018). These range from the creation of completely new paths to path diversification, path importation, and the renewal of existing paths. Whilst these are ideal types, they point at the wide range of sources and mechanisms at play in the evolution of new regional industries.

However, current conceptualisations do not sufficiently capture substantial transformations of existing paths, such as the case of the self-driving cars (SDCs) that is in focus in the empirical part of this paper. We introduce the concept of 'path transformation', referring to a form of path development that is characterised by two distinguishing features. First, it involves the transformation of an existing industrial path based on radically new technological, organisational or market innovations. Second, the outcome is an industrial path being substantially different from the initial one, due to the disruptive nature of the innovations introduced. Whilst previous concepts such as 'path renewal' have captured path dependent changes within a mature industry, path transformation refers to a more radical case of path development, where both input and output factors are substantially altered.

EEG accounts of path development have been criticised for advocating rather narrow firm- and industry-centred explanations of regional structural change (Tanner, 2014; MacKinnon et al., 2018; Trippl et al., 2018). In response, scholars have forged a link between the RIS approach and EEG models to shed light on wider regional structural factors and conditions that shape new path development (Isaksen and Trippl, 2016). This has helped to highlight how existing RIS structures influence the rate and direction of regional structural change and what type of new path development is most likely to occur in regions with different RIS characteristics (Isaksen and Trippl, 2016). Conceptual and empirical work on how RISs and their organisational and institutional support structures need to change in order to facilitate the rise of new paths is scant (Tödtling and Trippl, 2013; Miörner and Trippl, 2017). Whilst the RIS approach has been criticised for not taking agency into account in explaining system change, actor-based approaches of new path development have neglected the potential inputs originating from and processes taking place at the system level. More recent work has sought to overcome these weaknesses by exploring how actor-level and system-level agency may lead to RIS changes (Isaksen and Jakobsen, 2017; Isaksen et al., 2018).

Building on the contributions outlined above, we investigate how RISs are tackling challenges related to path transformation. Mature industries are often backed by a well-established RIS. If traditional paths face disruptive changes and are substantially transformed, then the RIS also needs to be rebuilt. We analyse how such changes unfold, paying attention to the processes through which a variety of actors facilitate the reconfiguration of RISs.

However, with some exceptions (Tödtling and Trippl, 2013; Miörner and Trippl, 2017), the RIS literature has thus far been fairly vague about what regional system reconfiguration entails. In parallel, other strands of literature, most notably contributions inspired by the TIS concept, have begun to specify broad resource formation processes that underpin new path development (Binz et al., 2016) and to explicate how system functions might be spatially distributed across various scales (see, for instance, Binz and Truffer, 2017). A key question is thus how a RIS can be reconfigured to develop new functions, or to access or transplant functions taking place elsewhere. This resonates with the call to take into account meso- and macro-level circumstances and the 'outward' direction of regional system connections and influences (Martin and Sunley, 2015).

In the following sections, we combine insights from the RIS and Technological Innovation Systems (TIS) literatures to unravel the link between path transformation and system reconfiguration.

2.1 RIS elements and resource formation processes

Recent work on new path development has challenged the narrow focus on knowledge assets and knowledge dynamics prevailing in EEG. In studies of path creation, scholars have turned to the Technological Innovation Systems (TIS) literature to gain insights into the key system functions (or processes) that have to take place in order for new paths to emerge (Martin and Coenen, 2015; Binz et al., 2016; Steen, 2016). The TIS literature outlines six functions (that is, knowledge development and diffusion, entrepreneurial experimentation, market formation, resource mobilisation, creation of legitimacy and guidance of the search) that form the basis of a well-functioning innovation system centred around a specific technology (Hekkert et al., 2007; Bergek et al., 2008). Different variations of these functions can be found in studies of path creation, for example in Binz et al.'s (2016) study of the emergence of water recycling industries in China or Steen and Hansen's (2018) work on offshore wind in Norway. These contributions suggest that the creation of a new path relies in particular on four key resources, that is, knowledge, legitimacy, financial investments and markets, that need to be supported by formation processes in the TIS.

The TIS framework allows for analysing the functionality of an innovation system, but also serves as a useful lens for investigating the emergence and transformation of the system functions themselves. Path transformation represents a somewhat different case than path creation. Existing system functions are aligned to the existing path, which means that system functions may need to be changed, adapted, aligned or even created for path transformation to occur.

