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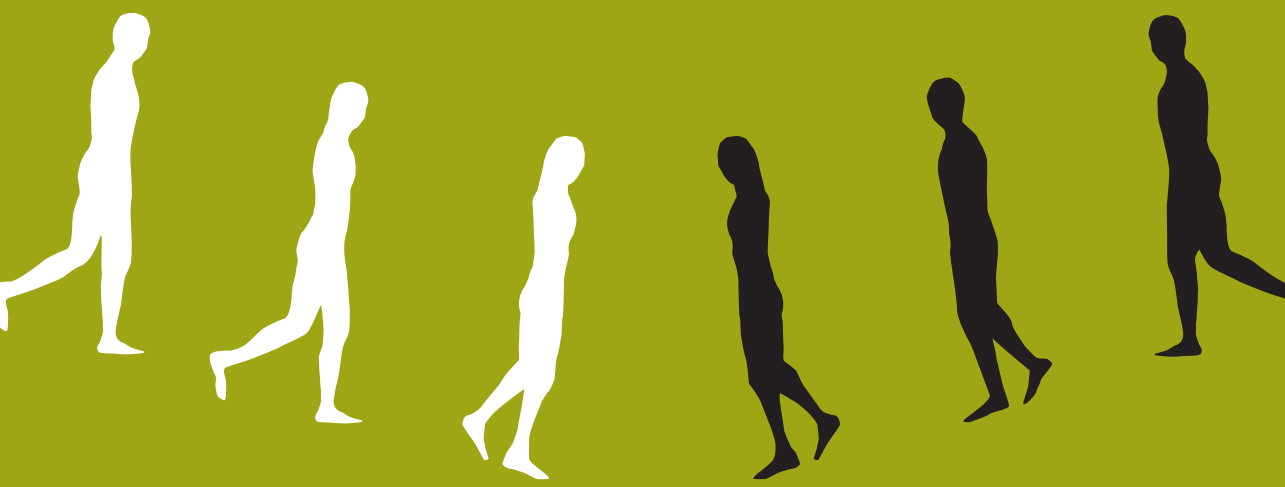

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CONCEPTUALIZING NETWORKS AS ASSEMBLAGES
A case study from the Spanish ceramics sector

LA CONCEPTUALIZACIÓN DE REDES COMO ENSAMBLAJES
Estudio de un caso práctico en el sector cerámico español

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Abstract
Network structures are being used to explain social interactions within and between organisations in many ways that have become very influential. Many of the sociological features of organisations are captured very effectively by network descriptions, but such descriptions also retain serious limitations. Some network theories, for example, are composed of fragmented and internally inconsistent theories, while others depend upon essentialist and reductionist models. Perhaps a more serious problem is that networks describe relationships rather than explain the mechanisms through which these relationships function. This paper introduces the notion of assemblages as a corrective to these problems. The concept offers a clear, though suitably complex, framework with which to clarify the dynamics and structures that afford engagement and enable collective action among diverse elements of organisations. Using brief examples from recent research in the innovation literature, supported by an empirical case study in the Spanish ceramics sector, this paper will illustrate how reconceptualising network relationships in terms of their assemblages enables a more robust and consistent theoretical grounding for network research.

Keywords
Assemblages, Innovation, Social Networks.

Resumen
El concepto de redes sociales es muy influyente en la explicación de la interacción social en las organizaciones. Muchas de las características sociológicas de las organizaciones se explican también por las redes sociales, pero el concepto tiene limitaciones importantes. Algunas teorías de las redes están hechas de fragmentos de otras teorías, otras se basan en modelos que son esencialistas o reduccionistas. Otro problema es que las redes pueden describir las relaciones de los objetos, pero no los explican. En este artículo se describe el concepto de conjunto para resolver estos problemas. El concepto de "ensamblaje" ofrece una clara, aunque compleja, estructura para mostrar las dinámicas de las relaciones de los distintos elementos en las organizaciones. Basándose en ejemplos recientes en el área de la innovación y en el análisis de un caso práctico en el sector cerámico español, este artículo ilustra cómo el conceptualizar las relaciones entre diferentes redes en términos de su "ensamblaje" permite un marco teórico más robusto para la investigación de redes.

Palabras clave
Ensamblaje, Innovación, Redes Sociales.

Introduction

Network models have been particularly effective in developing statistical and simulation models for examining organisations and other social phenomena (Wasserman and Faust 1994: 3-27). While the emphasis on developing such tools may in many ways be commended as a positive counterpoint to the overuse of vague analogies, network research has also recently developed a number of theories and descriptions to address questions concerning the mechanisms or practices of networks as found in social capital theory, embeddedness theory or diffusion theory (Borgatti and Foster 2003). Research using network theories and methods has become an important part of the literature in sociology and related disciplines. While some of the limitations of network methods have been identified (Marsden 1990) within this literature, very little research has been documented that aims to address the weaknesses of the descriptive powers of the concept. This paper will address this issue by presenting some of the conceptual weaknesses common to network theories and developing a corrective to enable a more robust theory to be applied to social science research; an approach able to express the dynamics of change in ways otherwise difficult to articulate. This corrective to network theory will be exemplified by research examining the ways that networks support innovation and corroborated by empirical research from the ceramics sector in Spain, concluding with suggestions concerning ways in which an assemblage approach can contribute to the network research paradigm.

