Activity-based analysis of socio-technical systems innovations

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Abstract

In this paper, we introduce activity-based analysis (ABA) for explaining and learning about socio-technical system innovation. The analysis is based on a conceptualisation of socio-technical (system) change as result of the resolution of the *contradictions* that develop within and between the activities carried out for the fulfilment of societal functions. We demonstrate the employment of ABA in two transitions of different type and size: the transition towards streaming in recorded music and the transition of the olive oil-producing sector in a region in Western Greece towards a form of circular economy.

Keywords: socio-technical systems, activity theory, transitions, contradictions

1. INTRODUCTION

Socio-technical systems are thought as ensembles of technologies, artefacts, technology development and use/consumption processes, groups of scientists, users, etc. that address specific societal functions. Innovations that change the structure and behaviour of such ensembles are referred to as *system innovations*, or socio-technical system *transitions* (Geels, 2018). In their study, the interest is to learn about the interaction of processes of technology development with social processes of use, and on how changes in these interactions/relations trigger changes at the level of the entire system.

Towards these objectives, various perspectives and models have been proposed. They are based on different system conceptualisations, as far as element granularity and composition are concerned, and include the Multi-Level Perspective (MLP) (Geels, 2005; Geels, 2010), which by adopting a quasi-evolutionary stance aims at explaining change as the result of the interaction of elements/processes at three levels: macro- (landscape), meso- (regime) and micro- (niche); the related to actor-network theory (ANT) (Callon, 1986) "Arenas of Development" (AOD) approach (Jørgensen, 2012), whose analysis is based on the consideration of *actor-worlds* (i.e. networks of humans, technologies, institutions, practices and visions that attain specific meanings through their interconnections and narratives; and a framework based on social practice theory and its suitability to deal with practices of use/consumption of technology and social novelty. In this, change is conceived as taking place from reshufflings in the shape and composition of systems of artefacts, competencies and meanings (Shove *et al*., 2012).

All three approaches have received criticisms for biases along the dimensions of agency-structure and production-consumption. For instance, the MLP has been criticised for being too structuralistic, for leaning towards technological determinism, for overemphasising bottom-up niche-induced change, and for reserving a rather vague, simplistic and passive role for agency in the transition process (Smith *et al*., 2005; Genus and Coles, 2008; Shove and Walker, 2010; Jørgensen, 2012; McMeekin and Southerton, 2012). In the opposite direction, AOD received criticism for overemphasizing agency and its cognitive dimension in an a-historical context, as, in

AOD, the success of technologies and change are contingent to the ability of some key actors (with assumed individual talent and vision) to build networks (actor worlds) (Miettinen, 2006). Finally, the application of social practice theory has been in a somehow asymmetric manner, concentrating mostly on processes of final consumption and use in everyday life, i.e. changes in user/consumer (micro) practices (Geels 2010), thus undermining the social processes in the production of technology (McMeekin and Southerton, 2012), and hence lacking direct reference to entire socio-technical systems. In addition, it was noticed that the flat ontology that underlies relational approaches (social practice and AOD), inevitably, results in poor handling of complexity and limits their overall scope of application (Geels, 2011).

Besides these criticisms, the above models provided consistent explanatory frameworks emphasising different aspect of the change process: the MLP surfaced the role of (technological) niches and slow changing social processes and institutions in the shift of regimes, the AOD put forward the power of the plurality of visions and antagonisms in change, and the social practice theory the role of everyday consumption practices. Accordingly, analytical approaches focused on identifying niches that under pressure from social trends and institutions substitute regimes, on human and non-human actors attracted by technologies to establish networks around them, and on converging trajectories of artefacts, competencies, meanings and carriers/agents of change, for each of the above approaches respectively.

In this paper, we introduce an alternative practice-oriented approach to the analysis of socio-technical change, which aims at addressing the theoretical and methodological issues raised in connection with the above approaches. In our perspective, the relationship between the social and the technical is formed during human objective-oriented activity that takes place for fulfilling a societal function. Socio-technical change is synonymous to change in the activity of the agencies involved, and is the result of attempts to resolve inconsistencies (*contradictions*) and tensions that develop internally by dialectic and conflictual historical processes, usually originating from other connected activities. We employ *activity theory*, which has practice-theoretic base and a systemic construct at its centre. Activity theory maintains that in order to understand a variety of social phenomena, it is necessary to focus on the regimes of

mediated activity at which individuals and organised associations of individuals are involved. Towards this end, it offers a structured construct, the *activity*, for facilitating this endeavour. In an activity perspective, change is manifested as change in the activities/practices of key agents of different size and complexity, who collectively define, at any time, the composition and behaviour of a socio-technical system.

Activity-based analysis (ABA) is based on activity theory and uses the *activity* to represent in a compact, structured form collective practices/activity towards motivational objectives, performed by subjects in mediated context (Engeström, 1987). In activity, the social and the technical are interwoven in a single construct. As an essentially practice theory, it overcomes the agency-structure dichotomy (Nicolini, 2013), while the systemic properties of activity allow ABA to analyse change originating from both the technology production and the consumption elements of socio-technical systems. By considering socio-technical systems as activity systems, ABA aims at understanding and governing change as the result of efforts to resolve internally and/or externally historically developed inconsistencies (*contradictions*) between the *subject*, the *objective*, and the *mediating context* of the activity.

Following, first, we introduce activity theory. Then, we discuss the activity-based conceptualisation of socio-technical systems, highlighting methodological issues of analysis. The presentation of two case studies of activity-base analysis (ABA) to socio-technical system transitions - the transition towards streaming in recorded music and the transition of the olive oil-producing sector in a region in Western Greece towards a form of circular economy - follows. The paper ends by summarising the main points of the paper and drawing conclusions.