A RIS can be conceptualised as consisting of a set of system elements, referring to actors (both public and private) involved in innovation processes, networks between different actors, and institutions guiding their behaviour (Asheim et al., 2011). In other words, elements in the RIS can be seen as contributing to system functions as defined above. For example, research and education facilities produce and diffuse knowledge, regulations shape the market conditions, and funding schemes provide capital to paths (see Table 1). System elements may not only contribute to one but to several functions in the innovation system. New education programmes for instance target the generation (and diffusion) of new knowledge but might also contribute to the legitimacy of an industrial path.

Table 1: System functions and system elements

System function / resource formation process	**System elements**
Knowledge generation	Education facilities, R&D organisations, vocational training schools, …
Experimentation	Incubators, accelerators, test facilities, …
Market formation	Demand-side policies, platforms, market regulations, action networks, …
Legitimation	Interest organisations, industry associations, consumer groups, standards, norms, …
Direction of search	Visions, strategies, expectations, …
Investment mobilisation	Banks, funding schemes, business angels, venture capitalists, …

Source: own elaboration

TIS scholars have argued that system functions, or resource formation processes, are taking place across space and scales in networked sets of independent subsystems (Binz and Truffer, 2017). Such subsystems are not necessarily spatially defined, which means that regional path transformation processes can rely on system functions that are developed in actor networks and institutional contexts that transcend national or regional borders. Regional system elements, that is, actors, networks and institutions, may thus contribute to the formation of resources regionally, or to linking up to resource formation processes taking place elsewhere.

2.2 RIS reconfiguration for path transformation

With the purpose of investigating RIS changes in relation to path transformation, looking only at the addition or removal of system elements would limit the explanatory power of the approach. It is easy to picture a case in which, for instance, educational programmes are created or adapted to meet continuous changes within existing paths, contributing to path extension rather than transformation. Regional path transformation requires more substantial changes and reconfiguration processes that support actors to generate new knowledge, develop markets, create legitimacy and mobilise investments.

Miörner and Trippl (2017) outline different mechanisms through which RIS reconfiguration can take place. Inspired by Mahoney and Thelen (2010) analysis of various types of institutional change and the application of these types to regional industries by Martin (2010), they make a distinction between different modes of change in the institutional and organisational support structure of RISs:.

- Layering: system reconfiguration may occur through the creation of new system elements alongside old ones. Examples of layering include the establishment of new education facilities and innovation support organisations, formation of new networks or the introduction of new institutional arrangements such as regulations and standards.
- Adaptation: system reconfiguration may also take place by adapting existing system elements, for instance, by reorienting existing educational and research programmes, networks, funding schemes or innovation support instruments to better fit the requirements of paths in transformation.

As noted above, path transformation signifies major changes within an existing regional industry. This implies that the analysis must depart from a regional perspective and adopt an 'inward-outward' perspective of structural and agentic circumstances (Martin and Sunley, 2015). We are not analysing the formation of a global innovation system around an emerging technology. We rather take a regional industry perspective and investigate how RISs are reconfigured with the aim to provide 'old' transforming paths with new resources. For that purpose, we outline three types of regional system reconfiguration, which are characterised by different spatial patterns.

Type 1: Developing system functions within the region

Regional system reconfiguration may take place in order to facilitate resource formation processes within the region. Several previous studies have demonstrated how regional system elements, such as education programmes, research institutes and funding schemes, are layered or adapted in order to provide paths with new knowledge and other resources (Dawley, 2014; Steen and Karlsen, 2014; Miörner and Trippl, 2017). This reflects the endogenous dimension of path transformation, where resources are developed regionally and regional system elements are directly associated with one or several resource formation processes linked to new activities in the mature path.

Type 2: Accessing system functions elsewhere

In addition to developing resources regionally, system reconfiguration can take place in order to link up to extra-regional resource formation processes. This type of system reconfiguration refers to the development of regional system elements that support the mobilisation or transfer of resources that emerge from system functions in other regions, and the processes through which such resources are transformed into 'locally sticky' ones (Binz et al., 2016). For example, knowledge important for path transformation might be developed through R&D efforts in other regions and accessed by regional actors through the initiation of strategic collaborations and other inter-regional networks, or through the development of formal collaboration platforms focusing on forging links between regional and non-regional actors (Trippl et al., 2018). In other words, this type of system reconfiguration takes into account the fact that system elements may serve the purpose of establishing linkages or 'pipelines' (Bathelt et al., 2004) through which actors access resources formed through system functions elsewhere. Examples of this type of system reconfiguration include the creation of new organisations, such as technology mediating bodies, but also the formation of new network linkages to actors and activities in other regions.