The network of network theories

Attempts to describe and explain the social interactions that support organisations and other social phenomena make use of a variety of models and methods. There are, though, a limited number of paradigms that dominate the literature, and among these, emerging as the market leader, is that of the network. Stephen Borgatti and Pacey Foster illustrate the exponential growth of network-based research outputs with bibliometric data (Borgatti and Foster 2003: 992), arguing that the network paradigm forms part of a more general move "away from individualist, essentialist and atomistic explanations toward more relational, contextual and systemic understandings" (Borgatti and Foster 2003: 991). In this section, this paper will briefly examine the key features of network theory and examine attempts to classify network research, followed by an examination of its underlying assumptions, while focussing on some of the areas that an assemblage approach would be able to illuminate; an approach which will be explained and examined in section three.

The network paradigm does not represent a unified approach to research; network models are themselves diverse but share characteristics and assumptions. The use of such models in addressing the issue of innovation (the theme of this paper) seems

a sensible choice as networks are able to capture a sense of the interdependencies of organisations and the channels of exchange that enable the relationships necessary for innovation to develop and be maintained (Freeman 1991). Equally, network descriptions can be applied to a variety of innovation-related phenomena. Examples include Powell, Koput and Smith-Doerr (1996), who use network patterns to describe the growth in corporate partnerships and external collaboration and the purpose such relationships serve, while Bengt-Åke Lundvall, with a very different approach to organisational adaptation, uses network descriptions to exemplify the process of knowledge transfer and learning between different firms (see Lundvall 1992).

Network models have been used extensively in research questions addressing both internal organisational change and inter-organisational dynamics. This paper will focus on network research of both types of dynamics, and network approaches specifically addressing the topic of innovation, partly because innovation and change are particularly dynamic organisational themes, and also because they present a challenge for researchers and theorists due to the difficulty of setting the boundaries of the network, i.e. distinguishing what is included from what is excluded from the network. In addition, with an established, though rapidly growing, literature to justify new research, bold claims are being made about how networks are a fundamental part of an organisation's relationship to the innovation process: "It now appears that inherent successful innovation can be explained by the influence of the networks and social capital (Lewrick, Raeside and Peisl 2007: 38)".

The key feature of network analysis in this literature is that it emphasises the interdependence of individuals within organisations rather than conceptualising them as sovereign elements that act autonomously. As such, the relationship between individuals is perceived to be the unit of analysis of social structures, with such relationships conceptualised as conduits for the flow of resources, and in particular, information (Wasserman and Faust 1994: 4-5). Network theorists therefore attempt to identify the relationship patterns that form network structures and analyse the network relationships to identify the conditions that enable or obstruct specific activity. While there are common features in the types of methods and metrics used to identify such patterns, and shared assumptions concerning the importance of ties of interaction in investigating behaviour and activity, there are fewer commonalities in the theoretical basis of such analysis.

Theoretical positions developed in the early stages of network research – approximately 1970-1990 (Borgatti and Foster 2003: 992) – can be defined in terms of their opposition to structural-functionalism, in addition to an implied opposition to perspectives that emphasise purposive action and non-relation characteristics (Wellman and Berkoviz 1997). However, explicit theoretical or ontological frameworks with which to support the assumptions of a network analysis are typically absent. Mustafa Emirbayer and Jeff Goodwin (1994) claim that there are, in fact, three *implicit* models or frameworks in network analysis, although all three models – structuralist determinism; structuralist instrumentalism; and, structuralist constructionism – seem to have fundamental problems (see Emirbayer and Goodwin 1994: 1425-1436). They characterise structuralist determi-

nism as infrastructural, while structuralist instrumentalism is characterised by its predominant focus on interest seeking as a network mechanism. The third of Emirbayer and Goodwin's categories of network research, structuralist constructionism, is characterised as explaining action in terms of the interaction of normative commitments and network structures. While this typology helps in clarifying a number of theoretical presuppositions – and identifying some important tensions and flaws in these theoretical types – more importantly it draws attention to what is missing: there is a lack of engagement in analysing such presuppositions, especially in terms of a network's basis for explanation, unit of analysis or method of addressing the problem of multiple scales. The typology could be accused of being somewhat contrived, directed almost exclusively towards network consequences rather than causes, and overemphasising the theme of agency in analysing network models. Nevertheless, it provides a useful way of positioning the research paradigms of the *early* period of network research.

A broad analysis of more recent network models (Borgatti and Foster 2003) identifies a number of research streams and research dimensions with which to categorise the literature. While the themes are useful in demonstrating the degree to which concepts such as social capital, embeddedness and social cognition have gained resonance with network researchers, the four research dimensions that Borgatti and Foster identify is itself a useful tool in drawing out some of the current theoretical positions. The first dimension, the direction of causality, shows that research examining the consequences of networks is often informed by the paradigm of structuralism, while research directed towards the causes of network formation typically use concepts centred on individual motivation and psychological properties in diametric opposition to the structuralist scheme. Additionally, Borgatti and Foster show that many of the agent-based models base their simulations on simple individual motivation to explain causes of network behaviour. The second dimension they identify is the level of analysis. The scale and complexity of the unit of analysis can often determine the type of theoretical framework employed. For example, networks of people are different from networks of organisational units, not merely in having different characteristics and capabilities, but in that the relationships themselves have different functions and meaning. As such, individualist and essentialist assumptions do not easily scale up to the organisational and macro levels, which could help explain why structural theories are more prevalent in organisational network research. Finally, the two remaining dimensions are examined together to analyse the underlying assumptions of network models. Borgatti and Foster examine the way these dimensions – explanatory goals and explanatory mechanisms – relate to the theories network researchers employ. Their initial observation is that much of the research, especially that influenced by Burt: "seems to add a rational actor assumption to social capital theory to the effect that actors deliberately choose their ties (i.e. manipulate the network structure) specifically in order to maximise gain" (Borgatti and Foster 2003: 1002). Borgatti and Foster add more nuance to this claim and use their "explanatory goals" and "explanatory mechanisms" dimensions to identify four canonical types of network studies. The first two – structural capital, and environmental shaping – are positioned as structuralist in the

