The Collective Construction of Technology; Re-Narrating the Bicycle Development in ANT Atmosphere

Rahman Sharifzadeh

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ABSTRACT

One way to compare different theoretical approaches to the study of technologies is to see what the difference is between their narratives of the construction of a particular technology. In this paper, we re-narrate the bicycle construction from the perspective of actor-network theory (ANT), comparing to SCOT's first account of the construction. Although SCOT has moved closer to actor-network theory later by paying more attention to co-construction and materliaty, Pinch and Biker have not modified their account of the bicycle development according to these theoretical changes, despite the fact that one decade later Bijker allocated one chapter, 'king of the road', to Safety bicycle development again. An ANT's narrative of bicycle development can provide a basis for a concrete comparison between ANT and the classic version of SCOT. Or it could be argued that this narrative could complement the story of Pinch and Biker of bicycle development. While we present a new narrative of bicycle development in comparison with SCOT's one, we offer a methodological framework in the ANT literature that can be considered as a methodological procedure to the study of artefacts in general; this framework has three elements: 1. Phenomenal Bracketing, 2. Collective construction, and 3. Co-construction.

1. Introduction

The sociologists of science and technology have been trying to give a more realistic picture (than deterministic approaches) of the innovation of artefacts and scientific facts through a series of empirical studies. The empirical studies[1] generally in a constructivist approach, have shown that truth and efficiency (as well as falsehood and inefficiency) cannot cause success (or failure) during the process of construction. Efficiency and inefficiency are constructed; they are not inherent characteristics of an artefact.

One can distinguish between two constructivist approaches in empirical studies of technology: the Social Construction of Technology (SCOT) and actor-network theory (ANT). The two approaches, although both oppose determinism, have significant differences. The first approach was developed by Pinch and Bijker according to the main theme of the Empirical Program of Relativism (EPOR), one of the leading approaches in sociology of scientific knowledge (SSK). SCOT explains the shape and success/failure of artefacts based on the struggles among the relevant social groups and closure or stabilization mechanisms. Through a methodology consisting of interpretive/design flexibility, closure mechanisms, and linking the mechanisms to the wider socio-political environment, Pinch and Bijker (1984) explain how social context (relevant social groups and their divergent interests/values) shaped the bicycle in a particular form and lead to the success and establishment of the Safety bicycle.

In ANT, first, constructive factors are not confined to so-called social groups but include non-human actors too. Alongside the so-called social factors, natural and technical actors play non-negligible roles in shaping artefacts. The 'social' is replaced by 'collective' in ANT to cover heterogeneous human and nonhuman agents. Second ANT studies artefacts as actor-networks not as materials being under pressures of social forces; the very dichotomy of content-context is redefined.

2. ANT

ANT as a methodological framework, one can argue, revolves around three concepts: 1. Phenomenological Bracketing (Suspension); 2. Collective Construction; and 3. Co-construction. First, we should study artefacts like an anthropologist, not like a philosopher or sociologist, in its classic definition. The anthropological strangeness (Latour and Woolgar 1986) is the phenomenological aspect of ANT. We suspend rigid theories in the study of technology. We also will not go into the study of technology by a pre-made model. Because these models will usually sacrifice part of the data (Latour 2005, 142) for the purpose of simplification.[2]

Second, in the study of technology, we should not limit ourselves to the study of certain actors (such as social groups). Any actor that influences the development and shaping of an artefact must be welcomed, whether human or non-human[3] (Latour 1993b, 9). The study also includes those who are opposed to a program of action for making an artefact (i.e. anti-programs of action such as anti-cyclists).

Third, society is not the context of technological development but at the same time is redefined by it. Social groups change profoundly through technology. Since an artefact is an actor-network, one cannot study the agency of network on the actor without studying the agency of actor on the network. These two studies are in fact one single study because the essence of an actor is its network and vice versa. So while an artefact is constructed, the society is constructed as well. For example, as the Kodak camera was changed/developed, social groups changed; new groups emerged and new social interests were brought about. Eastman introduced a new social group by introducing the concept of 'amateur photographer' because photography was a professional work at the time; the idea that anyone could shoot was not a 'social interest' before the camera to influence the determination and the success of the camera. Rather, it was 'made' at the same time as the camera was made (Latour 1987), and one of the actors involved in this social group-making was the developing camera itself.

Based on these three components, we re-narrate the story of bicycle construction from ANT's point of view. We have chosen bicycle development to make a room for comparison between SCOT's narration and the one we offer here. It should be noted that SCOT welcomed more materiality later: 'social theorists need to attend better to materiality: the world of things and objects of which technical things form an important class' (Pinch 2008, 461), and has attended more to co-construction, as is clear from the title of the book Bijker (and Law) edited: 'Shaping Technology/Building Society: Studies in Sociotechnical Change' (1992). However, their first account of bicycle construction (1984) was not modified despite the fact that one decade later Bijker (1995) allocated one chapter, 'king of the road' to Safety bicycle development.

2.1 Phenomenological Bracketing

It is a wonder that Pinch and Bijker who claim to explain the shaping of the bicycle (Pinch and Bijker 1984, 414) ignore the first phase of its development. They have overlooked important parts of the story of bicycle construction (including Drais's, Johnson's and Gompertz's bicycles) and focused much of their discussion on 1860s onwards. The first reason could be that they believe that the bicycle has some intrinsic characteristics; so they did not put those machines into the category of the bicycle at all. Some believe that there is a fundamental difference between those bicycles (commonly referred to as Draisine/velocipede) and the later phases (from the 60s onwards) and there is only a 'family resemblance' between the first phase and the other phases (Smethurst Paul 2015, 22–23). This reason seems incompatible with the constructivist approach of Pinch and Bijker, and the challenges that exist against essentialism also can be cited against such a position. As we will see, without studying the bicycles of the first phase, it is difficult, or even impossible, to explain the shape and design of later bikes.

The second reason, which is more likely, is that they have failed to apply their methodology to the data of this phase. Although they insist 'that our model is not used as a mold into which the empirical data have to be forced' (1984, 419), they have not explained why their model failed to cover those earlier machines. The answer is that they may not have been able to explain the shape of Draisine based on the interests and values of social groups of the time.