Type 3: Transplanting system functions from elsewhere

Finally, system functions required for path transformation may exist in other locations, and system elements that contribute to these functions may be transplanted to the region. An example would be the relocation of R&D units from one place to another, that is, the importation of knowledge production activities. System elements might also be created in order to ‘import’ certain system functions more implicitly, for example by initiating funding schemes aiming at attracting researchers or start-ups that are experimenting with and developing solutions in other regions, but require them to physically relocate to the region in order to access the funding. The spatial characteristics of this type of system reconfiguration are thus different from linking up to extra-regional system functions (type 2), as the focus is not on accessing resources formed elsewhere but on moving resource formation processes to the region.

Path transformation is likely to involve a combination of different types of system reconfiguration, and by studying these we believe that it is possible to gain a deeper understanding of how path transformation unfolds. Thus, our empirical analysis will identify different types of system reconfiguration, but also pay particular attention to how certain actors coordinate and steer their activities towards pre-defined or emerging goals.

3 Methodology and case background

We deploy a case study methodology (Flyvbjerg, 2006; Yin, 2013) to conduct an in-depth investigation of system reconfiguration in the context of path transformation. The empirical analysis is based on an extensive document study, including material from a wide variety of sources such as newspaper articles, industry newsletters, reports, PR material, financial information, legal documents, policy documents and video material. In addition, a total number of 21 respondents have been interviewed. Interviews lasted between 60 and 90 minutes. The interviews were conducted between March 2017 and May 2018. The selection of interviewees is summarised in Table 2. Apart from their organisational belonging, 16 out of the total number of interview partners were chosen based on their long experience with the automotive industry in West Sweden. Informal meetings with three representatives of the regional development organisation provided complementary material. Key interview partners were identified during the document study and through a ‘snowballing’ technique. All interviews were transcribed and coded. The coding process for both documents and interviews took place in two steps, first an ‘in-vivo’ coding procedure (King, 2008) identifying interesting themes and patterns, followed by a focused coding based on analytical categories derived from the conceptual framework (Saldaña, 2015). Finally, data from different sources have been triangulated in order to increase the robustness and consistency of the findings.

Table 2: Overview on interviewees

No.	Role	Organisation	Background
1	Expert / Researcher	Research organisation	Academia
2	Expert / Researcher	Research organisation	Academia / automotive industry
3	Program director	Innovation support organisation	Automotive industry
4	Senior advisor	City of Gothenburg	Spatial planning
5	CEO	Automotive technology firm	Automotive industry
6	Department director	Automotive firm	Automotive industry
7	Project leader	National agency	Spatial planning

8	CEO / Program director	Innovation support organisation	Automotive industry
9	Researcher	Academia	Academia
10	Unit director	Region Västra Götaland	Regional development
11	Project leader	City of Gothenburg	Spatial planning
12	CEO	Public company	Mobility sector
13	CEO	Public company	Energy sector
14	Unit director	IT firm	IT industry / start-up
15	COO	Public company	Automotive industry
16	Senior consultant / Expert	Consultancy firm	Academia
17	Unit director	Innovation support organisation	Regional development
18	CEO	Innovation support organisation	Shipping industry
19	Unit director	Automotive technology firm	Automotive industry
20	Unit VP	Automotive firm	Automotive industry
21	Board member	Network organization / Innovation support organisation	Automotive industry / Public sector

Source: own compilation

The Swedish automotive industry is concentrated in the region of West Sweden (Nutek, 2009). It employs approximately 35,000 people (BRG, 2017), which represents 40% of the total employment of the Swedish automotive sector. Of the total number of workers in the region, 81% are employed in firms manufacturing automotive vehicles, and another 19% are employed by firms manufacturing vehicle parts (VG, 2016). West Sweden is home to large firms such as Volvo Cars, Volvo AB (trucks), HCL Technologies Sweden, CEVT, Autoliv and IAC.

