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Innovation as a Possibility. Technological and Social Determinism in Their Dialectical Resolution

Summary

This paper analyzes the specific conditions of the innovation of the prehistoric wheeled vehicle innovation according to affordance and *Eigensinn* of this new technology. The use of wheeled vehicles is a social practice that results from the interests and capabilities of their users, but also from their technical affordances and *eigensinn*. Wheeled vehicles/wagons expand and restrict their users' potentialities of action. The realization of possibilities of action is linked to specific interests and technical requirements. Today, wheeled vehicles are the symbol of mobility. However, this is an affordance that was realized only late in history and was not the starting point of this particular innovation.

Keywords: Innovation; affordance; *Eigensinn*; Actor-Network Theory; wagon; chariot.

Die spezifischen Bedingungen der Innovation des Wagens werden hinsichtlich Affordanz und Eigensinn der neuen Technologie untersucht. Wagen sind eine soziale Praxis, die zum einen aus den Interessen und Fähigkeiten der Nutzer, zum anderen aus der technischen Affordanz und dem *Eigensinn* der Wagen resultiert. Wagen erweitern ebenso die Handlungsmöglichkeiten der Nutzer wie sie sie beschränken. Die Umsetzung von Handlungsmöglichkeiten ist mit spezifischen Interessen und technischen Anforderungen verknüpft. Für uns sind Wagen heute ein Symbol von Mobilität. Diese ist jedoch eine Möglichkeit, die erst spät in der Geschichte realisiert werden konnte; sie war nicht der Ausgangspunkt der Innovation des Wagens..

Keywords: Innovation; Affordanz; Eigensinn; Akteur-Netzwerk-Theorie; Wagen; Streitwagen.

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Innovation has always been a central theme in archaeology – so it seems not very innovative to address this issue again. The grand narratives of human history are success stories, primarily of technical developments. Through increasingly differentiated technical requirements and solutions we have arrived where we are today: in a highly technological world that is able to feed seven billion people and exterminate multiples thereof at the push of a button. Archaeology has written a large part of the chapters of this "success story."

The diachronic perspective is a great strength of archaeology, but it also reveals one of its weaknesses. The largely fragmented archaeological record leads to long periods in which a historical depth of field is attained only through an accumulation of individual observations, though their coherence cannot usually be adequately clarified. The single picture obtained through the archaeological evidence has a low resolution and it hardly shows contours. Relying on several pictures with the same or similar representations compresses the evidence and increases the resolution of the historical picture. And yet, the individual observations remain disparate phenomena, separated from each other by a large spatial and temporal distance. This finds its clearest expression in the classical archaeological distribution map: The find spots suggest a contemporaneity and an inner coherence.

Zenon's arrow paradox, which states that a flying arrow is located at a clearly defined place at a particular time and therefore does not move, seems completely valid here: Individual static observations are combined and seen in their entirety as if in movement. Zenon's arrow paradox can be resolved mathematically, but this is not possible for an innovation process. The unity of the process is not given and a find spot cannot causally be deduced from the position of a preceding location. Connections between individual observations remain hypothetical, discontinuations are rarely recognized.[1] The overall process of a particular technical development is only visible in its totality, and also only from its end. Models that are constructed in this way are inevitably teleological and success-based. Functional benefits are at the core of archaeological representations of technical developments. In retrospect this is easy to justify. Zooming in, however – which is indeed possible for individual processes, especially in their early stages – one can see, as in the case of iron technology, the pitfalls of such assumptions. At first, the new iron technology was in technical terms a step backwards compared to the established bronze technology: The tensile strength of forged iron is well below that of those bronzes that have already been made in the Bronze Age. Only through the advancement of iron technology was an increase in quality achieved, which made iron a superior material with respect to hardness.[2]

1 See in contrast Müller and Lohrke 2012.

2 Maddin, Muhly, and Wheeler 1977; Wheeler and Maddin 1980.

Something else also determines the archaeological investigation of innovation processes: Archaeological evidence consists exclusively of materializations of various kinds and origins, i.e., objects and findings (or matter and substances). The purely material-based access to the past prefigures our view of the history of mankind. It is no coincidence that an early – and still common – classification of prehistory is based on material groups: stone, bronze, iron. And the developmental phases of civilization identified later by Gordon Childe – neolithic, urban, and industrial revolution – are similarly determined by material parameters. It is not surprising that the socio-typological stages, like those identified by neo-Evolutionists, are barely able to gain a foothold at the operational level in archaeology.[3] With the given archaeological record, the sociological and ethnographic criteria for socio-typological classifications of pre-modern societies present a huge challenge that is hardly resolved in a satisfying way.[4]

The logic of the archaeological record promotes a technological perspective on social development and this development follows – at least as far as the traditional narrative goes – a teleological, functionalist logic. I go even further here and suggest that our concepts of the relationship between technology and society indirectly affect our understanding of innovation processes. The banishment of God from the sciences and the Cartesian view that both the human mind and matter determine the reality of the world fundamentally changed the modern world view. On the one hand, natural science and natural laws placed emphasis on the autonomy of the material world; on the other hand, the consciousness of the creative powers of the human spirit emphasizes the human being as an acting subject. This leads to two conflicting viewpoints which have ever since significantly influenced the discussion: To simplify matters, they can be referred to as technological determinism and social determinism.