2. ACTIVITY THEORY: A SHORT INTRODUCTION

In general, activity theory is a philosophical and interdisciplinary framework for studying various forms of human behaviour and social practices (Bai and Henessey 2012). It considers the activity interaction between individuals, organisations, social groups etc, with their context (culture, norms, rules, values, technologies, artefacts, power structures), as the basic unit of social systems. The analysis of socio-technical change introduced in this paper is based on *Cultural and Historical Activity Theory*

(CHAT) (Engeström, 1990) which an upgrading of the original theory developed by Vygotski and Leont'ev, by introducing a more systemic construct, the *activity system*, which includes the *context* in which activity/practice take place (in this paper, we use the terms "activity" and "activity system" interchangeably with reference to Engeström's 2nd generation "activity system").

The central tenets in CHAT are, first, *mediation*, which means that all practices/activities, at all levels of analysis, are accomplished *through* a range of ideational constructs and material artefacts that originate from a cultural *heritage* of social milieu (the context) (Nicolini 2013), i.e. there is no direct interaction of agency and its historically-developed context/structure; and second, *contradictions* which are the means through which activities change and lead to innovations. The internalised, through participation (in the activity), mediatory signs and symbols, which are associated with external artefacts, influence the norms, ways of acting, techniques used, etc of the individuals and collective agencies associated with the activity. The implication of this is that, in activity theory, ways of thinking and identities are not properties of individuals and organisations, but inherently social and cultural historical phenomena associated with activity, and that human action is necessarily action-in-context. Mediation makes practice a historically-situated social phenomenon.

In the model of Engeström (1987) (Figure 1), depending on the level of analysis, the *subject(s)* can be a person, organisation, or social group, that is/are engaged in the activity with its individual or collective cognitive-knowledge, ideological and intentional attributes, (which may be different for the same physical entity in the different activities involved). For the food/nutrition system activity, for instance, the subject may be the food industry. *Object(ive)* is the problem space to be transformed, or shaped, by the activity (to provide food products and gain profits) into an *outcome* (e.g. for the subject "food industry", food products and money) with the help of tools/instruments.

Tools/instruments are the mediating means (technological artefacts or other "softer" means, such as language and signs) through which the activity is carried out (e.g.

processing equipment, technical language associated with food products and their characteristics). The transformation of the object is possible only through these historically developed means, which also participate in the construction of the identity of the subject. *Rules* are the cultural norms, rules, regulations and restrictions governing the performance of the activity (e.g. quality standards). The *community* denotes those that have interest and are involved in the activity (e.g. consumers, scientists, regulators, banks, etc.), while the *division of labour* signifies who is responsible for what, who does what, and how roles and power hierarchies are organised (e.g. safety assurance organisations test and guarantee the safety of food).

The elements of Engeström's activity model define a *system*, in which each element performs a specific mediating function between the other two. For example, the relation between "community" and "object" is mediated by the "division of labour" that defines who from the community does what for transforming the problem space (objective). The inclusion of the subject, object and context in a single construct implies that, in analysis, ways of thinking and identities are not properties of individuals and organisations, but inherently social and cultural historical phenomena associated with activity, and that human action is necessarily *action-in-context*. It is important to note that, in the socio-technical systems context, the community and the rules of the Engeström's activity model are the carriers of the influences of the social context to the agents (subjects), whereas the tools and the division of labour influence the ways of thinking and acting imposed by technology and technology artefacts.

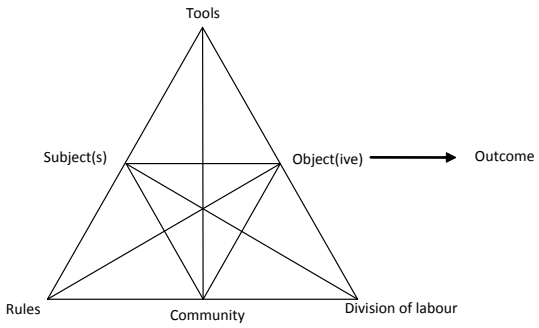

Figure 1. Engestrom's model of the structure of human activity

Activities are long term phenomena with no clear-cut beginning and end. They produce actions and are realised by means of actions, but, as an emergent phenomenon, is not reducible to actions and operations (Engstrom, 2000b). Activity systems enclose a multitude of points of view, histories, interests and practices that result in tensions and conflicts in the construction of the object. In this way, they constitute the origin of the source of energy for the change and expansion of activity systems and their components (Engeström, 1990; Nicolini, 2013). In fact, relationships within activity systems are made orderly, for a specific period of time, only through the association of agents with the object of the activity (Engeström, 1987). The activities' inner structural "inconsistencies", or *contradictions*, are mitigated either by structuring/change practices that produce coordinated activity and hence stability, or by the interaction with other "compensating" activity (systems) in a network (this is why in the third generation of CHAT, Engeström proposes at least two activities as the minimal unit of analysis (Engeström, 2000a)).

Contradictions are historically accumulating structural tensions principally originating from interaction with, and influence from, other activity systems. They are identified as tensions between the elements of the activity, and are responsible for disturbances at the level of activity. As contradictions escalate, some participants of the activity start to question, and deviate from, established practices/norms resulting in a

deliberate change effort that eventually affects the activity. This means that changes are not the result of individuals' actions or visions, but of historically developed contradictions. An *expansive transformation* of the activity takes place when, after contradictions emerge, the object of the activity is reconceptualised to embrace a radically wider horizon of possibilities.