sense that the content of the ties is less emphasised, with the main focus being the patterns of interconnection. Such approaches tend to perceive the actor as a rational active agent, exploiting their position to maximise gains or reach objectives. The remaining two categories – social access to resources, and contagion – are described as connectionist in the sense that networks are perceived as conduits for the flow of resources, and emphasis is given to these flows rather than to network structures. These perspectives are not intended to be mutually exclusive, but merely to emphasise differences in the conception of how ties, and ultimately networks, are said to function.

Borgatti and Foster present, then, an expanded typology that is largely compatible with the type of network patterns identified in Emirbayer and Goodwin's critical typology. The structuralist vs. connectionist approach also expands on a number of other network binary oppositions which have been useful in characterising network approaches: equivalence/cohesion, structural/ relational, typology/flow, girders/pipelines, positional/ relational, to take a few examples. These typologies are, though, limited to dividing approaches according to their orientation rather than ontology, i.e. they draw distinctions between the different ways that ties create exploitable structures and the way they enable resources flow through such structures (opportunities vs. restrictions) without accounting for the nature of the component parts of such structures, or considering how they are formed or affected at different levels of interaction.

While these typologies are useful, and the paper will return to the categories they outline in the following sections, the dearth of ontological considerations in the network literature leads to, and is compounded by, a number of methodological weaknesses. For example, in research designed to address networks, genuine theories are generally overlooked in preference to descriptions. In addition to this, some of the stronger claims supporting these descriptions rely on data sets such as patent data and citations, which are weak indicators of sophisticated networks, while other research relies wholly on surveys and questionnaires, often leading to perceived ties being treated as actual ties (Marsden 1990). In this way, such research is unable to develop findings through which new concepts or theories are able to emerge, thus perpetuating the choice of concentrating on description, or worse, on implicitly retaining internally inconsistent theories and concepts based on fragmented and unexamined models.

The problem is that while the authors of these explanations often support their claims with empirical evidence, demonstrating that networks form a condition of the organisational dynamics able to facilitate innovation, there is little actual theory to explain, rather than merely describe, why the processes function, what deeper mechanisms are at work, or how the changing components of the networks impact on the processes produced by earlier interdependencies or the process of feedback and emergence on changes within collaborative groupings. As Gerald Salancik argues, "network analysis has been used mainly as a tool for analysing data about organizations rather than for understanding organizations per se" (Salancik 1995: 345). Thus while it is true that describing the effects of network phenomena may be useful, in addition, it would be much more powerful if it were coupled with explanations concerning why they exist in the form that they exist,

particularly if the research is to be applicable to other cases and, more ambitiously, to address the nature of the ontologically primitive elements that constitute network theory's basic concepts (Parkhe, Wasserman, and Ralston 2006: 561-563). To address these gaps, and identify the range of actors and ties responsible for organisational change within such networks, an alternative perspective must be developed that can encompass all of the features of the typologies developed by Emirbayer and Goodwin, and Borgatti and Foster, and, in addition, offer an account of the ontological features so as to improve our conceptualisation of networks in general. This paper examined one such alternative, which originates in the approach taken to explaining social interdependencies by theorists such as Gilles Deleuze, Manuel DeLanda, Michel Callon and Bruno Latour, but developed in response to the more fundamental problem of scale within social theory. The next section introduces this problem and details the concept of the assemblage as a solution to the problem of scale and, by extension, of network theory itself.

The Role of Assemblages

The problem of scale is relatively simple to describe: the structures arising from interactions are irreducible to the features of their constituent parts. For example, my political views, produced in the course of using my brain, cannot be described in terms of the anatomy of my brain however detailed the account; my views are an emergent property of my brain and describing them using a narrative of neuroscience is merely to describe epiphenomena, rather than the thought process such views represent. With networks, individuals interact with other individuals, communities, businesses, markets and a range of organisations and vice versa. We are engaged in networks that encompass social systems and populations (macro level) as well as individual action and uniquely occurring interactions (micro level). The problem of scale is how to hold the macro and micro together without reducing the macro to a series of micro epiphenomena or erasing the micro by reducing it to the functions of social forces. As Mark Granovetter observed: "A fundamental weakness of current sociological theory is that it does not relate macro-level interactions to micro-level patterns in any convincing way (Granovetter 1973: 1360)"

Granovetter's criticism still applies to much of contemporary social and organisational theory. Many of the "solutions" to this problem simply defer the reductionism from the macro to the meso level such as with Anthony Giddens' theory of structuration (Giddens 1986), the concept of (transformative) praxis (Bhaskar 1997), the notion of the routine within the multi-level perspective (Nelson and Winter 1977) or by different forms of conflation based on act aggregation or agent orchestration (see Archer 1995: 93-134). Network theory might offer a promising alternative, one that Granovetter himself suggests, and yet network theory itself possesses the same weakness. The problem of addressing the limitations of existing network theories identified in the previous section can be coupled with this requirement to develop a theoretical solution to the problem of scale. It is

for this reason that the concept of the assemblage becomes a very powerful theoretical framework for network theory.