Bijker incorporated this prehistoric phase into the picture later (1997). However what he actually did is merely to offer a summary of some historiographies on bicycle development. He does not discuss how their model can explain these early technologies or how these technologies can influence later technologies. So his discussion does not help the reader to understand how SCOT can capture the prehistoric stages of Safety bicycle.

2.2 Collective Construction

One of the problems that existed long before the design of the bicycle was how to build a machine that works only with human power. According to the human and non-human factors in different times and places, this general problem takes different translations. For example, a century before the design of the first bicycle, the problem was translated in Japan into ‘how to make a human-powered machine that helps us to cultivate rice easier and faster’. One of the most successful designs was Riku-Hon-Sesya; a boat-shaped machine with three wheels (Tony and Lessing 2014, 6). In fact, it was a combination of boat and tricycle. A set of human and nonhuman factors are involved in explaining the shape and design or what called the technical content of this machine including Japanese farmers’ interests in fast and easy rice cultivation, boats, the watery environment of rice fields, and tricycles. Deleting any of these would make the Riku-Hon-Sesya design incomprehensible. For example, if rice planting did not require a watery environment, the interest in fast and convenient rice cultivation does not lead to a boat-like machine, and vice versa.

In the construction of the bicycle, another answer to the question of a human-powered machine, many human and nonhuman actors have also been involved. When you read the story of bicycle development from a variety of historical sources you will come across a variety of actors that have all played a role in the shaping and success or failure of bicycles, including workers, women, the middle class, wages and expenses, newspapers, cartoonists, laws, roads, hills, volcano, oats and harvest, horses, skating and horse-riding skills, the community of physicians and surgeons, animal welfare society, religious, ethical, and aesthetic values, metal industry, sewing machines, chain drive industry, pneumatic tires, human body structure, tricycles, blacksmiths, Victorian and colonial society, and the garment industry. In ANT framework, one cannot reduce the agency of these diverse actors to narrow social groups,[4] and still want to explain the shape or design of artefacts.

In the Draisine design, two wheels of equal size are aligned in a line. How did this design come about? How can one explain the particular shape of the Draisine only referring to social groups? According to many historians, Draisine was an attempt to replace horses. In fact, the issue of a human-powered machine was translated here into ‘how to make a horse-like machine that does not require oats?’ In 1815 the Tambura volcano erupted and large amounts of ash entered the atmosphere of Asia and Europe. That huge amount of ash in the atmosphere prevented light from reaching Earth and consequently, the weather gradually cooled in some areas. The following year, known as the year without summer, Europe suffered from severe harvest failure and as a result, many livestock, including large numbers of horses, were killed and the price of oats and horses went up dramatically. This environmental-economic-social issue made people like Carl Drais thinking of a machine like a horse. As the early bicycles were called ‘hobby-horse’ or ‘dandy-horse’ (Lessing 2001), the bicycle structure is a simulation of the structure of the horse body. Like a horse rider, the cyclist put down his feet on both sides of Draisine and propelled it by pushing off the ground with his feet while steering (reining) it. Therefore, one can argue that some features of horse body structure are embedded in the Draisine (and bicycle in general) which should not be ignored in understanding the technical content of the machine. Besides, a bicycle is somewhat anthropomorphic; that is human body structure (that we usually have two hands and two legs, and our spine has certain characteristics) affected the shape of the bicycle.

The important question here is why did the Draisine-builders think people would trust a machine with two wheels in a line? Keeping the machine balanced requires a particular skill. This skill already existed, not in cycling but in skating. Drais had taken into account the skating skills of men and women (Herlihy 2004). But skating was fun for young men and women. Therefore, social groups that lacked such skill could not trust Draisine.

However, without the socio-economic need to replace horses with bicycles, all these factors did not lead to the formation of Draisine. So there is a wide variety of factors ranging from horses, skates, human body, carriages, social groups' interests to replace horses with an inanimate entity to other human and non-human actors, that leave their mark on the shape or the content of Draisine. In other words, some features of those actors are embedded in the machine. Draisine was at least at the intersection of sociology, economy, anatomy, physiology, and agriculture.

Why Draisine was a failure? Whatever the answer is, it is not that it was not efficient. Efficiency is a socio-technical construct. Many heterogeneous factors contribute to the success or failure of artefacts. The first enemies of Draisine were hills. The machine was heavy because it was mainly made of bulky woods. And since the Draisine was driven by feet-pushing, cyclists could not ride uphill and sometimes they had to piggyback it. This techno-environmental feature meant that it was only welcomed by a specific group of strong young men. We also noted that the lack of skating skills in some social groups was an obstacle to their interest in Draisine. However, these factors are only part of the story of the Draisine failure.

Johnson's Bicycle, the English version of Draisine, somewhat alleviated the weight problem of Draisine (Herlihy 2004). The machine was lighter and more compact and had a more 'elegant appearance' than Draisine; some parts of the machine including the bike's fork were made of iron (Nick 2016). Johnson's Bicycle was a response to social groups' needs to have a lighter and more steerable machine. However, this social interest is not enough to explain the shape of the bicycle. Without considering the metal industry and blacksmiths' skills, the social construction of the artefact remains always an under-construction. Johnson's Bicycle construction was at least at the intersection of sociology and metallurgy.

Adding a saw-toothed pinion on the front hub and a hand crank on the front wheel, Lewis Gompertz increased the speed of his velocipede compared to Drais' and Johnson's bicycles. Pulling the crank toward the body, the rider empowered the front wheel and the speed was increased. However, the problem was that the crank prevented the front wheel from spinning backward (Herlihy 2004). Besides, steering and cranking at the same time probably was not so convenient (Ritchie 1975, 122). Gompertz's machine never led to mass production.

How did social groups' interests in riding more speedy bicycles construct the special design of Gompertz's machine? Here again, there is an under-construction. This social interest, logically, can be embedded in various forms. Why Gompertz's design? Sociology is just part of the construction. We should seek another intersection. The crank mechanism of the machine 'was common on winches and other machinery, such as the winding mechanism of a watch' (Tony and Lessing 2014, 222). So one can argue that the Gompertz's design was an encounter between the social groups' need for a more speedy Draisine and the unidirectional clutch of winches; an intersection between sociology and mechanics.