There are four types of contradictions within activity systems. *Primary contradictions* are fundamental and persisting and are manifested at the level of individual elements reflecting the tensions that stem from the difference between use value and exchange value (Bai and Henesey, 2012). For instance, the object of food manufacturers in the food activity is dual: to provide safe and tasty food (use value) *and* to increase revenues (exchange value). *Secondary contradictions* take place between two elements of an activity (e.g. between tools and rules) and are usually exacerbated when trying to remediate a primary contradiction. *Tertiary contradictions* arise between new and old definitions of individual elements, whereas *quaternary contradictions* arise when a change in a connected activity generates contradictions in the relations with its neighbours.

3. SOCIO-TECHNICAL SYSTEMS AS ACTIVITY SYSTEMS

Activity-based analysis of socio-technical change is based on a number of ontological and epistemological assumptions. The main ontological assumption is associated with its underlying practice perspective, i.e. the assumption that the world is made and remade in practice, using tools, discourse and our bodies. Practice theories emphasize the role of interests in human behaviour and hence they take explicitly into account power, conflict and politics in the analysis of social reality (Nicolini, 2013). In this line, activity theory maintains that *these* are the determining factors of change and innovation. For the activity-based conceptualisation of socio-technical systems, this has two consequences: first, as activities are in continuous tension due to diverse interests, regimes as relatively stable states in the evolution of the system are rather ideational constructs introduced for facilitating the analysis (a similar distinction has been indicated by Shove *et al*. (2012)); and second, that a regime as an assumed state of the system is principally determined by the (relatively constant) objectives of the collective activity of the subjects in the system. So, in the context of activity analysis,

it is more appropriate to talk about the development of new practices than transitions to new regimes.

Engeström (2000b) stresses the distinction between *goal-directed actions* and lower-level *motive-driven activities*. Frequently, activity-based analysis requires the unfolding of the higher level activities and consideration of more concrete, lower level ones (motive-driven), which are in a stratified relation with the latter. Zooming-in to lower level activities is required to trace and understand change as a result of contradictions in a specific micro-activity propagated through the network of activities and eventually manifested at higher levels of abstraction (Nicolini 2013).

In ABA, the analytical lens of activity (the "*magic triangle*" of activity (Nicolini, 2013) moves up and down the activity hierarchy and across different activities, as the inquiry process unfolds. From a single high-level activity representing the collective effort of diverse agents involved in the accomplishment of societal function to the limited in space and time activity (actions) of individual agents (and in the opposite direction), and from the isolated activity to the connected activities and their internal hierarchies. In this line, ABA frequently requires the consideration of distinct activity systems for production and consumption (Bai and Lindberg, 1998) (Figure 2). The outcome of the production activity constitutes the instrument through which the consumption activity is carried out. Both activities may further be decomposed at the level of operations-at-large activities/actions, such as, production of technology, supply of raw materials, etc. performed by the corresponding actors. "Lower level" activities (functional specialisation) are usually identified by considering the division of labour node of higher level ones, and, depending on their spatial extent and temporal persistence, they may be associated with divert practices, thus constituting a socio-technical niche.

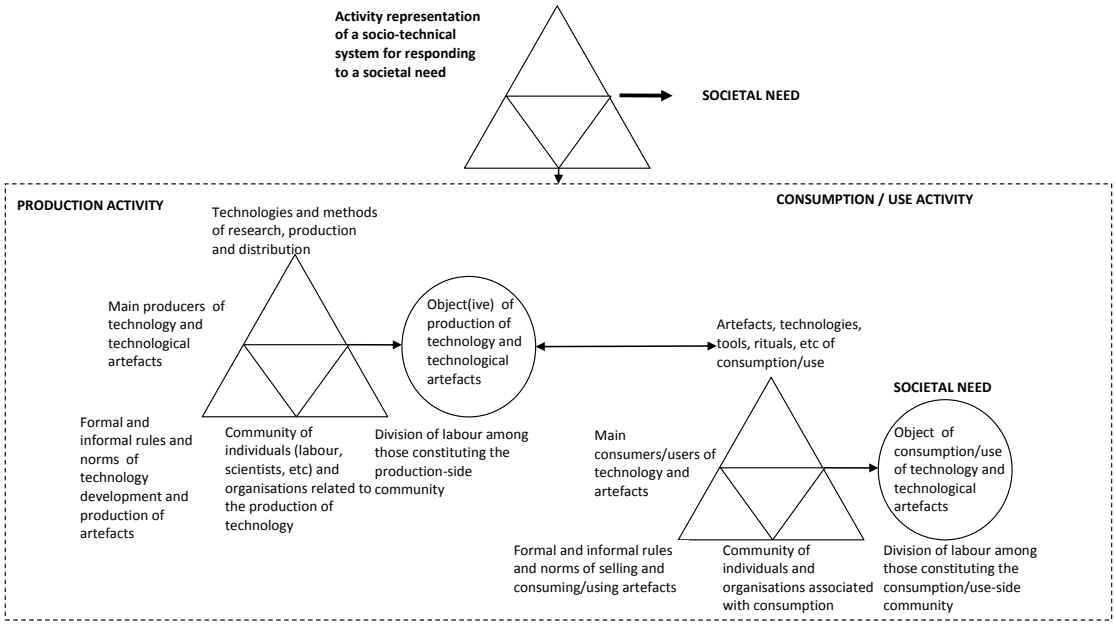

Figure 2. The production and use/consumption sides of activity in socio-technical systems

The "systemness" of the activity construct implies that the principal unit and departing point of analysis should be a single activity corresponding to the entire socio-technical system associated with a societal function: e.g. the activity of higher education, the activity of health care, the activity of nutrition, etc., with their corresponding principal subjects, i.e. higher education organisations, health care organisations, the food industry (Engeström, 2000b). In any case, the objectives of analysis are: i) the historically developed *contradictions* that initiated change in key activities, and ii) the *learning* and/or *adaptation* processes, through which these contradictions were resolved and resulted in the formation of a new activity configuration(s).