While many of the features of assemblages are found in existing network descriptions, unlike existing network theories, the concept of the assemblage was not developed from fragmented theories with different supporting ontological assumptions, but devised with a clear purpose and directed towards a specific problematic within a unified philosophical scheme, though one which is complex and requires a series of steps in order to be fully conceptualised (Deleuze and Guattari 1988: 323-337). The term "assemblage" is derived from the Greek word *sumbolon* meaning the act of bringing together. Deleuze describes an assemblage (*agencement*) as a "multiplicity which is made up of many heterogeneous terms and which establish liaisons, relations between them" (Deleuze and Parnet 1987: 69) and uses the term as a way of conceptualising a wide range of patterns that hold heterogeneous elements together. These collectives are therefore devised in order to serve as the unit of analysis in explaining events on the micro, meso and macro scale. An assemblage structure, which will be described in detail shortly, expresses network relationships in which synthetic processes or emergent properties are not reducible to the properties of a network's individual parts and thus a means of engaging macro-level and micro-level configurations without recourse to reductionism. Unlike other approaches that suggest ontological distinctions between levels (for example, the way we are taught in school the difference between physics, chemistry and biology), the assemblage concept is used to explain the way in which each entity exists on the same ontological level, but differs in the scale in which it resides: "The minimum real unit is not the work, the idea, the concept or the signifier, but the assemblage … which is always collective, which brings into play within us and outside us populations, multiplicities, territories, becomings, affects, events (Deleuze and Parnet 1987: 52)".

This research will outline details of assemblage structures and attempt to build on these conceptualisations as a way of developing a framework to contrast with existing network approaches to express organisational dynamics. However, for the concept to contribute to this goal, it will need to be clarified and its advantages over existing descriptions need to be explained; a very technical undertaking. I will therefore begin with an overview of the development and application of the concept and give a brief account of its role in the analysis of social and organisational dynamics.

The concept of an assemblage, as developed by Deleuze and Guattari (1988) and later refined by DeLanda (Delanda 2006a; 2006b), was designed to explain the synthetic processes that sustain and modify the structures of entities such as formal and informal networks, organisations, industries or regions etc. in non dialectical terms. Unlike dialectical and organic wholes, the concept provides a non-reductionist and non-essentialist description for the properties of the entities it is applied to, enabling different intermediate scales to be represented in terms of appropriate units of analysis rather than epiphenomena. This is because unlike an organic totality with mutually constituted parts fused into a seamless whole, the components of an assemblage have a degree of autonomy from the whole, which allows them to be disconnected and reassigned to other assemblages.

To use an example, an extended family is an assemblage comprised of, but not limited to, different components of a biological, organic, technological, spatial and informational nature configured into, and modified by, a range of socio-cultural assemblages such as languages, medicine, community and consumption. These emergent assemblages are themselves components serving larger assemblages, from small networks and organisations to nation states and global events. The ontological status of these larger assemblages becomes, in turn, "that of a unique, singular, historically contingent individual" (DeLanda 2006a: 40). In this way, the study of a specific cluster of assemblages is not prior determined according to a particular unit of analysis or pressure (such as individual agents, labour, utility and profit maximisation) as is often the case with network theories, but determining the scale, components and assemblages to be included in the description forms a part of the investigation, which recognises the impact of using these, rather than other components, in framing the analysis (Callon 1998); a point I will illustrate in section four.

Deleuze, individually and with Guattari, developed and refined this model in relation to a number of features of his philosophical system, which collectively resist being transplanted unchanged within more traditional narratives of networks or organisational change. In order to benefit from such an engagement of ideas, it is therefore necessary to stipulate the boundaries of the concepts and formulate these limits in terms that engage with existing concepts in the literature. The work of DeLanda (2006a; 2006b; 2010), exemplified with some features from more mainstream research interests in assemblages, will greatly contribute to this task.

The power of the assemblage approach in capturing this variety of organisational dynamics, then, is that it presents an alternative to explanations based on organic totalities or descriptions based upon the organism metaphor. This is because unlike organic parts, the components of assemblages can be switched between assemblages while preserving their identity, as occurs on a daily basis in every organisation. Consequently, the properties of the components do not explain the relations which constitute the whole, as the properties of the assemblage are not the result of the aggregation of components properties but the exercise of their capacities. This needs to be clarified further and the work of Manuel DeLanda will provide such a clarification in that he attempts to develop a full theory of assemblage as a framework with which to model sociological and geographical phenomena (DeLanda 2006a: 1-7) as well as historical and linguistic phenomena (DeLanda 2010 5-30 & 53-68). While acknowledging the concepts needed to develop such a theory are dispersed throughout a number of Deleuze's texts, and such concepts are not given in a style suited to a straightforward interpretation, DeLanda identifies key features of a simplified scheme with which to develop a full assemblage theory framework; a framework this paper will attempt to operationalise shortly. The four key features identified as of particular importance in the scheme are the following:

• Each individual entity is comprised of component entities at the immediate lower scale, i.e. scale relations are parts to wholes.