Draisine (and Johnson's and Gompertz's machines) were not suitable for out-of-town roads and long distances due to their low speed. In fact, they were used for recreation rather than transportation. Roads outside the cities were not appropriate for these bicycles as well. As a result, they were more restricted to the streets of cities. But the streets were full of high-speed bulky carriages; so the streets were not safe for a half-pedestrian-half-cyclist (as the rider propelled the machine pushing off his feet on the ground). As a result, many Draisine-riders used sidewalks. But this time the machine was dangerous for pedestrians and led to accidents on the sidewalks. These accidents were reflected in newspapers (Nick 2016). 'The hobby-horse had such a bad press by 1820 that it remained difficult to persuade the public back to the bicycle 50 years later' (Smethurst 2015, 13). Cartoonists also caricatured and ridiculed cyclists (Nick 2016). As a result, bicycles were banned from entering sidewalks in several cities, resulting in fines and even confiscation of the bicycle (Tony and Lessing 2014, 25).[5] The expulsion of bicycles from sidewalks was a form of 'legal repression' (27–28) against bicycles and bicyclists. Soon bicyclists who were neither allowed to ride on the sidewalks nor felt safe on the streets became discouraged.

Harvesting in the fall of 1817 was also at the expense of Draisine. In the following year of the year without summer the harvest was good. As a result, horse and oats prices decreased and one of the most important incentives for Draisine buyers/builders was lost (Herlihy 2004).

Therefore, the failure of Draisine was not due to mere technical factors or to mere social factors. Rather, all of these factors together with environmental and natural factors played a role. Heterogeneous factors such as heaviness, roads, hills, harvest, legal issues and politicians, high price,[6] relevant social groups (including anti-cyclists, journalists, caricaturists, etc.) were involved. Removing any of these factors makes it difficult for us to understand the agency and power of other factors.

In the 1860s, Boneshaker (co-produced by Pierre Lallement and Pierre Michaux in France) was introduced. The significant change here is to install a pedal and a crank on the hub of the front wheel. The front wheel was also a little bigger, and as a result, the machine speed increased. Compared to Draisine, boneshaker also makes the rider independent of the ground because the rider can ride the machine without pushing off his feet on the ground. So cycling in muddy and watery roads became easier.

How can the pedal, crank and front-wheel size be socially explained? Again, social interests alone do not construct the design. Because the interest does not necessarily show itself as a crank and pedal. Other things should be added. Here the impact of the sewing industry should be taken into account. The design of the bicycle pedal and crank was influenced in some ways by the shape of the hand-cranked and treadle-driven sewing machines (Tony and Lessing 2014, 37). The skills and craftsmen of both the Weed Sewing Company and the Coventry Sewing Company, in which Pierre Lallement and later James Starley worked or collaborated, were influential in the development of Boneshaker and other bicycles (Nick 2016; Tiina and Myllyntaus 2019, 138).

A nineteenth-century bicycle and a nineteenth-century sewing machine from a mechanical and manufacturing point of view shared about 95% of the same DNA. Sewing machines had been developed over the first half of the 1800s, with metalwork and bearing that were similar to those that would feature on a bicycle and on roughly the same scale. A workforce that could make a sewing machine could very easily transfer its skills to making a bicycle (Hutchinson 2017, 38).

The mechanical structures of bicycles and sewing machine (particular treadle-driven ones) are very similar because the functionality of both is based on leg-power as the hands should be free to steer handlebar or fabric. Note, however, that without social factors, the sewing industry does not construct the shape of Boneshaker either; because if there is no social interest to have more speedy and independent bicycle the sewing industry couldn't affect the bicycle. Therefore the boneshaker was at least at the intersection of social groups' interests/values and the sewing machines. In other words, some features of sewing machines and social values/interests were embedded in the Boneshaker and later bikes since the later machines inherit some feature of the previous intersections of their history without being determined by them.

2.2.1 The Historicity of Bicycle

One of SCOT's problems is that they don't pay attention much to the temporal order of the bicycle construction. Pinch's and Biker's discussion goes on as if the bicycles of Penny-farthing (1869), Lawson (1879), Kangaroo (1884), and Safety (1889) were competing at the same time (or in the same socio-technical network), and divergent groups with different values and interests were in conflict to determine one design. And eventually, Safety succeeded because the social power of the groups to whom 'safety' was more important than 'speed' overwhelmed the power of other social groups. It seems that the fear of linear models and avoiding falling into the trap of technical determinism have led them to pay little attention to the successive versions of bicycle construction. This ignorance, however, has a significant cost: they, even Bijker's 'King of the Road' (1997), cannot recognize the agency and impact of previous versions of the bicycle on subsequent versions. In addition, as it is evident from the study of bicycle development, later versions sometimes answered problems of previous versions. Note that recognizing the effect of previous versions on subsequent versions does not make your model linear or deterministic; since previous versions are just one of several human/non-human factors playing roles in constructing future versions. So the next version is always contingent.

Why did bicycle-builders want to build more speedy bicycles? As Pinch and Bijker pointed out because social groups (such as adventurous men and athletes) have such an interest. So the interest in speed was embedded in the Penny-farthing in the form of a significant increase in the front wheel. But, again, the social interest in speeding up under- determines/under-constructs the special form of Penny-farthing. The social interest logically can be materialized in a variety of forms. Here, one cannot ignore the agency of the Boneshaker structure and also the Eugène Meyer's tension-spoke wheel. When the pedal has been mounted on the front wheel (in boneshaker), the easiest way to increase the speed is to increase the size of the front wheel (Berto 2014). Because when the circumference of the wheel is increased, by one pedal rotating the rider can travel more distance. However, if the weight of the wheel was not already reduced by tension-spoke wheels (Clemitson 2017, 10; Tony and Lessing 2014, 87), increasing the size of front-wheel would result in more weight and consequently more difficult pedaling and less speed.

So if Boneshaker and tension-spoke wheels had not been designed, the social interest in speeding up didn't materialize in the form of a very large front wheel. Likewise, if there was no social interest in speeding up, then, even with Boneshaker and tension-spoke wheels, the size of front-wheel didn't increase in Penny-farthing, or there was no Penny-farthing at all. Penny-farthing, like the rest of bikes, was constructed at the intersection of many human-nonhuman factors.