The region of West Sweden hosts firms from all parts of the value chain and this is complemented by strong competencies in the public sector. The higher education organisations in the region, most notably Chalmers University of Technology, are important sources of competence for the automotive industry. In addition, there are several independent research institutes focusing on technical as well as societal issues related to the automotive industry. Furthermore, there are many intermediaries, science parks (such as Lindholmen Science Park), innovation arenas and cluster organisations. The region is also home to a strong ICT industry, working closely with some of the automotive firms. In all, the automotive industry benefits from ‘thick’ regional support structures (Holmquist and Söderkvist, 2012).

The automotive industry in West Sweden is characterised by a high level of competence in the field of active safety technology. Active safety refers to the use of technologies aiming at avoiding accidents, such as the antilock braking system (ABS) and automatic warning systems. Innovations in the field of active safety required creation of networks between previously unconnected actors to ensure the combination of knowledge from a variety of fields, such as mechanics, electronics and IT. The development of active safety in West Sweden started in the 1980s and led to the re-alignment of the regional support structures. For example, SAFER was created in 2006, adopting the role of both a research institute and a network organisation for coordinating the work around active safety in the region (James et al., 2016).
In our interviews, Google announcing a self-driving car unit in 2009 was mentioned as a ‘global trigger’ for the automotive industry to start focusing on autonomous vehicles. In West Sweden, the origin of path transformation can be traced back to the year 2013, when the ‘Drive Me’ project was launched. The project is a joint initiative between Volvo Cars, Autoliv, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park, Chalmers

University of Technology and the City of Gothenburg. It is supported by the Swedish government and sub-projects are partly funded by Sweden's innovation agency Vinnova. The aim of Drive Me is to study the societal benefits of autonomous driving. The project's core is the introduction of fully autonomous cars to be driven by 'real customers' on public roads in Gothenburg. Based on Volvo's premium SUV, which include 'combined function automation' such as assisted lane-driving, the new autonomous version "*add hands-off and feet-off capability in special autonomous drive zones around Gothenburg*" (Drive Me, 2016).

The transformation sparked by the Drive Me project was initially based to a large extent on the existing technological path within the active safety segment of the industry. Nevertheless, for SDCs to become reality, there is a need to not only further develop state-of-the-art technology but also to generate new non-technological knowledge related to other change dimensions, such as consumer attitudes, spatial planning principles, market and business models, infrastructure and so on. It is crucial for the transformation of the regional automotive industry that the RIS supports and facilitates such processes.

4 Results and analysis

4.1 Developing system functions within the region

Over the past few years, an array of activities and initiatives has been undertaken to mould the RIS for progressing with SDCs. In order to support knowledge generation, new organisations have been added to the established system of support organisations. A case in point for such layering processes is 'Revere – Resource for Vehicle Research', a vehicle software lab focusing on autonomous driving technology created in 2016 at Chalmers University. Revere was initiated by Chalmers in collaboration with actors from the automotive industry (Volvo Cars and AB Volvo) and is supported by regional public and private funding sources. This new research facility contributes to the development of new technological knowledge around SDCs in distinct ways. It provides an environment in which software developers have access to full vehicles and vehicle systems provided by the automotive industry. This constitutes a break with traditional practices of vehicle research and development taking place at a low modular level.

Furthermore, existing education and research programmes at Chalmers University have been reoriented towards autonomous driving technology and new programmes have also been launched. Evidence from interviews shows that these layering and adaptation processes have been facilitated and shaped by long-standing networks between Chalmers and the local automotive companies, providing the latter with a forum to communicate their needs and 'co-guide' reconfiguration of the university's education and research agendas. Several of these networks are formalised in platforms or projects dealing with topics related to technology transfer and competence provision.

Another example for the region's capacity to build new system elements that serve knowledge generation is the establishment of an 'artificial intelligence' (AI) research facility in Gothenburg. In our interviews, Zenuity has pointed to the central role that AI holds for solving some of the remaining technological challenges for SDCs. In order to cope with the shortage of AI competence in the region, Zenuity has joined forces with Volvo Cars, AB Volvo, Autoliv, Ericsson and Chalmers University and initiated the setting-up of an AI centre at Lindholmen Science Park. As stated by an executive at Zenuity:

"We call it a world class AI ecosystem. [..] the idea is that we gather both competence and data at the same place… many in the academia is lacking data, and we could give them that, because we have connections to large car fleets, through our customers." (Interview)

Our findings suggest that the regional system building processes analysed above did not only benefit the generation of new technological knowledge needed for SDC development but have also produced side-effects in terms of legitimising activities around autonomous technology and stimulating cultural shifts within the regional car industry. Several interview partners alluded to a shift from a traditional 'engineering culture' towards a more agile software focused way of working within the automotive industry, and how new system elements such as the AI centre are contributing to a new mindset in the region that is favourable for transforming the automotive path towards SDC development.