• The component entities on each scale are interacting, and processes generated through these interactions are the source of the emergence of entities on a higher scale, as unintended consequences

• On emerging, a larger scale entity becomes a source of resources, but also sets limits for its components, i.e. the whole both facilitates and restricts the interaction of components.

• At each scale there is a concrete singular entity and as such there is no general entity or category as an absolute referent (DeLanda 2006b 251-252).

In terms of the Borgatti and Foster typology, an individual assemblage as represented by these features comprises *both* the structure *and* the flow of resources not as abstract aggregates, but as actual features of the narrative of the emerging network, i.e. the structuralist dimension identifies the components to be included in the assemblage, while the connectionist dimension dictates the patterns that the assemblage imposes on the components. An assemblage, then, is not driven by stable preference functions and their related constraints, nor is it driven by competing essentialist forces, but is generated and modified by a multiplicity of heterogeneous interests which only emerge with the unfolding of the assemblage itself in much the same way as a part of a network can switch from being an active part to a more passive part of a process as the organisation it belongs to evolves; for example, when a group of politicians vote to change the leadership of their party.

Up to this point, the paper has presented a checklist of features that a framework must have in order to tie its constituent parts into an (inorganic) unity. The innovative and important part of the theoretical positioning of this paper resides, though, in exemplifying the concept of an assemblage further: detailing its dimensions and illustrating the mechanisms that explain the relationships between components, and using the notion to analyse and explain different factors identified within and between organisations. This requires detailing the dynamic features of the assemblage model in actual cases or as applied to actual artefacts, objects or problems with which the network takes its meaning. Such an assemblage description will be introduced, exemplified and operationalised in terms of a case study derived from empirical research on innovation within the ceramics sector inn Spain outlined in the following section.

Operationalising Assemblages: ceramic tiles with integrated photovoltaic (PV) cells

In the previous section, an assemblage approach was shown to address a number of gaps identified with existing network theories: it is not based on predominantly statistical correlations or rational action theory, it is not merely a description, it does not imply homogeneous units, it details the ontological landscape and it is not a composition of multiple theory fragments. There is, though, an additional question facing networks that

needs to be addressed: what needs to be included (and what doesn't) in order to develop a relevant description or analysis of a network; for example, in an account of an innovative artefact. As with any network account, a description must be coherently bounded, addressing a finite number of features. It is this combination of components that forms the assemblage and it is in attempting to address this question that the concept of assemblage can be exemplified and operationalised.

To do so, this paper will discuss relationships and organisational practices centred on the development of a specific innovation within the ceramic tile industry. This innovation – the development of ceramic tiles with integrated photovoltaic (PV) cells – was one of five innovations examined in a research project carried out between 2007-2010 in Castellon, Valencia, as part of a CSIC-funded project on clusters and innovation in the Valencia region of Spain. Each of the five innovations – PV ceramics, Tile of Spain brand, digital tile decoration printing, non-slip tiles and self-cleaning surfaces – were chosen on the basis of being a partnership between firms (hence requiring some network relationships) and indicating some benefits from belonging to the Castellon ceramic tile cluster. Practical considerations such as access to key decision makers also informed the choice. Of the five innovations examined, I will present only one in detail. This case was chosen because it includes a greater diversity of components than the other case studies and illustrates the innovation process in multiple stages. Although it is otherwise unremarkable, each case study provides sufficient details to operationalise the assemblage concept. This individual case study was developed through nine ethnographic interviews ranging from 55 minutes to 90 minutes with key decision makers in the organisations involved in the innovation. The interviewees were chosen through a snowballing method on the basis of initial recommendations and contacts obtained through the first two interviewees. The interviews were supplemented with company documents, patent details, project reports and other data provided by stakeholders and experts based at the Universidad Politécnica de Valencia and with short telephone interviews to clarify and cross reference details with four of the nine interviewees after the face-to-face interviews had been completed. While such ethnographic interviews have their limitations, even when supplemented with additional data, these limitations do not undermine the specific objectives of the empirical part of this research: i.e. to describe the events and relationships through which a specific artefact emerged as an idea and an embodied technology, even though they depend upon a series of interdependencies spanning a range of organisations and based on temporary or informal relationships, which are difficult to capture. The paper will set out the key details of the case study and then exemplify the assemblages by placing these details into an appropriate context as confirmed by key actors themselves, which are then cross referenced with features of the typologies outlined in the previous section.

The development of ceramic tiles with integrated photovoltaic (PV) cells emerged as a consequence of collaboration between three Spanish firms: a ceramic tile manufacturer (Pamesa), a ceramic coating and glaze manufacturer (Fritta) and a Spanish solar energy technology manufacturer (Isofoton). The technology encompassed by this initial

collaboration became formalised as a patent for a ceramic "energy generating coating" (WO/2001/015239) obtained by senior technicians working for these companies. This technology later became embodied within a technological artefact – PV Soundless – constructed in Germany within the last decade. Examining the components that afforded or enabled the construction of this physical artefact will illustrate the way that the assemblage emerged from *and* structured the networks between these components.