From the viewpoint of technological determinism, technology exists outside of society and follows an internal logic. Technological rationalities cause changes that directly or indirectly impact society and result in social and cultural change. The US-American sociologist William Ogburn, for example, postulated that, at least in the current Western world, societal development is lagging behind technical advancement.[5] Also, in current technology debates, the demand for assessments of the consequences of technology draw their legitimacy from the *cultural lag* and the social problems arising from it.

In contrast, social determinism considers technology to be an integral part of society. Here, technology loses its autonomy. Without a life of its own, it is degraded to a mere instrument to fulfill human purposes. As Arnold Gehlen stated, following Herder, humans are deficient beings, using technology as a prosthesis for lack of bodily abilities to act and deficient sensory organs.[6] However, technology is more: It is a medium to

3 E.g. Feinman and Neitzel 1984.

4 E.g. Yoffee 1993.

5 Ogburn 1969.

6 Gehlen 1940, 77–78.

enforce social interests just as much as it is the result of societal interests and individual actions – and it consequently follows a social logic of interests.

There are a vast number of empirical studies that offer good arguments to confirm both points of view. Neither the technical rationality (and resulting causality) nor the logic of social agency are to be dismissed. The suppression of either the technical rationalities or the acting human subject leads to significant flaws in our understanding of innovation processes.

1 The railroad as multidimensional innovation generator

At this point I would like to return to the book by Wolfgang Schivelbusch, "The Railway Journey."[7] Schivelbusch's study played a significant role in adjusting the thematic focus of our workshop. The innovation "railway" and its diverse impacts on society are considered here in an admirable way – and with remarkable insights. The fact that the railway was an extremely profound innovation in the 19th century is indisputable. It gives modernity its public face. The inland distribution of industrial goods would not have been possible to the required extent without the railway. As a means of transport and a supplier of jobs, for example in railroad construction, the railway was an essential driving factor of the economic development of the emerging industrial nations. It is also the symbol of the expansion of the frontier into the North American "Wild West." The railway was thus not only an economic factor, but also a means of imperial penetration. Less known are the pompous plans of the European colonial powers to domesticate the African continent by covering it with a widely ramified railway network – plans that have thoroughly failed.[8]

The introduction of the railway was carried out with economic considerations: The coal fuel was cheaper than the feed for draft animals. Adam Smith calculated that a horse needs as much feed as eight workers. By eliminating a million draft animals in England, extra food could be rationed to another eight million workers. And the industrial demand for workers rose steadily. The railroad was the economic solution to an economic problem. However, one does not do justice to the phenomenon alone with economic expediency.

I would like to highlight two central aspects of Schivelbusch's study that already in the 19th century were perceived as essential to the railway: the annihilation of time and space. Both resulted from its speed, which initially was about 40 kilometers per hour, thus exceeding the usual travelling speed of stagecoaches three times. Passengers were confronted with unfamiliar sights and insights. Victor Hugo described the view from

7 Schivelbusch 1986.

8 E.g. Maggi 1997; Sunderland 2002.

the window of a moving train in 1837 as follows: "The flowers by the side of the road are no longer flowers but flecks, or rather streaks, of red or white; there are no longer any points, everything becomes a streak; the grain fields are great shocks of yellow hair; fields of alfalfa, long green tresses".[9] An illustrator of the time sketched his view of the landscape in the following way: Like a projectile – as it was described by many contemporary commentators – the railroad shot through the countryside, while the landscape vanished. Especially the nearby things faded away; the foreground dissolved into vague schemes. The landscape lost its depth of field and the travelers' relationship to the landscape changed: they were no longer in it, they were not part of it, but rather outside observers. The train travelers found themselves in an idle position while barely recognizable landscapes were carried past them like a scenery. The viewing habits of travelers changed.