Arguably, not all new knowledge required for transitioning towards SDC is developed within the automotive industry. Several interview partners underlined the importance of knowledge assets formed within other regional industries, most importantly the IT sector. Formation of collaborative linkages between Volvo Cars and Ericsson's local R&D centre can be traced back to the early 2000s, when the companies launched joined initiatives in the field of 'connectivity'. These initiatives subsequently became a valuable source of technological knowledge for SDC development, but with the ongoing changes in the automotive industry they evolved into also being an important source of non-technological knowledge, for example in terms of business models, 'mindsets', and ways of working with software development. This highlights the ways through which actors make adjustments to existing system elements, that is, well established networks, to solve challenges related to new activities and path transformation. Interactions between actors in the automotive and IT industry intensified and took new turns, from being organised as collaborative projects around certain features, to also include labour mobility and facilitate cross-industry recruitment of executives and specialists.

If looking at historically grown RIS elements, such as innovation support organisations and other platforms, the existing system was already strongly supporting the automotive industry. In the early 2000s, the region invested heavily in the creation of test facilities that met the needs of the automotive sector, leading to the establishment of platforms such as 'Test Site Sweden', physical test facilities such as 'Asta Zero', and road segments with adapted infrastructure. Whilst these were not explicitly targeting autonomous driving at the time of their establishment, through adaptations they have become a key element in the regional system around SDC development. Such facilities play an important role in the formation of technological knowledge related to verification and test methods, but also experimentation, legitimation and investment mobilisation. As one interview partner expressed it:

"There is an explosion of testing, and a lot of work is put into methods development … with all the layers and variants that needs to be tested. Asta Zero is world leading in this work." (Interview)

Finally, when it comes to elements related to investment mobilisation, existing public R&D programmes for active safety technology have been 're-branded', in some cases by the funding bodies themselves but in most cases by the participating firms, to fit SDC development agendas. For example, Volvo Cars decided to use the remaining funds in a large research programme on vehicle technology for advancing SDCs. Given the close technological relationship between active safety and SDCs, this was mainly a matter of wording and terminology but it had also important signalling effects in terms of demonstrating the importance of publicly funded R&D in relation to SDCs.

4.2 Accessing system functions elsewhere

Given the growing importance of software development in the automotive industry, traditional car firms are increasingly linking up with actors in IT regions such as Silicon Valley. New networks are formed by regional automotive firms in order to get access to knowledge and competences that are related to specific issues in SDC development. Volvo Cars and Autoliv have begun to form strategic collaborations with actors such as the process manufacturer Nvidia, the mobility provider Uber and the sensor developer Mobileye. These linkages represent a new form of networks, based on mutual exchange and collaboration around new technologies that have previously not been prominent in the automotive industry. In our interviews firm representatives also highlighted the establishment of 'probes' in start-up hotspots such as Silicon Valley in order to come closer to and establish collaborations with start-ups in other regions. This is being done by both Volvo Cars and Zenuity and is argued to serve as an important way to access knowledge available in other regions, as well as an opportunity for Swedish firms to showcase their SDC solutions and possibly attract additional investment. Furthermore, Zenuity has started development units in Munich and Detroit in order to mobilise non-regional competences.

Then there is also evidence that actors in the West Swedish automotive industry have linked up with experts in other regions to further develop non-technological competence, such as knowledge about user behaviour, norms and attitudes towards SDCs, and driver-car interaction. One such example is HEAD, an interdisciplinary inter-regional research project involving researchers from universities in several Swedish regions who are active in disciplines such as ethnography and interaction design. HEAD is hosted by Halmstad University and part of the Drive Me project. This illustrates how Drive Me is used not only to generate new resources within the region but also to coordinate regional activities with knowledge development taking place in other locations.