The analysis proceeds by questioning whether changes are the result of the multi-voiceness characteristic of the activity (endogenously emergent deviant practices), or have been introduced by other connected activities. If the sources of change are internal, the process continues by considering lower level activities of specific actors. The contradictions developed are identified and the mitigating actions are investigated in relation to the subjects involved. It is important to understand the conflicts and the power distribution among those involved. If the sources of change are external activities, first, it is important to investigate their relation with the main activity, then

to define their elements and find out which of them have been changed, and how these changes influenced the activity corresponding to the entire socio-technical system. The inquiry continues by investigating whether these changes were the result of internal developments or were caused by another activity, and the process continues as above. The whole process has a retroductive inference mode (Papachristos and Adamides, 2016) trying to identify the contradictions and remedial actions that may be responsible for the final/current state (regime).

To identify lower level activities that play significant role in change, consideration of the elements of "community" and "division of labour" of the high-level activities is necessary. A fundamental issue in this process is the definition of the boundary of the network of activities to be considered, i.e. which activities will be considered, and which will be left out. This is a fundamental systems analysis issue for which, no objective answer can exist (Yamagata-Lynch, 2010; Jørgensen, 2012) and the subjective judgment of the researcher plays a very important role. Although a number of methodological approaches have been proposed (e.g. activity settings and three planes of socio-cultural analysis (Yamagata-Lynch, 2010) or Critical Systems Heuristics (Ulrich, 2012)), in many cases it may be more appropriate to exploit case-specific information, such as an industry's value chain (Porter, 1998).

In the following section, taking into account the above discussion, we demonstrate use of ABA in the transition towards streaming in recorded music and the transition of the olive oil-producing sector in a region in Western Greece towards a form of circular economy.

4. THE EVOLUTION OF THE RECORDED MUSIC SOCIO-TECHNICAL SYSTEM TOWARDS STREAMING: AN *ABA* ANALYSIS

In CHAT and ABA, it is important to see the historical development of a socio-technical system for understanding the dynamics of the elements in the activities. The development of the (principally popular) music industry and the related socio-technical system can be traced back in the time of the discovery of recording. Since then, the evolution of the state of the industry has been the result of the interplay

between music content as a reflection of the direct and indirect social context, and the recording medium and sound reproduction technology. Influencing roles in the direction of evolution have been played by related sectors, such as radio and TV broadcasting, visual technologies (VCR and DVD), the live performances industry, the film industry, music instruments technologies, and, of course, lately, computer technology (Roy and Dowd, 2010; Geels, 2007; Harvey, 2016).

Music, as a form of indirect entertainment (not live performance), was initially associated with the radio broadcasting of bands playing live in the studio. At that time (1920's), the major record companies were closely associated with radio stations (Millard, 1995; Geels, 2007) forming until the beginning of WWII, stable oligarchies. As new technologies were developed, there was demand for recordings of longer time length, resulting in the introduction of the LP format in 1948 by Columbia against the shorter single (one song in each side) supported by RCA. After WWII, major record companies followed a fordist model of production (vertical integration), in which both formats had a place.

A major turning point in the evolution of the industry was the direct association of songs with recordings, moving away from the "faceless" content to concrete recording-performer relations (Harvey, 2016). This led to a shift from viewing recorded (popular) music as pure entertainment to seeing at as art. Later, to this shift contributed the artistic aesthetic of the album covers, and packaging in general. For many people, LPs became pieces of art to own, and the LP format started to win singles with the support of FM radio stations that favoured LPs. In parallel, the commercialization of the invention of magnetic tape resulted in the establishment of new small companies as recording became easier and cheaper, disintegrating the industry's model, at least as far as upstream activities concerned. Nevertheless, the distribution of industry's products remained in the hands of the major companies (Tennet, 2013), despite the fact that new music movements (e.g. punk) favored independent companies.

Until the 1990's, music had a strong social influence through the youth's ownership of music products that acted as part of their identity (Bourdieu, 1984; Leblanc, 1999; Hodkinson, 2002; Roy and Dowd, 2010). The spread of the cassette and personal

stereos (Sony's Walkman) introduced music in the everyday activities of people, making listening a personal experience (soundtrack of everyone's life). At the same time, the introduction of the CD made music more portable, while at the same time kept music's socio-technical artistic connotations.

The major shift in music industry came from the spread of the internet and the unlimited possibilities of copying/downloading music that it had. In addition, the internet strengthened the relationship between music and visual technologies. The support of music downloading by major electronic distribution shops, such as Amazon, and the possibilities of playing music of reasonable quality in a computer equipped with cheap extra hardware made music downloading a popular choice for those that did not want to own a tangible artistic product such as a CD. Of course, downloading made possible for listeners to choose their own repertoire at the single (music) piece level, transferring the focus of the industry towards songs (instead of complete works/albums).

In the last years, the industry had undergone another transformation, again with the support of digital technologies, the widespread of streaming. It has been argued that streaming became popular because it lifts the burden of ownership (financial, performance and social-based risks (Luck, 2016)) that lead people to prefer access over possession (Watkins *et al*., 2016). Streaming also contributed to the emergence of the playlist as the dominant listening format (Luck, 2016) and to the introduction of new players in the industry (content providers, such as Spotify) (Dolata, 2009) that have gone from zero revenues in 2008 to 1.1 billion in 2013.

The streaming model corresponds to the current mentality of the youth, which is the major consumer of (popular) music. Their approach to music is "playful, short-term, social, very visual and mobile" (Huber, 2013). Nevertheless, the industry currently supports three models of music distribution: physical distribution with a remarkable return of the vinyl LP, digital downloads supported by on-line stores and hi-fi equipment manufacturers, and streaming which exhibits the most remarkable dynamics of the former two, which, however, are preferred by more serious listeners (classic and jazz music aficionados).