Furthermore, art changed. In 1844, the picture *Rain, Steam and Speed – The Great Western Railway* by the English painter William Turner (Fig. 1) visualized the speed in a specific way. Again, forms dissipate; the static is converted into dynamic movement. Turner's later landscape pictures in particular lose their objectives as the contours blur. He inspired the French Impressionists with this style of painting that he had developed. The Impressionists' paintings had to do with capturing sensual appearances, the volatility of momentary impressions, and the transitory world.[10] A linear path from the impressions of railway passengers to the new forms of representation in painting cannot be demonstrated. However, one thing is obvious: The late Turner and the Impressionists codified the perception of volatilization and were for this reason well in the trend of the time.

Time is the next aspect that I would like to briefly touch upon with reference to Schivelbusch. The previously unknown speed of the railway ensured that routes were completed in a much shorter time. Distances fused together, and places grew closer. This means that space was compressed. Travel distances were often measured in hours traveled by foot: An average travel hour corresponded to 3.7 km or 2 miles. The train voided this measurement, and in 1850 the Ludwig's Railway Company could boast of having mastered the one-hour distance between Nuremberg and Fürth in 10 minutes. Now there were different time equivalents.

That was one side of the coin, while the other was the standardization of time. Up to this point every place had its own local time that historically depended on the position of the sun. Regional time differences between places disappeared in the course of travel. But with the new travel speed problems arose: As variations between local times became perceivable, national schedules were no longer meaningful. England took a pioneering role and in the 1840s began to standardize time. Each railway company initially

9 Quoted from Schivelbusch 1986, 55.

10 Güse 2001; Wagner 2001.

Fig. 1 Joseph Mallord William TURNER: Rain, Steam, and Speed – The Great Western Railway (Turner Bequest, 1856; © The National Gallery, London).

introduced a uniform and compulsory time on its route. The procedure to standardize time on the track was new, unfamiliar and – from today's perspective – idiosyncratic. The problem was that time in those days could not be passed on and communicated in real time. For the mail train of Grand Junction, it went like this: In order to ensure a uniform and compulsory schedule, each morning a messenger of the admiralty handed over a clock to a railway staff in London who rode on the train to Holyhead, the ferry port to Ireland, where it was given to an employee of the Kingston ferry. He brought it to Dublin, from where the clock was immediately returned to London and handed back to the messenger of the admiralty in the evening.

After the various railway companies connected their individual rail networks to each other, a common time, Greenwich Mean Time, was agreed upon. At first, it was solely a railway time that existed in addition to locally operating times. The more the regions were incorporated into the railway network, however, the more noticeable did the discrepancies between local time and railway time become. In 1880, the decision was taken to make railway time the universal time in England. Other countries soon followed the British example.

Why these examples that have rather anecdotal character for us today? I have only mentioned a few effects that resulted from the innovation of the railway. Many more could be added.[11] These effects are profound and extremely long lasting in their impact. However, there are also effects that do not initially come to mind when we think of the innovation of the "railway". If we were to examine these processes like an archaeological case, we would actually have problems, or even fail, to bring them into a causal connection with the introduction of the railway. The railway should not only be understood from its surface phenomenon "transport". It is important to identify the other effects as well, to make them visible in their causal connection, and to investigate them accordingly. This involves interactions and processes that remain so far outside the scope of innovation research, but that should be brought to light. Innovation processes usually have a main narrative which is considered particularly powerful. However, that is not the whole story; as the example of the railways shows, it is just a fragment.

2 Hybrid networks and affordances as a possibility of action

The example of the railway shows very pointedly that neither technologically nor socially deterministic views can sufficiently explain a bundle of processes of innovation. Technical constraints and the intrinsic logic of technical phenomena caused changes in many ways. The unprecedented speed in particular put more innovation into transition. The viewpoint of technological determinism will put forward good arguments that this technological aspect entailed numerous cultural, social, and political consequences. There were, however, social actors who ultimately enforced these changes due to specific new experiences. New styles of painting are not logical consequences of railway journey, they are an opportunity that was identified and realized by certain individuals. Without social acceptance and civil requirements for mobility – to spend the weekend by the sea, for example – the railway would not have experienced this triumphant success. It is social actors and social interests, as the social-determinist position argues, that pushes the innovation process.

Since both technology and social actors determine the form and course of innovation processes, both sides have to be included in the analysis. As Werner Rammert emphasizes, a clear dividing line between a cultural world of socially constituted meanings and a technological world of blind rule-following can no longer be maintained.[12] Overcoming unproductive front positions of technological and social deterministic approaches could be achieved through the Actor-Network Theory (ANT).

11 See Schivelbusch 1986.

12 Rammert 2007, 51.

ANT is inextricably linked to the French sociologist Bruno Latour, but also his colleagues Madeleine Akrich, Michel Callon, and John Law.[13] Strictly speaking, Actor-Network Theory is not a theory in the sense of the word, because it was developed as an analytical tool to examine the actions of social actors. According to Latour, the purpose of this approach is explicitly not to explain anything, but rather to 'thicken' the description.[14] Once the description is saturated, the explanation of social phenomena crops up automatically. I am not going to elaborate on this assumption here despite the fact that such an understanding of the field of sciences needs critical assessment.