Furthermore, actors in West Sweden have established new networks with national organisations such as the Swedish Transport Administration (STA) to ensure access to and co-create knowledge about the future of road transport infrastructure and traffic management. These linkages between regional and national actors appear to have a strong influence on the direction of research in this field in West Sweden and are used by the latter in an intentional and strategic way for that purpose. As a representative of STA put it:

> *"[..] in order to solve certain issues, certain challenges need to be dealt with, and we push the companies to become interested in those particular challenges."* (Interview)

It is also possible to identify processes of alignment of system functions within and outside the region. Existing initiatives, such as SAFER, Lindholmen Science Park and Test Site Sweden, have become important 'nodes' in coordinating resource formation processes in the region and elsewhere. They perform important functions in terms of coordinating activities and aligning the regional system with processes of legitimation and experimentation elsewhere. For example, activities drawing on existing test infrastructure in the region were driven by the major firms but coordinated and in part facilitated by Test Site Sweden.

4.3 Transplanting system functions from elsewhere

In terms of investment mobilisation, our interview findings indicate that whilst both regional and national funding sources play an important role, the importance of investments by Volvo Cars' parent Chinese firm, Geely Automotive, should not be neglected. Over the last few years, Geely has invested heavily in the region, locating, for instance, new subsidiaries in West Sweden. There are also plans to build an innovation centre employing approximately 3,500 people. Our findings suggest that adapting the physical environment of the Lindholmen area has played a major role in this regard. Through long-term strategic planning led by city actors, the Lindholmen area has been transformed to attract not only automotive OEMs and suppliers, but also IT firms, a Chalmers University campus and technology consultancies. Several of our interview partners have highlighted the attractiveness of Lindholmen as a crucial determinant for why Geely has located its innovation activities in West Sweden. Another important factor, according to several interviewees, was the establishment of Asta Zero and other test facilitates and test infrastructure, discussed in previous sections.

Moreover, during the past few years, regional actors have taken several initiatives to increase the attractiveness of West Sweden as a "*the place to be*" (Interview) for engineers interested in autonomous technology. When firms such as Volvo Cars, Zenuity, and Autoliv faced the challenge to attract the 'right' competence for solving some of the remaining obstacles related to SDCs, they acknowledged the need for engaging with start-ups in ways not previously done in the industry. As one representative of Zenuity put it*:*

> "*We are searching for start-ups all over the world. It is of course easier if they are close by, so that you can have quicker interactions, build trust quicker and so on.*" (Interview)

A conventional approach would be to set up incubators or accelerators to support local start-up activities. Automotive firms in West Sweden chose to strike a new path to work with start-ups venturing on knowledge development that is of relevance for SDCs. Rather than developing regional functions that support the emergence of new knowledge through start-up activities, major industrial actors in the region initiated Mobility X-Lab, a platform not only for interacting with start-ups from elsewhere but for temporarily relocating small firms to the region. Mobility X-Lab offers a physical environment through which start-ups are co-located with the industry partners, facilitating collaboration and knowledge exchange between the actors. In other words, it is not only about scouting for start-ups but to anchor small firms in the regional system around automotive technology at the cross-section between the automotive industry and IT. The creation of Mobility X-Lab does indeed represent layering of a new system element, but the element is targeting the anchoring of system functions existing elsewhere, in the form of knowledge generation and experimentation. For example, representatives of Zenuity as well as of Mobility X-Lab highlighted the importance of attracting already established start-ups to the region, since the regional entrepreneurial system is somewhat underdeveloped. These start-ups operate in fields such as video recognition and deep-learning microprocessors. They come from entrepreneurial hotspots like Silicon Valley, Finland and Israel, and are thus the outcome of processes elsewhere. Mobility X-Lab represents a way of transplanting these system functions to the region.

"We see that it is mainly more mature start-ups that are coming to us, which is an advantage because we are not an incubator with a business development support function." (Interview)

It is also apparent from our interviews that firms engaged in SDC development have tended to 'externalise' the coordination of regional system functions to intermediaries such as Lindholmen Science Park. Though they share some goals and interests, their corporate cultures as well as partly competitive relationships prevent the major industrial actors in the region from engaging in collaborative projects without a neutral coordinator. Consequently, regional intermediaries have been found to play an important, if not crucial, role. One representative of Lindholmen Science Park stated that:

"it is about making an initiative neutral. Mobility X-Lab was possible to start because Lindholmen could go in as host for it, and make it neutral. Otherwise it would have become a Volvo incubator, a Volvo environment, where Volvo would have tried to invite the others to their thing… And it would not have been the same thing." (Interview)