Figure 3 presents the production and consumption activities of the recorded music system. Moving our analytical lens ("magic triangle") on the consumption activity, we can identify a new objective produced by everyday life activities and technological developments (e.g. listening to music while doing other things, such as commuting to work, downloading music from the internet, throwing away the burden of owneship). This has introduced a secondary contradiction between the "objective" of the activity and the instruments/tools element, which was propagated to the "outcome" and "objective" elements of the production activity, as well as a secondary contradiction between the "objective" and the "tools" (distribution media) of the same activity (production). These contradictions were remediated though the expansion/change of the objective (provide access to music) and the adoption of digital distribution.

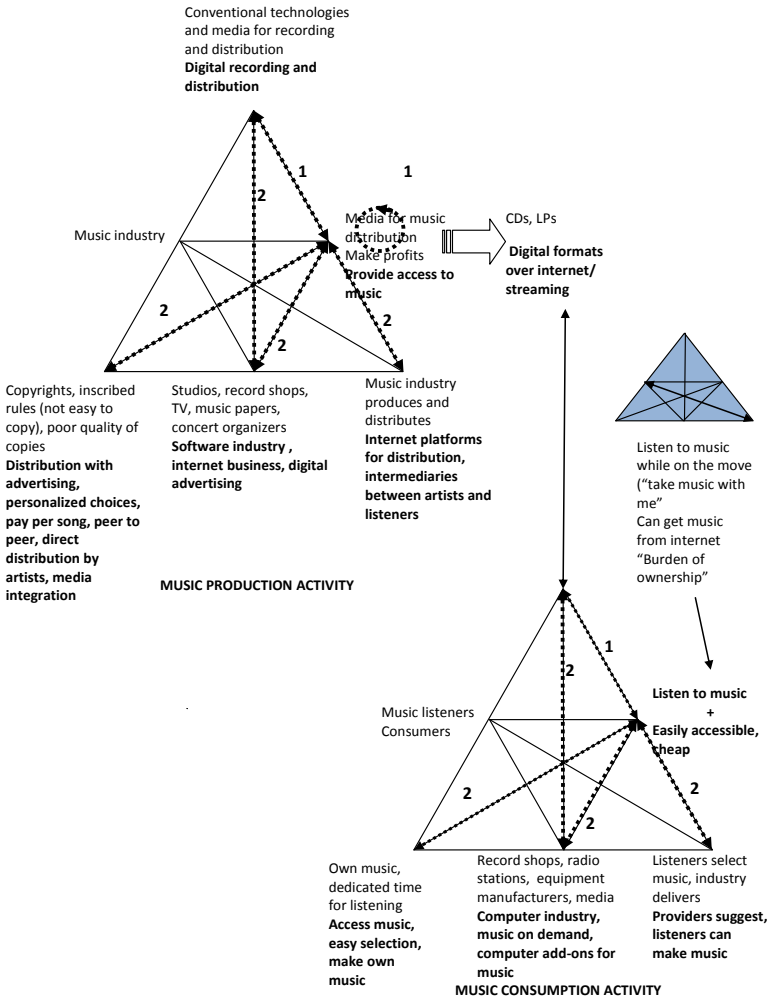

Figure 3. Activity-based representation of change towards streaming in the system of recorded music

The resolution of the first wave of contradictions in the production activity introduced a second wave of contradictions between the new "tools" and the "community" element remediated through the introduction of new players, such as the software and digital advertisement industries, and between the "objective", on the one hand, and the "rules", "community" and "division of labour" elements, on the other, which were remediating by modifying them accordingly, as indicatively shown in Figure 1 in bold.

Moving our analysis back in the consumption activity, the widespread diffusion of the digital distribution format, while remediated the first wave of contradictions (indicated by 1 in the figure), it introduced a second wave in the context of the activity (indicated by 2 in the corresponding links), that were remediated by introducing new items, as it is, again, shown in Figure 3. In addition, the enablement of new rules by technology in the consumption activity (as well as, in the production one), made possible the direct distribution of music from the artists, triggering a tertiary contradiction whose resolution may need further legislation and/or different strategies from the part of the established music industry. Clearly, the direct distribution from artists changes the division of labour (power relationships) and may lead to further changes in the system.

5. THE TRANSITION OF A REGION IN WESTERN GREECE TOWARDS SUSTAINABILITY: AN *ABA* ANALYSIS

The Prefecture of Achaia with an area of 3,271 Km2 and population of about 310,000 inhabitants is the largest prefecture in Western Greece with the third largest city of Greece (Patras). The economy of the region is based on services (70% of GDP) with tourism as a fast growing sector. Manufacturing and agriculture amount to about 20% and 10% of GDP, respectively. Due to the mountainous morphology of the area, agricultural activities are mainly tree-growing. There are almost 3.5 million of olive trees in the area producing around 21,000 tns of olive oil every year in 59 olive pressing facilities, most of them acting as independent firms (SMEs). Most of them have a local character, as far as supply of olives is concerned. All the 59 facilities produce 129,675,000 lt of waste (Olive Mill Waste Water, OMWW) every year. This

waste is processed either using government approved methods (having a small environmental impact), or it is disposed uncontrollably to nearby rivers, vastly contributing to the environmental degradation of the area. Clearly, this has a very negative impact, as far as tourism is concerned. In the area, there are about 130 registered accommodation-providing business, most of them in the countryside, with almost 8000 beds. There are also thousands of passing tourists, as Patras is the major entry point to Greece from Europe.