Another aspect is noteworthy: In network-like contexts of action, things join forces with human actors. The old humanistic opposition of person and object is eliminated; according to this understanding, people and things rank equally and they jointly shape the result of social action. Things become actors.

An example that leads us back to the controversy between technological and social determinism may explain this.[15] Who kills? The firearm or the one who pulls the trigger? The apologists of the National Rifle Association rely on the social argument and say: the person, of course. The critics advocate technology and recognize the weapon as responsible for murder – innocent citizens become murderers only through the weapon. To Latour, both are wrong; the basic error lies in the approach to look at only one side of each situation: weapon or person. The weapon does not kill by itself, the person perhaps may also not want to kill; however, the weapon offers him/her the possibility to realize an action. The person and the weapon fuse together and become one actor: a weapon-human or a human weapon. The relationship is symmetrical since without each other both would be something else – with an entirely different outcome. Neither weapon nor person act by themselves, the action is carried out by one actor, fused from the two: The actor is a hybrid player, an assemblage, a network.[16] Here, unlike in technological and social determinism, action does not have anything to do, figuratively speaking, with action and reaction, but rather interaction.

By creating a hybrid actor, the deeply rooted barrier in humanism between the subject and the object is lost. To what extent artifacts really have agency will, however, not be discussed further here. Their potency is indisputable, as Latour demonstrates with the example of the 'Berlin key'.[17] This key relentlessly determines the actions of its users when passing a door. Each artifact has its script, its demanding character, its potential to make people act accordingly.

A similar idea was previously developed by the American psychologist James J. Gibson.[18] Influenced by Gestalt psychology, he developed the concept of "affordances", a

13 For review see Belliger and Krieger 2006.

14 Latour 2007, 237–238; 252–257.

15 Latour 2006.

16 Latour 2006, 488.

17 Latour 1996.

18 Gibson 1982; for review see e.g. Greeno 1994; Jenkins 2008.

neologism that he derived from the English verb "to afford". In his understanding, the affordances of an environment are what it offers a living being, what it provides or furnishes.[19] Already in the Gestalt psychology of Kurt Lewin, things had *Aufforderungscharakter*;[20] Kurt Koffka spoke of "demand character".[21] However, the thingly effect was not seen as emanating from the thing itself but rather from the recipient. It was conceptualized from the recipient's perception and needs. The demand character was not an independent value of things. Gibson, however, saw that affordances exist even without the potential users, therefore affordance is a property inscribed in things.[22] Regardless of the viewer, the affordance of a thing is present, even if it is not perceived as such and also if it does not meet the current needs of the viewer.

Gibson's concept of affordance leaves open how the potential user realizes the possibilities of a given affordance. Possibilities or offers alone will not lead to action; an action evoking demand also does not emanate from the object. Moreover, since the exclusive focus on the thingly side excludes the actor, critics emphasize the importance of the specific situation of an action in which things and users converge. According to Chemero[23] and Knappett[24], affordances are not properties of things but of specific situations in which things and potential users meet. The object is thought of in accordance with its user.

While Gibson stressed that affordances open possibilities for action, Withagen et al. expand this idea: They define affordances as action possibilities "that can invite".[25] An object usually allows different ways of use, but not all affordances also invite to take action. The actions a user feels invited to depend on several factors. These include the user's specific skills, her or his experience and needs, but also the respective social context, which facilitates or hinders specific actions. The focus on the invitation character of things puts them into a mutual relationship with their users. Possibilities for action and potentials for use are realized only in specific situations; symbioses of things and users, hybrids, are the focal point of action. For both sides, a potential use arises in the situation of an action: The user can achieve the objective of the action in the action itself while the thing, in enabling the user, realizes one of its potentials that results from the affordance. The gain for things here, however, is only to be understood in a figurative sense, since objects have neither objectives nor interests, so that the realization of an affordance is not an aspired gain of things.

19 Gibson 1982, 137.
20 Lewin 1926, 353; Lewin 1935, 77.
21 Koffka 1935, 345–347; 355–357.
22 Gibson 1982, 150.
23 Chemero 2003, 187.
24 Knappett 2004, 46.
25 Withagen et al. 2012, 255.