The design of the Penny-farthing itself created two issues that were important for some social groups: Due to the high front-wheel, one had to help the cyclist to mount and then push it (Tony and Lessing 2014, 57). This would undermine the independence of the cyclist; it was not a problem, of course, in cycling competitions since there were always some helpers there, but for other situations such as outside the cities it was problematic. Second, the bicycle was not safe or even usable for some social groups, especially for women, children, and the elderly, because the very large front wheel falling forward off the bicycle was common for the riders of Penny-farthing, who were called 'the header' after the falling.

Was Penny-farthing efficient? To answer this question one should not only look at the bicycle itself but also at its socio-technical network. The Penny-farthing bicycle in a network in which women, children and the elderly have no interest in cycling, bike-makers are not interested in making more profits, or there are legal, environmental, and technical restrictions to changes the machine, it is very efficient and does not cause any significant problem. As we mentioned earlier, efficiency is constructed by many human and nonhuman factors. However the situation was otherwise; before Penny-farthing, the Boneshaker had attracted many men and women to cycling (Smethurst Paul 2015, 31). The first cycling race from Paris to Rouen, the pioneer of the Tour de France, was performed by Boneshaker (31). The race was held in the year 1869 as the first world cycling race with 325 participants. The Michaux Company was one of its sponsors. The race led to more popularity for the bicycle. So it is clear that Penny-farthing which excludes women and non-athletes, would be under social pressure.

After several lever-driven and chain-driven designs, including, the facile (1878), Lawson (1879), American Star (1880), and Kangaroo (1884), the Rover, one of the safety bicycles, was more or less stabilized. In this bike, the pedal and crank are mounted between two equal-sized wheels under the rider's feet attached to the rear wheel hub by a chain-drive. As the name implies, the social value of safety was embedded in the bike. But, again, how can one explain the shape of the Rover by appealing to the social value of safety alone? True, this bike is safer for many social groups than Penny-farthing (and even lever-driven and chain-driven bicycles after that), but it's not the only design that could ossify the value of safety. The problem with SCOT's 'design flexibility' is that it's not very flexible! Flexibility is not just between safe-low-speed and unsafe-high-speed designs. The value of safety (or speed) itself can be logically embedded in a wide variety of designs. What really makes one of these safe designs actualize is not just social factors. Again, without considering other human-nonhuman factors, the shape of the Rover cannot be explained.

To find one of those non-human factors we have to go a few years back. In 1878, a few years before the construction of the Rover (and other chain-driven bikes like Lawson's bicycle), James Starley (originally a sewing machine producer in Coventry and the Uncle of John Starley, the co-producer of Rover) designed a tricycle called 'Salvo', in which the rider pedals in the middle of two large wheels on his/her left and right sides. The power was transmitted to one of the wheels through a drive chain. The Rover was in many ways similar to the Salvo. On both machines, the pedal was positioned under the feet of the cyclist and the drive-chain mechanism was the same as well.

Removing the pedal from the front wheel was an important decision. If the pedal is not on the wheels, the power must be transmitted to the wheels using another tool. So this decision would not be made without the drive chains.[7] Hans Reynolds had been in chain designing for many years before designing Safety and Salvo. Later, he worked with the Starley family in Coventry, a city that had shifted from sewing machine to bicycle making (Tony and Lessing 2014, 150). Reynolds' skills in chain-making and the properties of the chains influenced the success of the Starley Tricycle, which was later called the Royal Salvo due to welcoming by the royal family. And as I mentioned before, the Safety bike inherits important features from Salvo. Accordingly, the Rover was designed at least in the intersection of the safety value of social groups and Salvo.

2.2.2 Flexibility and Closure

An artefact is not necessarily consolidated into a single form, so we may end up having multiple designs stabilized. This means that the design flexibility itself may be stabilized. If there are significant social groups with diverging interests, then the artefact may take different forms based on each individual's interests and needs, and neither of those designs can dominate and marginalize the other. But in the case of bicycles, the situation was different. The Safety became dominant and almost stabilized. Why? Because in addition to capturing the interest of social groups such as women and the elderly, the bike was also able to meet the interest of groups such as athletes. How? Partly through the agency of pneumatic tires. With the help of John Dunlop, Starley uses pneumatic tires originally to reduce the shakes of the bike. But it soon turned out that the tire would significantly increase the speed of the bike. As a result, both social interests of safety and speed were met. And it was also in the favor of producers and investors because they did not have to have two production lines. Therefore, along with other actors, the pneumatic tires had significant agency. If pneumatic tires did not accelerate the wheels, Penny-farthing would probably be survived alongside the Safety bike.

Accordingly, many human and nonhuman factors contributed to the shaping and success of the Safety; the social groups' interests, bike-builders, skilled working class, the increase of people's income and leisure time, Protestantism's values,[8] the medical community,[9] the tire industry, the drive-chains, and tricycle industry. And if we take into account the agency of previous versions of the artefact, the Safety has inherited many features from the previous intersection of its historicity including features of horse body, human body, skating, sewing machine, and social groups and values that have been constructed in the process of the construction in several decades. Again, it should be emphasized that this process is never linear or deterministic, as the fate of the bike is in the hands of numerous and unpredictable human-nonhuman actors. Any change in the actors and intersections would lead to another path. So the process is a contingent trajectory.

Among human-nonhuman agents that contribute to the shaping of artefacts, we should leave also some room to creativity and decisions of artefact-builders. Their creativity and decisions play a role at each intersection of bicycle construction without being able to determine it. Their decisions are one of the factors that contribute to the formation and success or failure of artefacts. It seems that one of the factors that led to the commercial failure of the Lawson' bicycle (Smethurst Paul 2015, 19) was that while the front-wheel is still larger than the rear wheel (a feature that it inherited from Penny-farthing), the chain-drive is geared with the small rear-wheel's hub. This decision slowed down the speed of the bike.

2.3 Co-Construction

One of the Winner's criticisms (1993) to SCOT is that the program ignores the effects of technology on society. Failure to pay attention to the mediation and agency of artefact makes it difficult to understand how other factors affect artefact. Of course, Pinch and Bijker do not deny the effects of artefacts on society. They may think that this is an independent study and has nothing to do with how technology is constructed by social context. In fact, in recent years the SCOT developers have recognized the impact of technology on society increasingly. For example Bijker, Hughes, and Pinch (2012) point out that SCOT researchers have somewhat changed their original positions; they also address the impact of technology on institutions. So one can rightly say that SCOT, at least now, concentrates on both sides: the impact of society on technology and the impact of technology on society. Our point, however, is that this two sides should be studied simultaneously. They are not two distinct studies but a single one. If the construction is reciprocal or circular, we have to pay attention to both constructions symmetrically and simultaneously. Since while society constructs technology, the technology constructs society as well; so if you want to know how society constructs technology you should not ignore the way technology, in development or 'in action' (Latour 1987), constructs society at the same time. In any cycle of the con-construction we have a new artefact and a new society.