Pressures from businesses and local inhabitants led to the consideration of alternative methods for processing OMWW with even lower environmental impact and lower cost, or even production of some profit. Technical and economic feasibility studies led to the proposal for establishing an OMWW processing unit for the production of biopolymers (PHAs), which is a form of plastics, and bioenergy (H2). This would form an industrial symbiosis (IS) system (Chertow, 2000) between olive-tree growers, processors of olives (mills), OMWW processors and plastics manufacturers, minimizing environmental impacts and stimulating economic activity. At the receiving end of the PHAs-based symbiotic scheme, there are three major plastics producers in the area, the largest requiring 4.4 tns of plastic as input each year (data for 2014).

Focusing on the economics of the PHAs-based IS in Achaia, all parties to be involved are located at a distance of 60 Km at most from each other. Clearly, symbiosis is economically feasible if the net benefit of each participant in the symbiosis is greater than its net benefit when not participating in it. Economic analysis of different IS implementation scenarios, as far as the capacity of the PHAs production unit is concerned, has indicated that a unit of production capacity of 14,400 m3/season serving ten olive processing facilities and producing 5,930 Kg PHAs per year and 16,776 m3 of H2 per year is economically the best choice (Mouzakitis *et al*, 2017). In the economic analysis investments in production equipment and transportation vehicles, as well as operational costs were considered. The economic analysis has also indicated that, for the olive mills, the cost of waste processing by PHAs production (paying for its collection) is marginally lower than the treatment by other means. Nevertheless, if one considers that the olive processors become free of any responsibility for their waste, the benefit becomes larger.

As far as the plastics production is concerned, the production of plastics from PHAs is more expensive compared to conventional plastics. However, premium pricing to account for the environmental characteristics in products for niche markets (e.g. medical prosthetics) may compensate the additional cost. In addition, such products in the product portfolio of the firm augment its environmental image.

Regarding the social context of the symbiosis under consideration and the related mechanisms of embeddedness (Baas and Boons, 2004), the dominant attitude of the inhabitants of the area towards environmental protection stems from an instrumental logic of "cleanness", not to inhibit tourism activities. This frequently leads to a NIBY behaviour and competition between local communities. Sometimes this attitude is present in the behaviour of olive processors concerning their waste

Figure 4 below shows an activity representation of the above discussion of the situation before any intervention towards change to a more sustainable production of olive oil. The economic activity in the region can be decomposed into the activities of olive oil production and tourism (among other activities that are not considered explicitly). There is quaternary contradiction between the two activities stemming from the poor processing or disposition of waste in the environment and its impact on the "tools" of tourism. The remediation of this contradiction through increased regulation introduces a secondary contradiction between the "objective" of the olive oil production activity and its "rules" element. In actual fact, this contradiction is the emergent result of a "participating", lower-level activity "waste management" (Figure 5), in which the contradiction between "regulation" and "objective" was resolved through the expansive transformation of the "objective" (bold letters in Figure 5). The resolution of this contradiction led to a secondary contradiction between the "objective" and the methods/technologies used for the management of waste ("tools"). The remediation of this contradiction through the adoption of PHAs production technology resulted in a third wave of secondary contradictions between the new "tools" and the "community" (resolved through the introduction of new players, such as carriers of OMWW, plastics producers, etc.), and between the "objective" and the "division of labour" (resolved by introducing and providing roles and power to the

new players, such as plastics manufacturers). In Figures 4 and 5, bold letters indicate the new state of activity elements after the resolution of contradictions.

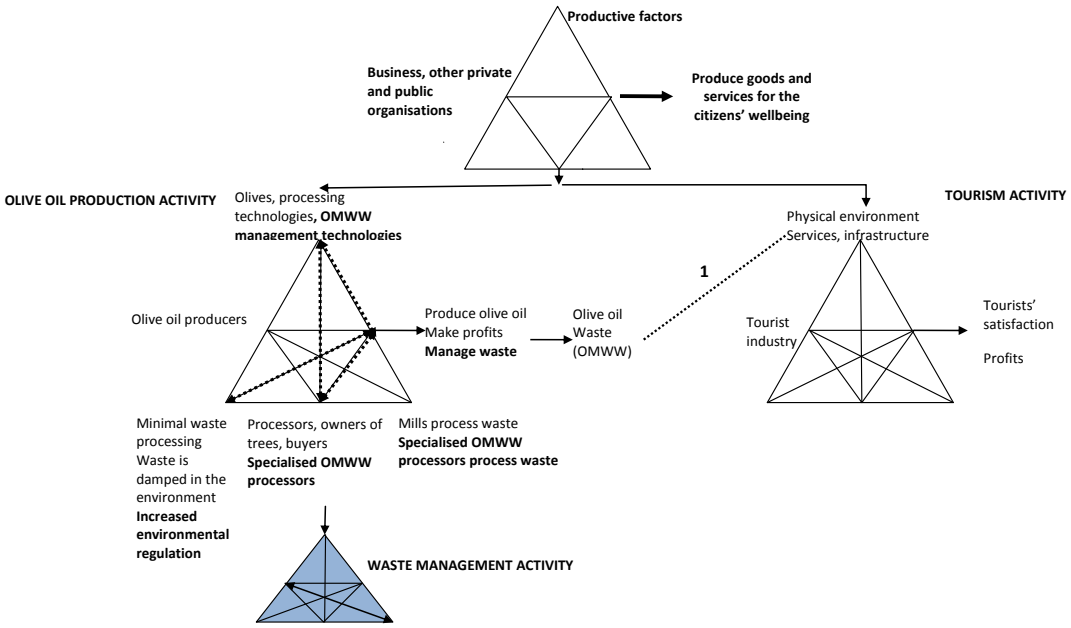

Figure 4. *Activity-based representation of change in a part of the economic system of a region in Western Greece*

Regarding the practicalities of the symbiosis, environmental regulation frameworks exist for all participants in the IS. The symbiosis facilitates cost-effective compliance, especially for the olive mills, which are embedded in the social processes of the communities of olive tree growers (the majority of units are located in small villages or in the outskirts of small towns). The plastics production factories are also located in the outskirts of small towns and of the city of Patras, principally within established industrial zones. This also seems an appropriate place for the construction of the PHAs production unit. Although industrial zones are situated near towns and cities, and despite having a labour force from urban environments, they are closely linked to agrarian life due to the historical links that their management and personnel have with villages: urbanization in the area is a relatively recent phenomenon. This is particularly important for the specific context, as, in general, in the institutional environment of Greece, personal relationships make business relationships (Psychogios and Szamosi, 2007).