3 *Eigensinn*

In order to realize potential uses of objects, the user must comprehend them. Following a concept by Hans-Jörg Rheinberger, Hans Peter Hahn refers to "epistemic things".[26] The user must assess potential and reasonable uses; the epistemic approach to the object is the prerequisite for its use. Known to everyone from experience, objects occasionally refuse epistemic access and the possibilities of their application cannot always be recognized.[27] Things often do not 'behave' as desired: On the one hand, they break down or fail us and on the other, their complexity bars the users from their use. They are – overstrained – unable to grasp the potential uses or retrieve them as planned: Things have *Eigensinn*, or obstinacy.[28]

Taking the obstinacy of things into consideration, the controversy described above between the technological and social deterministic approaches gains a new dimension. The interplay between the objective possibilities of things and the actual application by users bridges the artificial divide between the interests of the acting individual and the constraints of technological rule enforcement. As much as things have their obstinate objective possibilities that enable or constrain actions, users also have *Eigensinn*. Their skills and expertise in application, as well as their interests, likewise determine options for action in the use of things. Just as users 'overstrain' or 'understrain' the used items with their possibilities and objectives, they are 'overstrained' or 'understrained' by the affordances of things. Things break through wear and improper use, and they escape their intended use, thus limiting options for action. However, because of their affordances they also offer options for action that are not requested or recognized by the users. Due to the objective possibilities of both sides and the users' specific target of action, users and things exist in an antagonistic relationship that is pushing for a balance in each specific application.

But let us return to the actual topic at hand here: the investigation of innovation processes. The ongoing discussion about the relationship between technology and people, or, as commonly discussed more recently, the relationship between things and users, suggests that things, their scripts and their logic must be involved in the analysis.

4 Innovation as reason for change

Innovation as social appropriation of the new has to be clearly separated from invention, the actual creation of the new.[29] The origin of inventions may be sought in the

26 Hahn 2013, 17–19.

27 See, e.g., with impressive examples Norman 1989; likewise Hahn, this volume.

28 Hahn 2013.

29 Burmeister and Müller-Scheeßel 2013.

need to overcome restrictions that are determined by things or techniques and are seen as obstacles for action. New features can also broaden options for action and produce entirely new targets of action. Becoming aware of new areas of action eventually leads to the appropriation of a new feature, the actual innovation. It is easy to imagine that these new features confront users with their *Eigensinn* and put their specific affordances up for disposal.

New solutions often create new problems, however, and innovations usually entail unintended consequences and unforeseen side effects. Schivelbusch's survey clearly demonstrates this. The history of the railway is more than the planned enhancement of the efficiency of mobility and transport services. The teleological perspective of innovation research with its causalistic view that is centered on intention-orientated development processes falls short here, because it produces blind spots. The unexpected consequences of an innovation become invisible even though they affect cultural practices and configure social life. They are, therefore, a genuine subject of investigation. Innovation is, as Michael Schiffer accurately put it,[30] a cascading process that continuously triggers further developments.

In the workshop that is at the origin of this book, it was our goal to bring into view innovation processes and to do so within their broader context, that is, to examine the interdependence of innovations and their wider social framework and track their possibly unintended, unforeseen consequences. As stated in our call for papers for the workshop, we can imagine this kind of impact in a number of social fields of action.

Embodiment: Technological innovations require new skills and motor habits; altered manual activities can lead to the formation of new body techniques; the embodiment of new forms of knowledge and habitual techniques can produce not only new skills, but also limit the scope of established skills. Consider, for example, the development of fine motor skills which is required for the use of fine ceramics; or, in the negative case, the loss of capabilities to orient oneself today without modern navigation systems.

Perception: The acquisition of new technologies can change the perception of the material and immaterial environment; for example, it can be assumed that through domestication, human beings changed their relationship with animals substantially, or that the self-perception of humans has been re-shaped through the control of water or fire.

Practice: The manipulation of the natural environment may have an impact on procurement strategies, production, and consumption; these changes entail new cultural practices that can and should be explored.

30 Schiffer 2005.

5 The innovation of the wagon – possibilities and limitations of a new technology

In the following, I briefly discuss some of the broader aspects presented here with reference to a specific case: the innovation of the wagon. Despite numerous detailed studies, the history of the wagon is still underexplored and – in my opinion – carries some crucial misunderstandings. As with any archaeological case study, the beginnings of this technology are in the dark and thus escape systematic examination; much remains speculative and hypothetical. However, this should not prevent us from approaching the case intellectually, to encircle it, and – as I want to show – not only continue to illuminate but to understand this new technology in terms of affordances and *Eigensinn*.