PV Soundless was a 2001-2003 European Commission demonstration project (NNE5/397/2000) involving the construction and monitoring of the world's largest photovoltaic sound barrier in Freising, Germany. The project was coordinated by Isofoton partnered by the German firms Biohaus PV Handels and Fraunhofer Gesellschaft and the cities of Leganés in Spain and Helmond in Holland. The project was funded as part of the European Commission's 5th research Framework, with the specific aim of accelerating the market penetration of cost effective Photovoltaic (PV) technologies and the general aim of developing promising research on renewable energy. These aims are coupled with legislative initiatives and form part of the wider EU objective of meeting Kyoto agreement targets of generating 12% share of energy through renewable sources by 2010 and other EU targets of 20% of energy through renewables by 2020.

PV Soundless attempts to meet these objectives by using integrated PV ceramic tiles to solve one of the problems associated with the practical application of PV technology. Technology predating such ceramics includes a diverse range of solar cells and modules that provide a potentially key renewable source of energy as the technology is able to convert sunlight directly into electricity. However, system costs and the demand for plots of territory have limited its actual application. The PV Soundless barrier was designed to combine noise protection features with energy generation and thus enabled building costs and land space to be "shared" or offset between these two functions. The PV Soundless project demonstrates that integrated PV ceramic tiles enable these two features to be combined, and demonstrate the feasibility of inserting electricity generating tiles into the build environment in general. Thus far, this is the network account of PV ceramics. Once the ties to the individual agents are mapped, the research is complete; networks (Parmesa-Fritta-Isofoton) describe the emergence of the idea of PV ceramics and then describe the embodiment of the idea as it comes to market (Isofoton-Biohaus PV Handels-Fraunhofer Gesellschaft-Leganés-Helmond). The two networks complete our understanding of the invention and innovation of PV ceramics.

As an analysis, this would be very poor, although quantitatively accurate once the ties had been counted. Instead this is the starting point for tracing the assemblage. The interviews indicated that a wide range of features of the market for PV ceramic tiles encompassed a variety of different organisations, each of which is associated with this market and comprises the assemblage entity. Key components include ceramic materials, technicians, companies such as Isofoton and Fritta, contracts with key supply firms, partners, an annual trade fair, the Instituto de Tecnología Cerámica and the construction company. Other components, such as the residents of Freising – for whom noise is a problem; motorists – who produce the noise; the local airport – which is the focus

for Freising's traffic and the European Commission – with the objectives of funding the testing of renewable technologies – are also important features in the shaping of the assemblage as embodied in PV Soundless. Similarly, the meetings and communications between company managers, public managers and planners (in which protracted negotiations took place); the documentation and contract agreements that were changed in the course of deliberation; informal discussion among technicians; patent applications modified because of legal advice; conversations with suppliers about quality control and the processing of payment invoices were among the interacting component entities generating emergent entities at the scale of the PV ceramic tile assemblage. The reputation of the firms, the legitimacy of the contracts and patents, the solidarity expressed towards the environmental objectives, in addition to the actual content of negotiations and discussions and the wording of formal agreements play an expressive role within this assemblage, while the meetings, the traffic flows, the factories, environmentalist groups, the Isofton management team, etc. play a prominent part in the material role of the assemblage.

The development of a best practice model to enable standardised configuration using the prevailing PV ceramic technology developed in a range of pilot projects, and in addition to PV Soundless, represent territorialisation within the assemblage. The dissemination of the positive findings from the pilot project in influential industry publications (see Moreno 2006: 62-63), the award of first prize in the International Industrial Design and Technological Innovation Competition at the CEVISAMA trade fair in 2005, and new regulations encouraging renewable energy in new constructions have also contributed to assemblage territorialisation. Improvements in competitor technology grid-supplied renewable energy, efficient wind technology, and reduced costs for relatively clean non-renewable sources such as natural gas combustion and potential breakthroughs in methane-powered fuel cells, and, importantly, the financial crisis of 2007-2011 each represent deterritorialisation pressures as would powerful new entrants to the PV market with ambitious plans for extending the use of PV ceramic products.

Reports by organisations such as the International Energy Agency, the European Commission, and the Johannesburg Renewable Energy Coalition on climate change and renewable energy have acted to consolidate the territorialising effects of descriptions of applied technology and, as such, form an important part in the coding process for the assemblage, as do widely cited technical reports concerning the development of the technology around which an assemblage can be formed (Yu *et al.* 1995). The process of decoding, which as outlined earlier involves fluid, informal, local and personal perspectives addressing the assemblage, is found within examples such as the informal discussion of a speculative bubble for environmental technology, which divides PV ceramics technology that is deemed sustainable from ceramics firms that are deemed potentially uneconomic.

The finalised product available on the market, with its cost implications, path-dependent technology, production processes, safety procedures, fabrication conventions, etc. becomes the origin of new market activity for PV technology, but at the same time, the

product developed and sold by Isofoton implies a certain character and performance that constrains the artefact's form and structures a series of relationships with other firms and organisations. These relationships can be detected at the level of the PV ceramic assemblage where the specific supply and demand for the product are realised; relationships derived from the actual market and marketing practices that take place in actual exchanges whether they occur on-line, at trade fairs, in company warehouses or on faxed contracts.