The symbiosis is very venerable to the individualistic rational profit maximizing behaviours if trust is not built among the participants, or integration of activities along

the supply chain takes place. A step towards the sustainability of the IS would be to exert pressure towards making compulsory the treatment of waste for the substitution of conventional raw materials for plastics. Alternatively, the cooperative ownership and operation of the PHAs unit by the olive processors may guarantee its sustainability, at least, as far as the supply side is concerned.

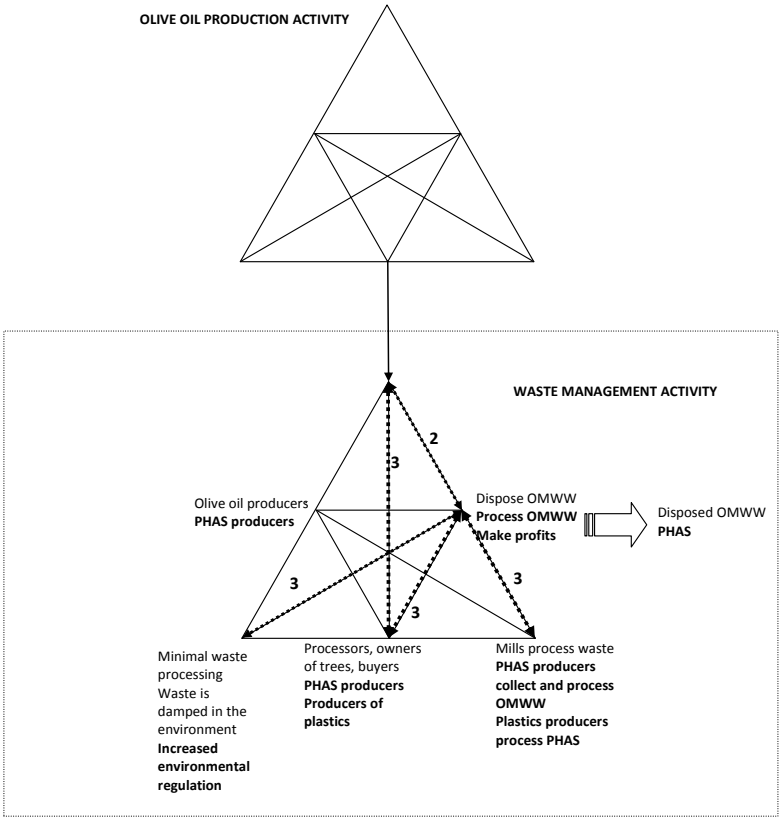

Figure 5. Activity-based representation of change in the waste management system (activity) of olive oil production

6. SUMMARY AND CONCLUSIONS

In this paper, we introduced activity theory in the analysis of the causes and the initiation of socio-technical system change. Activity theory, having a structured systemic construct at its centre, prompts to thinking about socio-technical change in operational terms, i.e. change in the context-situated human activities/practices, which constitute a socio-technical system. In addition, in the activity perspective, large-scale socio-technical changes/innovations do not come out of ideological vacuum, neither are products of vague a-historical processes triggered by individuals' actions or

visions. They are responses to historically developed contradictions that trigger the processes of change in the practices and context of the agencies involved.

The importance and distinct features of activity theory, and its corresponding activity-based analysis (ABA), lie in the concepts of *mediation* and *contradiction*. Mediation is the manifestation of an inclusive relation between agency acting towards an objective and the artefacts and the social context that surrounds this agency in action. This means that activity cannot be considered independent of the technology and artefacts associated with, neither from the social context (the stakeholders with their power relations and division of labour) in which it takes place. Hence, structure and agency are interlinked into a single inseparable construct (activity).

In addition to offering a holistic and symmetrical perspective to think and know about socio-technical systems, the employment of ABA to socio-technical change is associated with a structured inquiry process. The inquiry is based on a compact operational unit of analysis (the activity (triangle)) with internal and external causality relations (mediation) and does not rely on just correlated parameters and metrics. Through the identification of contradictions, the structure of activity and its relations with other activities, leads to the tracing of the real causes of change, the way the change actions are undertaken, and the effects they produce. This logic can operate in the reverse direction, when change is planned and needs to be managed. Artefacts, or more generally contextual mediating elements, can be used strategically to bring about change in a manageable way.

In the paper, we attempted to forefront the above issues. In addition, for demonstrating Activity Based Analysis to socio-technical change we have considered two cases of different type and size: the transition towards streaming in recorded music and the transition of the oil-producing sector in the region o Achaia in Western Greece towards a form of circular economy. The two cases demonstrate the activity-based representation of socio-technical systems, and the structure and explanation potential of the analysis process, as far as change and management of change are concerned. Through the presentation of the specific case, our objective was not to provide a data-rich extensive presentation of the particular system innovation, but to highlight methodological issues, i.e. how to think about system innovation by using

the properties of the activity construct to understand the events that cause change in institutionalised practices. The cases show how the analysis is guided by the structure and connectivity of activity systems, and how an explanatory narrative of socio-technical change is constructed by moving along the hierarchy of activity and across connected activities.