Function and importance of the wagon in prehistory are usually thought about from today's perspective. For us a life without wagons is hard to imagine; the possibilities offered by vehicles with regard to mobility and transport are so obvious that this potential is projected back into the past. The wagon is an integral part of the influential concept of the Secondary Products Revolution first formulated by Andrew Sherratt – but here we need to be exact: Sherratt stressed the importance of the use of animal traction which is clearly evidenced by early wagon finds.[31] Compared to the plough, however, the wagon appears to remain quite insignificant, although its potential for transport and mobility is widely accepted.[32] Is this the reason for the resounding success of the wagon? Hardly any other innovation has spread so rapidly in prehistoric times. In the middle of the fourth millennium BCE, we see the first archaeological evidence for the existence and use of the wagon emerging simultaneously in Northern Europe, the Caucasus, and Mesopotamia.[33] This astonishing and wide-ranging simultaneity provoked criticism of diffusionist models and led to the formulation of alternative polycentric development models – which can, however, hardly explain the phenomenon in better terms.[34] Just as impressive as the simultaneous first appearance of the wagon in different regions of the world is the diversity of the societies adopting it – just consider the contrast between the Funnel Beaker culture of Northern Europe and the early city-states of Mesopotamia!

We will not solve the problem via a positivist reading of archaeological distribution maps. Of course, we can assume that an innovation must be widely established before it manifests itself in the archaeological record. The origins of the wagon and its early spread likely go back a number of generations before their first appearance in the archaeological record. Expanding the scope of observation and looking for possible channels and networks of distribution, we notice the spread of the prestigious, heavy copper tools and jadeite axes after about 4,600 BCE which geographically matches that

31 Sherratt 1981.
32 Vosteen 1999 denies this potential.
33 For review, see Bakker et al. 1999; Burmeister 2011.
34 See Burmeister 2012.

of the early wagons.[35] It is in this environment that we may find, if not the origins of the wagon, at least the mechanisms of its distribution. Making use of these networks, it appears that primarily prestigious objects were traded and prestigious knowledge was communicated. If the wagon and its early success story can be seen in this context, does this also foreshadow its social significance?

In order to answer these and other questions, we must first look at the technological and physical characteristics of the wagon. As simple as the early wagons may seem to us today, their construction and mode of operation was complex. It was a composite technology that essentially consisted of three functional components: 1) the principle of rotation, which either involved a wheel rotating on an axle or an axle rotating beneath the carriage; 2) the body of the wagon that was attached to the chassis, which allowed the transport of persons and goods; 3) the use of animal traction. If only one of these parts is missing, there is no functioning wagon. In Central America, for example, the technological requirements for wagons were available, but the appropriate draft animals were not, so that wagons were not used before the arrival of European colonizers. It is unlikely that all individual components of the wagon were developed from scratch. Spin-off effects from already available technologies seem to be more likely. Ann Brysbaert refers to them as "cross-craft interaction".[36]

We can only speculate from where the functional components of the wagon technology had been adopted. Possible sources of inspiration for this innovation disappear in the mists of prehistory. The principle of rotation as well as the basic technical principles of the wheel can be found in the potter's wheel and in spindle whorls. Timber rollers are suspected to have been a common means of transporting megaliths. While the timber rollers can only be deduced hypothetically, however, the spindle whorls are contemporary with early wheels. And yet, since they are a secondary product of wool processing, they belong within the sphere of the Secondary Products Revolution. In contrast, the potter's wheel already existed in Iran and Mesopotamia in the fifth millennium.[37] In fact, it may have been a role model for the wheel.

The body seems to have been the least original feature of the wagon. We may assume that sledges and travois were already known, although definitive evidence from regions of early wagon use is lacking. The principle of a platform or a box as a load bearer or load container, however, is as simple as it is obvious. In general, it should be noted that the technological expertise of manufacturing the body of a wagon was available in all Neolithic and Copper Age societies: The long-established practice of house construction was a prerequisite for the craftsmanship needed for wagon building.

35 References see Burmeister 2012, 86.

36 Brysbaert 2011.

37 E.g., Fazeli Nashli et al. 2010; Moorey 1994, 146.

The outstanding and revolutionary feature of vehicles is the use of external energy for locomotion. This energy is usually obtained from the use of draft animals, but human draft power is also a possibility, similar to later vehicles in China. The novelty in the use of animal traction lies less in the technical than in the ideological realm: the subjugation, in the double sense, of animals to people. The subjugation and exploitation of animals generates a new quality – a quality that most certainly had an impact on the worldview and self-perception of people. In what context animal power was used for the first time remains entirely unclear. It is one of the essential characteristics of the Secondary Products Revolution and is therefore closely linked to the wagon. The actual importance of animal traction, however, lies less in its function as an engine for the wagon than in enabling plough cultivation and enhancing crop yields. So far it cannot archaeologically be determined what came first: wagon or plough. While earlier evidence for the use of animal traction can be identified based on pathological changes in animal bones, it is unclear what was towed here. It is conceivable that heavy loads, such as tree stumps were initially pulled directly by animals.