The effects of the bicycle have been so numerous and profound that some have called it the 'embodiment of modernity' (Harry 2016). The effects of cycling on lifestyle,[10] road construction (Reid Carlton 2015), marginalization, gender and class divide,[11] car and motorcycle industry, the creation of new social groups, and the garment industry are just a few of them.

For example, one can argue, that the bicycle had agency in making social groups like cyclist women who in turn had agency in bicycle construction. The gradual increase of mobility in Draisine led to gradual interests in speed in Boneshaker and Penny-Farthing, and that bicycles led to emerging a new and serious activity called cycle sport which had sponsors (Smethurst Paul 2015, 14). According to the actor-network theory, one can say, bicycles have translated people's interests over the decades. People who were interested in horse-riding and horse-racing before bike construction, were now interested in bike-riding and bike-racing.

The bicycle has also been a significant agent in changing the social relationships of men and women; bicycles played an important factor in challenging nineteenth-century Victorian society's class and gender hierarchy (Smethurst Paul 2015, 1–2).

Another effect of bikes was on the garment industry. One of the first barriers to women cycling, besides church and public culture, was their dress. The common women's clothing was not comfortable for cycling. The clothes did not allow women enough mobility. This problem, the 'clothing problem', has led some female designers and tailors to design new forms of clothing, particularly bloomers, for women cyclists (Kat 2018). Church and public culture had some issues with the bloomers; wearing bloomers they looked like men at first, something that was not much tolerated at the time, and partly their legs appeared while cycling (Michael 2010). To resolve this issue, cloth designers introduced new forms. However, the continuation of the invention of new clothing forms has gradually allowed women to dress more like men (Herlihy 2004, 271) and to appear more in society.

It is not our point that the bicycle had social impacts. No one, maybe except a fanatic instrumentalist, denies this. The point is that these kinds of influences have in turn contributed to the success and determination of the bike itself.[12] If more comfortable forms of clothing are designed for women, then a greater number of them will be interested in cycling. Therefore since the bicycle has historicity, its mediation in society for several decades will be part of the explanation of the success and determination of the final bicycle design. That is why the study of a technology construction is always the study of a co-construction.

3. Beyond a Narrative

The use of ANT as a methodological (and ontological) framework has been increased dramatically in recent years. Researchers from a variety of fields have found some methodological and ontological intuitions in ANT. However, despite some research that has tried to clarify its methodological elements and implications (for example, Sayes (2014) on the agency of nonhuman and its methodological implications, or Collin (2014) in defending methodological particularism based on ANT) some ambiguities remain in what this framework really is and how it is applicable in STS case studies. We have tried to present a new narrative of bicycle development in comparison with SCOT's and we have briefly offered a methodological framework in ANT literature that can be considered as a methodological procedure to study of artefacts in general; this framework has three elements: 1. Phenomenal Bracketing, 2. Collective Construction, and 3. Co-construction, and in some ways can be considered a compliment and extension of SCOT's model. Now I'd like to explain it in more detail and flashback to our narrative in comparison with SCOT's.

Phenomenal bracketing is an anthropological tactic that suspends rigid theories, notions, and also our familiarities with the object of the study. Bracketing familiarities is especially significant in the study of past technologies which was the case in bicycle studies. Our familiarity with the last solidified artefact may affect how we categorize it while we study its development. If we start a study about the history of bicycle with our today's definition of it, we probably don't like to concentrate on artefacts such as Draisine which are more distant from today's conception of bicycles. In the same way, if we begin our study with a rigid model in which we should detect enough related social groups, we may fail to recognize some part of the study due to lack of them and forget that the social groups are made over time alongside the artefact development. This tactic prevents us from removing or ignoring some parts of the development story, such as ignoring the prehistoric stage of bicycle construction in SCOT's narration, or imposing our pre-established molds on new data.

Two questions are raised right away: 1. Is it possible at all to bracket your rigid theory, notions, and familiarities? 2. To what extent should or can we bracket our familiarities with the phenomenon we are studying? Understanding the possibility of bracketing will be easier noting our semiotic characters in reading fairy tales or watching movies. We bracket many familiarities with, for example, filmmaking techniques. We 'assume' that the actors in a movie really kill, die, and fall in love. That's why we cry, laugh, fear, get upset, or cheer as we are watching a movie. We bracket 'no one is killed in movies' for a while. Furthermore, in reading a fairy tale, we 'assume' that a tree, for example, can speak or sing. We bracket our ordinary knowledge about trees and some other beings, for a while. In semiotic terms, we shift from reader-in-the-flesh (our real character) to reader-in-the-texts (our semiotic character) in such situations (Akrich and Latour 1992). The mechanism of this shifting is bracketing. In this way, researching is the act of a semiotic character. You should shift from researcher-in-the-flesh to researcher-in-the-text. The second question is a practical one. It is clear that we cannot and should not bracket all familiarities; 'A total newcomer is unrealizable in practice' (Latour and Woolgar 1986, 44). We just bracket 'some aspects' of the phenomenon we are engaged with. For example, if you are studying the construction of a scientific fact, 'apprehend as strange those aspects of scientific activity which are readily taken for granted' (29).

Collective construction draws our attention simultaneously to human and non-human factors and their interactions, translations, and mediations. So instead of focusing on mere social or mere technical factors, we need to trace the intersections between humans and non-humans, their translations and mediations. Ignoring non-humans, as we saw several times, makes the technical content of the artefact incomprehensible. For example, without noting the mediation of the sewing machine, alongside the mediation of related social groups, the technical content of the chain-pedal system of the safety bikes is not explainable. There is a 'historical trajectory' link between bicycle and sewing machine (Mari 2021, 13) that should be analyzed in any description/explanation of how the particular technical content of safety bikes, among logically many ones, has been solidified.