REFERENCES

Bai G, Lindberg LÅ. 1998. Dialectical approach to systems development. *Systems Research and Behavioral Science* **15**: 47-54.

Bai G, Henesey L. 2012. Coping with system sustainability: A sociocybernetics model for social-economic system architecture. *Systems Research and Behavioral Science* **29**: 263-273.

Baas LW, Boons FA. 2004. An industrial ecology project in practice: Exploring the boundaries of decision-making levels in regional industrial systems. *Journal of Cleaner Production* **12**: 1073-1085.

Bourdieu P. 1984. *Distinction: A social critique of the judgment of taste*. Harvard University Press: Cambridge, MA.

Callon M. 1986. The sociology of an actor-network: The case of the electric vehicle. In *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World*, Callon M, Law J, Rip A. (eds). Macmillan Press: Houndmills; 19-34.

Chertow MR. 2000. Industrial symbiosis: Literature and taxonomy. Annual Review of Energy and the Environment **25**: 313-337.

Dolata U. 2009. Technological innovations and sectoral change. Transformative capacity, adaptability, patterns of change: An analytical framework. *Research Policy* **38**: 1066-1076.

Engeström Y. 1987. *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research.* Orienta-Konsultit: Helsinki.

Engeström Y. 1990. *Learning, Working, Imagining: Twelve Studies in Activity Theory*. Orienta-Konsultit: Helsinki.

Engeström Y. 2000a. Activity theory as a framework for analysing and redesigning work. *Ergonomics* **43**: 960-974.

Engeström Y. 2000b. Comment on Blackler et al. Activity theory and social construction of knowledge: A story of four umpires. *Organization* **7**: 301-310.

Geels FW. 2005. *Technological Transitions and System Innovations: A Co-Evolutionary and Socio-Technical Analysis*. Edward Elgar: Cheltenham.

Geels FW. 2007. Analysing the breakthrough of rock n' roll (1930-1970).Multi-regime interaction and reconfiguration in the multi-level perspective. *Technological Forecasting and Social Change* **74**: 1411-1431.

Geels FW. 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level Perspective. *Research Policy* **39**: 495-510.

Geels FW. 2018. Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. *Energy Research & Social Science* **37**: 224-231.

Genus A, Coles A.M. 2008. Rethinking the multi-level perspective of technological transitions. *Research Policy* **37**: 1436-1455.

Harvey M. 2016. The rise of the LP: Politics of diffusion innovation in the recording industry. *Business History* **58**: 1095-1117.

Hodkinson P. 2002. *Goth, Identity, Style and Subculture*. Berg: Oxford.

Huber M. 2013. Music reception in the digital age – empirical research on new patterns of musical behaviour. *International Journal of Music Business Research* **2**: 6-34.

Jørgensen U. 2012. Mapping and navigating Transitions—The Multi-level perspective compared with arenas of development. *Research Policy* **41**: 996-1010.

Leblanc L. 1999. *Pretty in Punk: Girls' Gender Resistance in a Boys' Subculture*. Rutgers University Press: New Brunswick, NJ.

Luck G. 2016. The psychology of streaming: exploring music listeners' motivations to favour access over ownership. *International Journal of Music Business Research* **5**: 46-61.

McMeekin A, Southerton D. 2012. Sustainability transitions and final consumption: Practices and socio-technical systems. *Technology Analysis & Strategic Management* **24**: 345-361.

Miettinen R. 2006. The sources of novelty: A cultural and systemic view of distributed creativity. *Creativity and Innovation Management* **15**: 173-181.

Millard A. 1995. *America on Record: A History of Recorded Sound*. Cambridge University Press: Cambridge.

Mouzakitis Y, Aminalragia-Giamini R, Adamides ED. 2007. From the treatment of olive mills wastewater to its valorisation: Towards a bio-economic Industrial Symbiosis. *International Conference on Sustainable Design and Manufacturing*, Springer: Cham, pp. 267-276.

Nicolini D. 2013. *Practice Theory, Work and Organization: An Introduction*. Oxford University Press: Oxford.

Papachristos G, Adamides E. 2016. A retroductive systems-based methodology for socio-technical transitions research. *Technological Forecasting and Social Change* **108**: 1-14.

Porter ME. 1998. *Competitive Advantage: Creating and Sustaining Superior Performance*. The Free Press: New York.

Psychogios AG, Szamosi LT. 2007. Exploring the Greek national business system, *EuroMed Journal of Business* **2**: 7-22.

Roy WG, Dowd TJ. 2010. What is sociological about music? *Annual Review of Sociology* **36**:183-203

Shove E, Pantzar M, Watson M. 2012. *The Dynamics of Social Practice: Every Day Life and How it Changes.* Sage: London.

Shove E, Walker G. 2010. Governing transitions in the sustainability of everyday life. *Research Policy* **39**:471-476.

Smith A, Stirling A, Berkhout F. 2005. The governance of sustainable socio-technical transitions. *Research Policy* **34**:1491–1510.

Tennett KD. 2013. A distribution revolution: Changes in music distribution in the UK 1950-76. *Business History* **55**: 327-347.

Ulrich W. 2012. Operational research and critical systems thinking - An integrated perspective. Part 2: OR as argumentative practice. *Journal of the Operational Research Society* **63**: 1307-1322.

Watkins RD, Denegri-Knott J, Molesworth M. 2016. The relationship between ownership and possession: observations from the context of digital virtual goods. *Journal of Marketing Management* **32**: 44-70.

Yamagata-Lynch LC. 2010. *Activity Systems Analysis Methods: Understanding Complex Learning Environments.* Springer: New York.