Normally oxen were used as draft animals. For this purpose, they had to be trained, which was a tedious process, and they could not be used as food resource for many years. Their maintenance costs are considerable as well:[38] Draft animals are a means of production with high investment costs. This is echoed in the Code of Hammurabi, which states that two-thirds of the rent for a four-wheeled wagon (*ereqqu*) went towards the draft animals and associated driver.[39] Fields are usually only ploughed once or twice a year, but the necessary draft animals must be fed throughout the year. For economic reasons, it is hard to imagine that the plough was the starting point for the use of animal traction. Since harnessing techniques are a prerequisite for power transmission for wagons and ploughs alike, a *spin-off* effect or a reciprocal influence can be assumed.

Wheel and wagon exist in a socially embedded technological context. Technology neither emerges nor functions on its own. These interconnections are circumscribed rather vaguely in Ian Hodder's concept of entanglement.[40] In a preliminary article, he discussed the wheel that was, as he emphasized, not a product of the 14th millennium but of the fourth millennium BCE. He stressed that it is the task of archaeology to work out through contextual analysis, "why the wheel did fit so that it became selected in the fourth millennium".[41] It is common place that every thing needs a social context in which it becomes effective; every innovation, consequently, needs to occur in the right place at the right time to be realized. And yet, Hodder's argument is justified in every respect. The willingness and ability to adopt wheel and wagon reveals itself only

38 See Ebersbach 2002, 153–155.
39 Salonen 1951, 30.
40 Hodder 2012.
41 Hodder 2011, 185.

in retrospect and based on the knowledge of their social context. For this reason, it is essential to take a closer look at the *Eigensinn* of this new technology.

Wagons consisted of various joint wooden parts; individual components were sometimes kept in position by ropes, but many construction elements were also attached by connectors. This required a precise treatment of the wooden parts as well as a permanent protection of the wood from drying out. Moisture loss caused the parts to shrink, preventing their exact fit. The result could be premature wear and breakage. The untroubled wagon ride demanded precise manufacturing techniques and regular maintenance. In order to prevent the wood from drying out, wagons were kept moist, whether in their entirety or in parts. The frequent finds of wagon parts along lakeshores or on the edge of bogs may likely be explained by the "watering" of wagons.[42] Consequently, the wagon was a device that required regular "service".

Numerous archaeological examples exist that demonstrate how breakdowns were a regular aspect of wagon rides[43]: As axles ran hot, they could set axles and wheels on fire, a secure fit and the greasing of the moving parts were necessary precautions – but they did not guarantee protection. Due to wear and overstraining, axles broke at the weakest point; damaged components had to be replaced on the spot. Since the repair parts could not be crafted readily on the spot – and spares were rarely carried – the operating range of wagons was limited.

Seen from today's perspective, certainly the most peculiar feature of early wagons is that they were not steerable. We have to distinguish two basic modes of construction: the single-axle, two-wheeled cart and the two-axle, four-wheeled wagon. The former can be turned around the axle and was thus steerable, the latter was not. The wagon requires a king pin or pivot plate, so that the front axle is turnable; however, these were apparently not developed until the first half of the first millennium BCE.[44] Thus, it took nearly three millennia from the first appearance of wagons for the steerable wagon to emerge.[45] Bearing in mind that two-axle wagons had a wide distribution and, according to the archaeological record, were in many regions the only wheeled vehicles, we have to question the functionality of the wagon. Numerous finds with traces of wear and repairs at wheels and axles suggest that they were used in everyday life. The unwieldy wagons seem to have been primarily suitable for driving straight, which is even more surprising given that the landscape of, for example, Northern and Central Europe was barely open until the Bronze Age.

This technical limitation had serious implications for the use of the wagon as it meant that wagon rides required linear routes or straight paths. In the Northern Alpine

42 Burmeister 2004, 334.

43 Burmeister 2003.

44 See Burmeister (in press) for discussion and references.

45 See Burmeister 2012, 87–88; for discussion see Burmeister 2010.

region, the first tangible use of wheeled vehicles goes hand in hand with a transformation of settlement structures. The formerly scattered settlement plans turned into more linear settlement patterns where houses stood close together with their gables aligned and facing a paved village street.[46] This new type of settlement was better suited for the use of wagons than the previous one. However, whether this change can be causally related to the use of wheeled vehicles is difficult to determine based on archaeological evidence alone. While the carts common in this region may not have required such an adjustment, it was certainly conducive to traffic within the settlement. Such a redesign of settlement layout would have also impacted the organization of village life.