Some of those mediational effects come from the past; since any artefact has its own historicity, the agency of previous human-nonhuman actors on the present version should not be ignored. As we saw some features of previous versions of bicycles could be identified in later versions. Furthermore, we should give some room for the unexpected agency/mediation of actors, as was true in the case of pneumatic tires, which were designed to reduce the shakes of the bike but unexpectedly increased the speed too, and also creation/decision makings of the human builders.

And co-construction refers to the two-way relationship of the artefact and its socio-technical context; the context and the artefact are constructed at the same time, and studying their transformations simultaneously gives a clearer picture of how the artefact under study is developing.

Collective construction and co-construction answer multiple questions (see Table 1), including when does the program of action begin and how does it transform over time? What are the human and non-human actors involved in the program of action and anti-program of action? How to describe the actors, their relations, mediations, and translations in the program? How do the mediations of the human/non-human actors embed in the technical content of the artefact? How do the artefact and its context shape each other? What problems they makes for each other and how the related actors respond to them? In the answer to the first question, for example, the program of action of bicycle-building, based on a variety of sources, starts in 1817 in Germany, and at least has been transformed contingently four times, from early velocipedes (such as Draisine/dandy-horse) to safety bicycles (such as Rover). In each transformation, the main interest and problem of the program changes to some extent, and the artefact is solidified or black-boxed in a particular technical content. For example, the problem in Karl Drais' program of action was how to build a horse-like machine that does not need oat. Draisine was a solution to the problem of 'transportation' in a socio-technical network in which horses were dying from lack of oat. As the program transforms over time, all the actors, the aim, the problem and consequently the artefact are redefined. The problem of transportation changes to the problem of ‘recreation’, ‘competition’, ‘sport’, or a combination of them.

Table 1. Elements, questions, strategies and methods/tools of ANT’s model.

The elements	**Main questions**	**Strategies**	**Method and tools**
• Phenomenological bracketing	• What presuppositions may bias the study? • How they can be bracketed?	• Using bracketing skills in literature and Semiotics	• Shifting from character-in-flesh to character-in-text
• Collective construction	• When does the program of action begin and how has been transformed? • What are the human and non-human actors involved in the program of action and anti-program of action? • How to describe the actors, their relations, mediations and translations in the program? • How do the mediations of the actors embed in the technical content of the artefact?	• Retracing • Thick description	• infra-language • syntagmatic and paradigmatic relations • ethnographic observations • participant observation • breaching experiments • thought experiments
• Co-construction	• How do the artefact and its context shape each other? • What problem they makes for each other and how the related actors respond to them?		

In studying collective construction and co-construction, ANT’s approach provides us with several methods, tools and, techniques, including *infra-language, syntagmatic and paradigmatic relations, ethnographic observations, participant observation, breaching experiments, thought experiments,* to describe the artefact development. They are data gathering, organizing, and writing tools and techniques or methods. Infra-language, for example, is the language of writing the ANT style narratives. Infra-language is neither a meta-language to explain phenomena (like those that are in the hand of Marxist theorists) nor your informants’ language. ‘The inquirer not to confuse his or her infra-language with the rich objects that are being depicted’ (Latour 2005, 133). The task of a researcher is to provide a ‘thick description’ of the phenomenon she is studying through infra-language, through ‘the weak terms’ like ‘group, actor, agency, translation, and fluid’ (174). Such a description, as we have attempted in our narrative, neglects as few as possible human and nonhuman actors and their translations/mediations.

Instead of applying this model to a new case, we used the bicycle construction, a familiar case in technology studies. This was for two related reasons. First, SCOT's narrative is the only existing narrative of the bicycle construction. Due to the deep influences of this technology and its significance for STS, I think it would be fruitful to re-narrate it from a different theoretical perspective. The second reason is that studying a particular artefact from a new perspective helps readers to more easily compare the advantages and disadvantages of different theoretical approaches. In science and technology studies, researchers do not usually seek to re-study a technology from a new perspective; it seems that the fate of any case study should only be tied to one theoretical approach, which seems unjustified.

4. Conclusion

In this paper, we attempted to offer a short re-narration of bicycle construction based ANT's main components, Phenomenological Bracketing, Collective Construction; and Co-Construction in comparison with SCOT's original one. The first component does not allow us to ignore some parts of the story or some of the actors involved in the construction of artefacts. SCOT's initial narration (1984) ignored the prehistoric phase of bicycle development, Draisine, probably because Pinch and Bijker failed to apply their model. Even though Bijker (1997) tried to fill this gap by discussing some artefacts of the prehistory one decade later, he has not offered but a historical summary; SCOT's model has not been applied. According to the second component we were encountered with heterogeneous actors that played roles in shaping and success/failure of bicycles, from Tambura volcano, hills, horses, skates, human body, sewing machines, winches, tricycles, tires, to women, athletes, politicians, press, law, workers, middle class and other factors commonly referred to as 'social'. In other words, bicycles were constructed at the intersection of various fields from sociology to metallurgy, geography, mechanics, economy, anatomy, physiology, industry and so on. The third component draws attention to the simultaneous construction of the artefact and its socio-technical network. Though co-construction and the importance of materiality have been recognized later by SCOT developers, these theoretical changes have not led to the modification of their first account. So according to these three methodological components, we can argue that ANT's approach to bicycle development has at least three advantages over SCOT's; First, it can better explain the emergence of this technology; ANT's approach, as we have seen, can cover the prehistoric stages of the development of bicycles; that is it can explain how early versions emerged in a heterogeneous network of human and non-human actors and how they leave traces on later versions. Secondly, it better explains its stabilization; as we have seen, SCOT could not easily explain the stabilization of bicycle by simply referring to social factors; any such explanation would be an under-explanation. Third, it can better describe how the bicycle and its socio-technical network change each other at the same time, instead of concentrating on a passive material under the social pressure of some social groups.

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Additional information

Notes on contributors

Rahman Sharifzadeh

Rahman Sharifzadeh has received his Ph.D. in Philosophy of Science and Technology (from Institute for Humanities and Cultural Studies, 2011–2015). His undergraduate and postgraduate degrees were respectively in philosophy (from Shahid Beheshti University), and Logic (from Tarbiat Modarres University). He is now assistant professor at Iranian Institute for Information Science and Technology (IranDoc). His fields of study and interests include STS, ethics of technology, ethics and philosophy of information, philosophy of technology, philosophy of science, and history of science and technology.