The case study therefore illustrates the four key features that define an assemblage structure as outlined in section three: 1) scale relations are parts (autonomous companies, patents, cities) to wholes (the PV ceramics network); 2) interactions are the source of the emergence of entities on a higher scale (the PV market is afforded by the *interaction* of the expansion of Munich international airport near Freising, patents, Isofoton's alliances, renewable energy policy, etc.) as unintended consequences; 3) the whole facilitates a market for PV ceramics, but restricts the interaction of companies (for example by patent protection, path dependent technology or by signed contracts); and 4) the PV ceramics network has no general entity or category as an absolute referent (there is no common denominator for sunlight, patent applications and traffic).

In this way, the inclusion and/or emphasis on specific components as part of a descriptive assemblage, whether organisations, technology, champion firms, marketing tools, are the features that enable specific narratives to be developed. Focussing on combinations of such components from which richer narratives can be developed means that identifying or outlining specific assemblages is not a process of discovery, but an interpretation. An assemblage description enables the mapping of these components. However, the assemblage only becomes apparent through these evolving interdependencies, although once mapped, the interdependencies of the components begin to explain the networks they form, rather than being a static description. This can be clarified by an example from the case study. Consider the importance of path dependency: Pamesa, Fritta and Isofoton worked together on the energy generating coating patent because the same technicians had previously worked together on an unrelated patent application and they kept each other informed of potential collaborative opportunities (one worked for a ceramic company, another for a PV solar panel company, so "sooner or later the idea of putting them together was inevitable" (Interviewee 3, my translation). Isofoton targeted funding from a European commission demonstration project because it had been successful in obtaining funding for a previous project, knew how to frame a winning application and the necessary partners were suggested through contacts made through the previous application stage "before having had the right product, I had the right method of testing it in a public way with adequate funding" (Interviewee 1, my translation). The network didn't just happen, it was drawn from a range of existing and new contacts by the needs of the artefact itself, and its components were not passively linked but were, instead, actively modified through their many interactions (and a series of unintended consequences) to create the artefact in its final form(s).

To clarify how the things in a network are drawn in, we must again reflect on the structure of the assemblage it represents. Each component in an assemblage can be mapped in terms of the roles it plays, which extend from the wholly material role at one end of the spectrum to a wholly expressive position at the other end. The material role in the case study is characterised by actual locations and orientation of people and artefacts and thus includes features such as Spanish clay, a stretch of German motorway, and inventors and technicians Fernando Lucas-Martín and Jesus Alonso Reviejo. These are equated with the structural approach discussed in section two. The expressive role is characterised by communication, not just between, for example, Fernando Lucas-Martín and Jesús Alonso Reviejo, but through the reputation of Pamesa, Fritta and Isofoton, the aesthetic tastes of German planners, and the European Commission demonstration project refereeing process. These features are equated with the connectionist approach outlined in section two.

In addition to material/expressive roles, components are involved in processes which either act to hone and sharpen boundaries and increase internal homogeneity within a specific space – i.e. territorialisation, or, alternatively, act to destabilise such boundaries and instead increase internal heterogeneity, i.e. the process of deterritorialisation. Interviewees taking part in the case study identified alliances, collaboration with competitors, joint marketing and various "social capital" factors, such as trust, in ways that can be described as territorialisation. Examples of deterritorialisation identified by interviewees included Chinese firms expanding into markets presently dominated by Spanish firms, new alliances with Italian rivals and the new market for different PV ceramics (e.g. roof tiles with the PV coating) in the built environment.

A third dimension in which an individual assemblage can be conceptualised is the degree to which the assemblage's identity is consolidated and coded or destabilised and decoded (DeLanda 2006a: 15). This dimension can be used to detail the type of linguistic or coding roles that exist to add meaning to, or enable, an analysis of a particular landscape. In the case study interviews, the synergies of "the new Spain, enjoying economic growth through innovation in traditional industries [while] demonstrating leadership in environmental sustainability [as contrasted with] ... low quality and opportunist Chinese firms" (Interviewee 2, my translation) making the Spanishness of the assemblage a feature on which to base potential research and development decisions in the future, and to ensure that Valencia's CEVISAMA trade fair and the Instituto de Tecnología Cerámica remain central to the assemblage. A more detailed account of the implications of these assemblage relationships for the unfolding of the innovation process are outlined in Haynes (2008).

Finally, the relationship between PV ceramics and other ceramic tile companies and associations should also be very clear: the PV ceramic tile assemblage becomes a component of the ceramic tile sector assemblage when viewed from this immediately higher level assemblage; one populated by a range of components as autonomous and complex as that of PV ceramics such as non-slip glaze, digital printing, etc., which form a heterogeneous but coherent collective termed "the Spanish ceramic tile district" (see

Molina 2005: 82-92). Patterns within the ceramics sector as a whole can be expressed in terms of its structure of economic performance as an aggregate of macro-economic factors, or in terms of the decision making of individual firms or managers. However, the patterns within and between the components can also be described in terms of its multiplicity – and not simply mapped as homogenous atoms, forces or network nodes – thus explaining something about the patterns rather than merely presenting a reductionist description of the features at either the macro, micro, or meso level. It also, of course, simultaneously becomes a part of the PV and solar panel assemblage with its own structures and interdependencies. In this way, as the case study presented illustrates, a network does not explain anything until its assemblage has been detailed or otherwise captured.