The wagon thus offered potential in terms of mobility and transport, which expanded the options for action by people. However, in order to exploit this potential, several conditions had to be met. Above all, these concern the operability of the wagon itself and the operational readiness of the draft animals. The limited steerability, in contrast, considerably restricted the potential use of wagons. Driving off-road requires a largely unobstructed landscape, which certainly only existed in the vicinity of settlements. Supra-regional transport requires a good road system; roads must be kept clear, which requires regular maintenance; a functioning supra-regional road network needs overarching coordinating entities, which likely did not exist in most pre-Iron Age societies. It is therefore hardly surprising that the first evidence of road construction originates from the first millennium BCE.[47] The social context of the Neolithic and Chalcolithic cultures obstructed the functional use of wagons for supra-regional transportation.

Our ideas of mobility and fast coverage of spatial distances can hardly be applied to the wagon in prehistoric times. This technology had its *Eigensinn* which practically restrained the realization of the potential use of wagons that is so familiar to us today. *Eigensinn* reduced the operating range of wagons to the immediate environment of settlements. If the wagon offered an economic benefit, it was the transport of harvest and leaf fodder into settlements.[48] Purely utilitarian considerations can therefore hardly explain the triumphant success of the wagon in the fourth millennium BCE. At least from today's perspective, its practical utility was kept within limits; additionally, it required high maintenance costs for draft animals. Therefore, we have to ask for the affordances of the wagon beyond transport and mobility. The early archaeological record can give us a first hint here: From the beginning, the wagon was also a stately and divine vehicle – a function that was likely encouraged by the economic obstacles of using the wagon on an everyday basis. The wagon also granted people a completely new kind of movement: self-movement – or automobility – which physically lifted the driver out of the crowd. Sitting or standing on top of the wagon, one experienced a kind of movement

46 Schlichtherle 1997, 93–95; Zeeb 1996, 101.

47 See Burmeister 2012, 91–92.

48 Burmeister 2012, 93.

Fig. 2 Chariot drawn by a team of oxen in the entourage of the Nubian prince Hekanefer.

that was virtually abstracting from the body: One did not arrive, one appeared. We can easily imagine that this spawned a new sense of self.

This sense was developed further with the introduction of the horse-drawn chariot. In the second millennium BCE, this vehicle allowed riders to reach the previously unknown speed of up to 40 kilometers per hour. Speed was depicted, for example, in contemporary Near Eastern and Egyptian epigraphy and iconography, where it was ideologically exaggerated. The driver experienced a veritable thrill of speed; driving the chariot also placed special demands on the driver's dexterity. Again, we see a new kind of movement that exceeded the former everyday experience. For this reason, the mural in the grave of a high Egyptian official with the presentation of a Nubian princess on a chariot drawn by oxen (Fig. 2) functions as a propagandistic representation of a world upside down and, from the Egyptian point of view, of a re-establishment of the ethnic order, which had begun to sway due to the Egyptianized Nubian elite.[49] Affordance here becomes caricature.

49 Burmeister 2013.

In summary, it can be said that the wagon enabled new forms of movement and we may assume that this exerted a great fascination. We can imagine that prehistoric people might have reacted in a way similar to the visitors of the Paris Motor Show of 1955 when the Citroën DS was presented for the first time to the public. Roland Barthes has analyzed the encounter with a car that was considered futuristic and revolutionary at the time, as the magic of the new object and its appropriation.[50] Fascination, admiration, and a quasi sacral magic of objects also need to be considered alongside the innovation of the wagon – without these factors, an understanding of this technology would hardly ever be possible.

The brief consideration of *Eigensinn* as well as affordances of the early wagon demonstrates the possibilities and limitations of this technology; it shows that both social context and actors on the one hand, and technical prerequisites on the other contribute to our understanding of this innovation; it cannot be understood – and, consequently, cannot be investigated – solely from the perspective of acting subjects or from that of technical rationality. Wagons are a social practice that results from the aims and capabilities of the users just as much as from the technical affordances and the *Eigensinn* of the wagon. Thus, wagons have their particular place that is tied to a specific cultural and historical context.

Taking *Eigensinn* and affordances into consideration, we learn more about the technical and social changes that lie beyond the obvious aspects of mobility and transportation. Some are introduced here: production technologies in wood processing, investment in animals as a means of production, shaping of landscape and settlement structure, new forms of movement, and changing self-perception; others are yet to be discovered and discussed.

Affordance and *Eigensinn* of wagon technology expand the options of action available to the user, and they limit others, against all expectations, such as mobility. The example of mobility in particular demonstrates clearly that affordances can only be realized under specific cultural conditions. Today's importance of mobility stems from making use of further affordances of the wagon – affordances that could not yet have been realized in prehistoric times.

50 Barthes 1972, 88–90.

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