Notes

1. See for example: Pinch and Bijker (1984) on Bicycle development; Bijker (1989) on Bakelite; Michel Callon (1986) on Electric Machines; Latour (1996) on the Failure of the Aramis; Latour (1993a) on the construction of microbes; Collins and Pinch (1993) on a series of case studies on the construction of scientific facts; Law (2002) on building a military artifact; Mol (2002) on the multiple construction of a disease.

2. This does not mean, of course, that the mind can be emptied of all assumptions and notions. Assumptions and notions are flexible and change in the face of data, but models and theories are more rigid and orientating and usually sacrifice part of the data. Although 'Actor-network Theory' contains 'theory', it is not a theory but a toolbox to study phenomena empirically (Latour 1999b, 19).

3. The dichotomy of human-nonhuman does not imply that human has no non-human aspect and vice versa. Ontologically they are hybrid and have each other (since as actor-networks they define each other) but semantically they are two kinds of actors.

4. The social groups, in Pinch's and Bijker's study, are categorized generally by gender, physical ability, and age. They do not address social groups such as workers, the middle class, and in general issues around labor and capital. This neglect has been highlighted by some critics (Russell 1986). Of course, Pinch and Bijker responded that 'our aim was to review empirical studies of technology which treated the content of the technology seriously' (Trevor and Bijker 1986, 348). Separating macro and micro studies of technology, they say that Russell's discussions are about the theory of macro sociology, while their aim is to explain the social content of technology through micro studies. This answer seems odd given SCOT's and EPOR's third stage. One of SCOT's goals is to link the closures mechanisms to a larger and wider social context.

5. Gompertz even suggested authorities to allocate part of the streets (a special line) to bicycles (Tony and Lessing 2014, 25). Gompertz was an animal rights advocate (Herlihy 2004). Moral motives may have been also involved in the making of Gompertz's bike and insisting on changing the driving rules of the time.

6. Draisines' high price (£ 8–10) 'put them beyond the reach of the working class' and soon became the symbol of young 'noblemen' (Tony and Lessing 2014, 25). High price has always been a threat to this machine, and this may also have been one of the factors for the non-popularity of tricycles (Smethurst 2015, 14).

7. Ropes were also an option but had many problems, including tearing, loosening, and frictional loss.

8. The church's response to the bicycle was mixed. One of the ideas that have influenced the popularity of the bicycle in England has been the theory of the Muscular Christianity of the Protestant Church (Michael 2010, 338); bicycles help to turn the weak Christians into muscular Christians.

9. Although some physicians (e.g. The London College of Surgeons) have described the use of Draisine as dangerous, causing hernias (Herlihy 2004). But in the following decades, the medical community took a more positive position on bicycle as a tool to promote human health.

10. Bicycles made romantic appointments very easy, enabling people to easily meet their friends on the outskirts of town and in nature; so bicycle was a significant factor in changing courtship rituals (Michael 2010).

11. For British women, cycling was seen as a means of liberation (Kat 2018). The bicycle as a means of transportation and recreation gave American women a sense of independence (Fleming 2015). Designing forms of clothing for women cyclists introduced women designers into the patent world (Kat 2018).

12. The agency of bicycle is also collective; that is to say, it is due to the technical characteristics of the bicycle as well as other human-nonhuman actors of the bicycle's network. We regard the bicycle (and any other artifact) as an actor-network, not an isolated causal power. The nature of an artifact, and any other actor, transcends its technical-material boundaries. So the change that bicycle is making in society is the result of the interaction of the bicycle and innumerable human-nonhuman actors. This protects us from Woolgar's criticisms (1991) to MacKenzie and Wajcman (1985) and also Winner (1980).

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References

1. Akrich, Madeline, and Bruno Latour. 1992. "*A Summary of a Convenient Vocabulary for the Semiotics of Human and Nonhuman Assemblies*." In: Bijker Wiebe and Law John, eds., Shaping Technology/ Building Society: Studies in Sociotechnical Change. 259–264. Cambridge, MA: MIT Press. [Google Scholar]
2. Berto, F. J. 2014. *The Birth of Dirt: Origins of Mountain Biking*. 3rd ed. San Francisco: Van der Plas/ Cycle Publishing. [Google Scholar]
3. Bijker, W. E. 1989. "The Social Construction of Bakelite: Toward a Theory of Invention." In *The Social Construction of Technological Systems.* edited by W.E. Bijker,T.P. E. Hughes and T.J. Pinch, 159–194. Cambridge: MIT Press. [Google Scholar]