Our findings clearly indicate that the intermediary role played by Lindholmen Science Park and other organisations has gained in significance over time. This has been connected to processes of adaptation within the organisations, guided by the new needs of actors operating in the automotive industry. Worth mentioning in this context is also the role played by 'Drive Sweden', a national strategic innovation programme for the future of mobility, with a special focus on driverless and connected cars. Drive Sweden is not a regional programme but is hosted by Lindholmen Science Park and thus has a strong regional presence in West Sweden. Our research suggests that Drive Sweden serves as an innovation network that helps to transplant system functions from the national level (mainly in the field of new business models and legitimacy for SDCs) to the region. As one interview partner put it:

"In this mission, we are completely national and transparent. It is not that you should try to attract things to Lindholmen and only talk to companies here, but work all over the country and also globally. But then there are situations where the ecosystem can play a role, or the built environment, and then of course you can benefit from being part of Lindholmen as well, of course." (Interview)

Finally, there are many ongoing activities that in different ways are geared towards the formation of a 'regional SDC agenda'. These are concerned with branding the region as an SDC region, and enhancing international visibility. Whilst one cannot claim that these activities have a direct influence on the formation of new resources, they are important for situating the regional system in the emerging global SDC system. Several interviewees have highlighted that Gothenburg is considered as an attractive environment for firms working with SDC development. However, the formation of an SDC agenda should not necessarily be seen as a case of layering, but rather as a process of adapting existing system elements. Of the activities identified in our study, a majority of them seek to 'implant' incremental changes to existing plans and strategies. There are several examples of this. Industrial policies have to date not been re-aligned to focus on SDC development. Public actors are trying to find overlapping areas in existing policies related to industrial development, spatial planning and public transport. Experts from the city planning department in Gothenburg are involved in a nationally funded project where they, together with actors from the automotive industry, investigate what SDCs mean for city planning practices and principles as a sub-project of ordinary planning strategy work. Whilst it is formulated as a way for city planners to learn about the implications of SDCs, it has contributed to putting Gothenburg on the global SDC map, as it is actively promoted as a way for the city to prepare for a 'driverless future'.

Table 3: Summary of empirical findings

Type of reconfiguration	**Regional system element(s)**	**Reconfiguration mechanism(s)**	**System function(s)**	**Key actors(s)**
Developing regional system functions	Funding schemes	Adaptation	Investment mobilization	Automotive OEMs; Automotive suppliers
Developing regional system functions	Innovation support organisations/platforms (Test Site Sweden, Lindholmen Science Park)	Adaptation	Knowledge generation; legitimation; investment mobilization	Automotive OEMs; Automotive suppliers; Regional policy actors
Developing regional system functions	Physical infrastructure	Adaptation	Experimentation; legitimation	Autmotive OEMs; City actors; National policy actors
Developing regional system functions	Regional inter-industry networks (Automotive-IT)	Adaptation	Knowledge generation; direction of search	Automotive OEMs; IT firms
Developing regional system functions	Demonstration project (Drive Me)	Layering	Legitimation; Experimentation	Automotive OEMs
Developing regional system functions	Research centre (AI)	Layering	Knowledge generation	Automotive OEMs; SDC firms; IT firms; University
Developing regional system functions	Research lab (Revere)	Layering	Knowledge generation; direction of search	Automotive OEMs; University
Developing regional system functions	Research programme (Chalmers Transport Area of Advance)	Layering	Knowledge generation	University
Developing regional system functions	Courses and education programs	Layering; adaptation	Knowledge generation; legitimation	University
Developing regional system functions	Test facilities (Asta Zero)	Layering; Adaptation	Experimentation; knowledge generation	Regional policy actors; Automotive OEMs; Innovation

				support organisations
Accessing system functions elsewhere	Intermediaries (SAFER; Lindholmen Science Park; Test Site Sweden)	Adaptation	Direction of search; Legitimation; Experimentation	Automotive OEMs; Automotive suppliers; University
Accessing system functions elsewhere	Physical environment	Adaptation	Investment mobilization	City actors; Automotive OEMs
Accessing system functions elsewhere	Extra-regional network initiatives	Layering	Direction of search	National policy actors
Accessing system functions elsewhere	Inter-regional research projects	Layering	Knowledge generation; direction of search	Automotive OEMs; SDC firms
Accessing system functions elsewhere	Inter-regional strategic collaborations	Layering	Knowledge generation	Automotive OEMs; SDC firms
Accessing system functions elsewhere	'Network-probes' in other regions	Layering; Adaptation	Knowledge generation; investment mobilization	Automotive OEMs; SDC firms
Transplanting system functions from elsewhere	Agendas and visions (SDC agenda; city planning principles)	Adaptation	Legitimation; Direction of search	City actors; foreign actors
Transplanting system functions from elsewhere	Innovation networks (Drive Sweden)	Layering	Knowledge generation; Experimentation; Direction of search; Legitimation	National policy actors; Automotive OEMs, Innovation support organisations
Transplanting system functions from elsewhere	Innovation support organisation (Mobility X-Lab)	Layering	Experimentation; Knowledge generation	Automotive OEMs; Automotive suppliers; SDC firms; IT firms