Conclusion

This paper has identified some of the features of network theory that need to be addressed in order to provide a more robust theoretical basis to such research. The paper has also introduced the concept of the assemblage, describing in detail the theory and structure of the concept and has detailed the ways in which conceptualising networks in terms of assemblages might address some of the limitations identified with network theory. The paper then exemplified the concept in terms of a detailed case study so as to begin the process of operationalising the concept. This has, of necessity, been a very selective and incomplete account of network theory, the assemblage concept and the case study exemplifying the concept.

Earlier, the paper set out some of the advantages of the assemblage approach such as being ontologically consistent, being neither reifying, essentialist nor reductionist, and affording explanations rather than being merely descriptive. There are, though, more established alternative approaches to research on innovation: complex systems, process theory, diffusion theory, etc. I will briefly contrast the approach set out in this paper with two such examples: those approaches most comparable with the account given in this paper, i.e. social network theory and actor network theory.

Social network theory has developed a number of practical statistical methods for mapping ties to quantify relationships between individuals and across organisations. In addition, social network models generally use familiar units of analysis, such as individuals, friendship ties or organisations, and typically with boundaries that the actors themselves impose; factors which are appealing to researchers concerned primarily with the interaction of individuals in and between organisations as these interactions can be mapped by relatively uncomplicated models. However, the descriptions they provide do not explain, or even illustrate the importance of, specific individual ties, but merely map their occurrence and frequency. Research based on social network theory tends to suggest that the existence of specific ties need only be correlated with specific outcomes to be deemed part of the explanation for the outcome. This need not be the case or else

such ties might be the consequence of these outcomes. For example, powerful individuals within organisations often attract ties *because* they are powerful, rather than being powerful because of these ties. The terminology developed by social network theory and the patterns they describe are useful, but they do not explain, for example, why an innovation fails. The concept of assemblage is able to go beyond these limitations because it explains that the processes generated through interactions, as the source of the emergence of entities on higher scales, can, in this example, kill an innovation or sometimes afford a series of innovations, for example by ensuring that patents do not exclude the stakeholders that the innovation requires. A social networks approach could map the social networks of influential entrepreneurs and thus illustrate that Isofoton's CEO, Ángel Luis Serrano, is a bridging agent, or represents a structural hole within European PV technology research, but it doesn't explain very much about this specific innovation: why it involved Pamesa and Fritta over other similar companies for which equally strong ties exist, why a demonstration of solar power in Germany rather than take up existing partners in Cyprus, which, after all, has more sun.

The second alternative is that of Actor-Network Theory; an approach which remains popular in more theoretical network research, particularly in France and the UK. Actor-Network Theory shares some similarities with the assemblage approach – it emphasises the need to hold heterogeneous elements within a network, and is neither technologically deterministic nor sees technology as entirely passive, although it relies on a different material-semiotic paradigm to that of assemblages. Actor-Network Theory is a method used to describe elements in specific networks, and to ensure that non-human elements are not excluded from being part of the process of agency. It is a descriptive method directed towards creating chains of association, but it does not explain why a specific network emerged and how it impacts on, and relates to, other networks, unlike the concept of the assemblage, which, for example, uses the concepts of territorialisation to explain how some potential network nodes are excluded, while other similar nodes become central nodes. An Actor-Network Theory approach doesn't, in a sense, know when to stop, which in ceramic tile innovation soon multiplies the "actants" to be included in the network, for example, the number of factors and organisations associated with the production of even a single unit soon multiplies. There are at least twelve different stages in which raw materials become transformed into finished and packaged products, and there are planners, transport infrastructure factors, individual firms, support agencies, university departments, machinery manufacturers, designers, chemists, energy suppliers, consumers and many more components which criss-cross the transformation process, becoming active features in the decision making process at some point within the process. Actor-Network theorists are reluctant to prematurely exclude any object or limit the process of description and narrative, ironically often producing narratives that revolve around a single hero of the story. Conversely, an assemblage approach, with a small number of concepts (for example, material/expressive roles; de/territorialisation; de/coding) quickly identifies central components and their relationships (for example, levels of scale; emergence; resource generation).

The concept of the assemblage, then, offers a framework for network approaches, but any insight depends upon how it frames the components within the network and seeks to explain the change that the network enables, and the structure that the networks describe. The network is not a component that explains phenomena itself, and where it is used to do so, for example "the market mechanism" in economics, it merely becomes a reified generality – the network requires explanation from "outside" as provided by implicit and ad hoc theory, or, better, by the use of an explicit and coherent approach, such as provided by the concept of the assemblage. Employing the concepts generated by an assemblage approach enables researchers to ask questions about the network that might otherwise not be considered: what forces drew these components together; which forces maintain the structure and which threaten the network, or indeed offers a better network; which discourses and narratives influence how the assemblage is coordinated and which problems it faces or addresses. These types of questions are indicative of the type of framework and category classifications able to form the basis of surveys or interviews to provide wider descriptions with which to provide evidence to explain ways in which higher and lower scales afford the actual network being researched. It is not an alternative to network analysis. Indeed the more we can say about the network, the easier it is to explain its corresponding, and related, assemblages. Instead it asks researchers to focus on what is present in the network itself (rather than attributing importance based merely on counting ties or artificially naming shapes that ought to be present) and to examine evidence concerning the ways in which modifications in the practices captured by networks have altered individuals, organisations and the interdependencies that share, or once shared a presence in the network. This is important if, as Borgatti and Foster (2003: 991) argue, networks are to play a role in the transition toward a more relational, contextual and systemic understanding of the entities we encounter.

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