4. Bijker, W. E. 1995. 'King of the Road: The Social Construction of the Safety Bicycle'. In *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*, edited by Wiebe E. Bijker, 19–100. Cambridge, MA: MIT Press. [Google Scholar]
5. Bijker, W. E. and Hughes, T. P. 2012. *The Social Construction of Technological Systems*, edited by T. Pinch, Cambridge, MA: MIT Press. [Google Scholar]
6. Bijker Wiebe and Law John, eds. 1992. *Shaping Technology/ Building Society: Studies in Sociotechnical Change*. Cambridge, MA: MIT Press. [Google Scholar]
7. Callon, M. 1986. "The Sociology of an Actor-Network: The Case of the Electric Vehicle." In *Mapping the Dynamics of Science and Technology*, edited by M. Callon, J. Law, A. Rip, M. Callon, J. Law, A. Rip, 19–34. London: Palgrave Macmillan. doi: 10.1007/978-1-349-07408-2_2. [Crossref], [Google Scholar]
8. Clemitson, Suze. 2017. *History of Cycling in 100 Objects*. New York: Bloomsbury Sport. [Google Scholar]
9. Collin, Finn. 2014. "Who are the Agents? Actor Network Theory, Methodological Individualism, and Reduction." In *Rethinking the Individualism-Holism Debate*, edited by Julie Zahle Finn Collin. New York: Springer. [Crossref], [Google Scholar]
10. Fleming, Jenna E. 2015. "The Bicycle Boom and Women's Rights." *The Gettysburg Historical Journal* 14 (3). https://cupola.gettysburg.edu/ghj/vol14/iss1/3 [Google Scholar]
11. Harry Collins, and Pinch Trevor. 1993. *The Golem: What Everyone Should Know About Science*. New York: Cambridge University Press. [Google Scholar]
12. Harry, Oosterhuis. 2016. "Cycling, Modernity and National Culture." *Social History* 41 (3): 233–248. doi:10.1080/03071022.2016.1180897. [Taylor & Francis Online], [Web of Science ®], [Google Scholar]
13. Herlihy, David V. 2004. *Bicycle; The History*. New Haven: Yale University Press. [Google Scholar]
14. Hutchinson, Michael. 2017. *Re: Cyclists: 200 Years on Two Wheels*. London: Bloomsbury Sport. [Google Scholar]
15. Kat, Jungnickel. 2018. *Bikes and Bloomers : Victorian Women Inventors and Their Extraordinary Cycle Wear*. Cambridge, MA: Goldsmiths Press. [Google Scholar]
16. Latour, Bruno, and Steve Woolgar. 1986. *Laboratory Life: The Construction of Scientific Facts*. Los Angeles: Sage. [Google Scholar]
17. Latour, Bruno. 1987. *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, MA: Harvard University Press. [Google Scholar]
18. Latour, Bruno. 1993a. *The Pasteurization of France*. Cambridge, MA: Harvard University Press. [Google Scholar]
19. Latour, Bruno. 1993b. *We Have Never Been Modern*. Cambridge, MA: Harvard University Press. [Google Scholar]
20. Latour, Bruno. 1996. *Aramis, or the Love of Technology*. Cambridge, MA: Harvard University Press. [Google Scholar]
21. Latour, Bruno. 1999a. *Pandora's Hope, Essays on the Reality of Science Studies*. Cambridge, MA: Harvard University Press. [Google Scholar]
22. Latour, Bruno. 1999b. "On Recalling ANT. In *The Editorial Board of the Sociological Review*, edited by J, Law and J, Hassard, 15–26. Oxford: Blackwell Publishers. [Crossref], [Google Scholar]
23. Latour, Bruno. 2005. *Reassembling the Social: An Introduction to Actor-Network Theory*. Oxford: Oxford University Press. [Google Scholar]
24. Law, John, and Michel Callon. 1988. "Engineering and Sociology in a Military Aircraft Project: A Network Analysis of Technological Change." *Social Problems* 35 (3): 284–297. doi:10.2307/800623. [Crossref], [Web of Science ®], [Google Scholar]
25. Law, John. 2002. *Aircraft Stories: Decentering the Object in Technoscience*. Durham: Duke University Press. [Crossref], [Google Scholar]
26. Lessing, Hans-Erhard. 2001. "What Led to the Invention of the Early Bicycle?." In *Cycle History*, 28–36. San Francisco: Cycle Publishing. [Google Scholar]
27. MacKenzie, D., and J. Wajcman. eds. 1985. *The Social Shaping of Technology*. Milton Keynes: Open University Press. [Google Scholar]
28. Mari, Carlo. 2021. *A Business History of the Bicycle Industry*. cham: Springer. [Crossref], [Google Scholar]

29. Mol, Annemarie. 2002. *The Body Multiple: Ontology in Medical Practice*. Durham, NC: Duke University Press. [Crossref], [Google Scholar]
30. Nick, Clayton. 2016. *A Short History of the Bicycle*. Gloucestershire: Amberley Publishing. [Google Scholar]
31. Pinch, T, and W. E. Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14 (3): 399–441. doi:10.1177/030631284014003004. [Crossref], [Web of Science ®], [Google Scholar]
32. Pinch, T. 2008. Technology and Institutions: Living in a Material World. *Theory and Society,* 37 (5): 461–483. doi: 10.1007/s11186-008-9069-x [Crossref], [Web of Science ®], [Google Scholar]
33. Reid, Carlton. 2015. *Roads Were Not Built for Cars; How Cyclists Were the First to Push for Good Roads & Became the Pioneers of Motoring*. Washington DC: Island Press. [Google Scholar]
34. Ritchie, A. 1995. *King of the Road: An Illustrated History of Cycling*. Berkeley: Ten Speed Press. [Google Scholar]
35. Russell, Stewart. 1986. "The Social Construction of Artefacts: A Response to Pinch and Bijker." *Social Studies of Science* 16 (2): 331–346. doi:10.1177/0306312786016002008. [Crossref], [Web of Science ®], [Google Scholar]
36. Sayes, Edwin. 2014. "Actor–network Theory and Methodology: Just What Does It Mean to Say That Nonhumans Have Agency?" *Social Studies of Science* 44 (1): 134–149. [Crossref], [PubMed], [Web of Science ®], [Google Scholar]
37. Smethurst, Paul. 2015. *The Bicycle – Towards a Global History*. London: Palgrave Macmillan. [Crossref], [Google Scholar]
38. Taylor, Michael. 2010. "Rapid Transit to Salvation: American Protestants and the Bicycle in the Era of the Cycling Craze." *The Journal of the Gilded Age and Progressive Era* 9 (3): 337–363. doi:10.1017/S1537781400004096 [Crossref], [Google Scholar]
39. Tiina, Männistö-Funk, and Timo Myllyntaus. 2019. *Invisible Bicycle, Parallel Histories and Different Timelines*. Leiden, NL: Koninklijke Brill NV. [Google Scholar]
40. Tony, Hadland, and Hans-Erhard Lessing. 2014. *Bicycle Design: An Illustrated History*. Cambridge: MIT University Press. [Google Scholar]
41. Trevor, Pinch, and Wiebe Bijker. 1986. "Science, Relativism and the New Sociology of Technology: Reply to Russell." *Social Studies of Science* 16 (2): 347–360. doi:10.1177/0306312786016002009 [Crossref], [Web of Science ®], [Google Scholar]
42. Winner, Langdon. 1980. "Do Artifacts Have Politics?" *Daedalus* 109 (1): 121–136. [Web of Science ®], [Google Scholar]
43. Winner, Langdon. 1993. "Upon Opening the Black Box and Finding It Empty: Social Constructivism and the Philosophy of Technology." *Science, Technology & Human Values* 18 (3): 362–378. doi:10.1177/016224399301800306. [Crossref], [Web of Science ®], [Google Scholar]
44. Woolgar, Steve. 1991. "The Turn to Technology in Social Studies of Science." *Science, Technology, & Human Values* 16 (1): 20–50. doi:10.1177/016224399101600102 [Crossref], [Web of Science ®], [Google Scholar]