Source: own compilation

Table 3 summarises our empirical findings and shows that the transformation of West Sweden's automotive industry towards self-driving cars is linked to complex processes, involving a combination of different types and mechanisms of system reconfiguration.

5 Discussion and conclusions

The point of departure in this paper was to contribute to the path development debate in economic geography by investigating how mature regional industries can be substantially transformed and how regional system reconfiguration supports such processes. Our conceptual contribution has been twofold. First, we introduced the notion of 'path transformation' to describe a type of path development involving a radical type of change within existing industries. Second, we combined insights from regional and technological innovation systems literatures and elaborated on a conceptual framework to analyse different types and mechanisms of regional system reconfiguration underpinning path transformation. By doing so, we have established a connection between regional system elements and the resource formation processes for new path development.

Our empirical analysis confirmed the importance of the three types of system reconfiguration identified in our conceptual discussion. System functions facilitating resource formation processes were developed regionally, by the layering and adaptation of research labs, education programmes, test infrastructure, innovation support organisations, funding schemes, and intra-regional network linkages. New inter-regional network linkages were also formed, accessing system functions established in other regions, such as Silicon Valley but also linkages to other Swedish regions were found to play a role. Apart from creating new linkages, existing system elements were adapted to take on coordinating roles in managing the external connectedness of regional actors. Finally, we found that the transplantation of system functions, such as investment mobilisation and experimentation, through the establishment of new regional system elements, was vital.

The empirical case study also highlights the importance of activities undertaken by incumbents in path transformation. Established automotive firms, such as Volvo Cars and Autoliv, played a crucial role in both initiating new activities and facilitating system reconfiguration processes. To some extent, this finding is contrary to conventional wisdom saying that incumbents are not usually the initial leaders of transition processes (see, for example, Geels, 2011). The study also highlighted the role of regional public actors and their contribution to some system functions, such as legitimation and the direction of search. Furthermore, it presented us with interesting examples of how non-local actors can influence RIS reconfiguration. For instance, the national Swedish Transport Administration provided access to system functions, whilst Drive Sweden and the Chinese owners of Volvo Cars contributed to the transplantation of system functions from elsewhere.

By analysing our empirical case using the proposed analytical framework, three important points can be made. First, whilst the relative importance of developing system functions within the region arguably have found been high in previous studies of path development, the relationship with the other types of system reconfiguration is not as clear cut when it comes to path transformation. Actors are guided by visions and strategies that are often developed regionally by industry incumbents, but it is not the case that the default option is to target system reconfiguration to develop other necessary resources regionally. Rather, actors tend to utilise previous networks and their position in global innovation systems to reconfigure the regional system in order to also access and transplant system functions already taking place elsewhere. It remains to be investigated whether this is true also for other industries than the automotive industry, and for different types of regions, which calls for this as a key topic for further empirical work.

Second, it is apparent in our study that regional system reconfiguration does not only target the development, access and transplantation of technological knowledge. In line with previous studies, our findings support the idea that it is necessary to account for the formation of a wide range of different resources, such as legitimacy, visions, regional mindsets and culture (see Binz et al., 2016; MacKinnon et al., 2018). The way through which the regional system is reconfigured to facilitate the mobilisation of these resources is likely to differ between regions and industries, pointing to another important direction for future studies of path transformation and system reconfiguration.

Third, it is important not to neglect the influence of other regional industrial paths on the transformation of an existing regional industry. The RIS may not only support one but several regional industries. In our case, the regional system was strategically reconfigured to exploit recombination potentials between the automotive industry and the regional IT industry. Elements were layered and adapted for 'tapping into' existing resource formation processes in the IT sector and using them for transforming the automotive industry. This resonates with findings from recent work on the importance of inter-path relationships (Hassink et al., 2018; Trippl and Frangenheim, 2018).

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