BEYOND OR WITHIN THE LIMITS? A MISLEADING DILEMMA FOR CURRENT TECHNOLOGICAL PROCESSES

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Abstract. The concept of limit offers an opportunity to summarise some milestones in the evolution of technological processes. Although this concept is theoretically and empirically problematic in the light of contemporary scenarios, both as a factor that generates processes and as a demarcation between nature and artifice, it remains essential in at least two areas, namely innovation and sustainability. Indeed, a series of material and immaterial limits influence, and sometimes impair, implementation of the technological processes. The incentive to manage these limits has often acted as a lever for innovation, both in terms of processes and products. Above all, dealing with limits has been at the heart of the orientation towards sustainability since its inception. The scientific community and the general public have come to terms with the finite nature of non-renewable natural resources and with the need to limit emissions. In both cases, the limit is used as a warning, with fear of the transition from alarm bell to death knell for the planet. The concept of limit is also relevant to the adaptation strategies to Climate Change. However, the concept of limit as something that clearly establishes a "within" and a "beyond" has supported a misleading dilemma in the face of the development of global economy. A change of approach is, therefore, called for, replacing the opposition of the limit by the integration of the continuum, bearing in mind that the right time and the right measure have always been an indispensable qualitative range for technological processes characterised by ethical principles.

Keywords: Limits; Technological Process; Technological Product; Climate changes; Innovation.

From the limit to the continuum

The limit is a concept to which any technological process (understood as a sequence of human actions leading from the identification of a need to its satisfaction, through the production of an artefact) can refer. The way in which technological processes relate to the limit is changeable, and its evolution can be traced with reference to both the Past and the Present. Indeed, the relationship with the concept of limits in a given context often implicitly expresses the underlying reference values. Although there has been no shortage of theoretical contributions on the comparison of virtuosity, economic, and user or need values, the tendency to consider technology as "value-free" still persists, just as the technological imperative ("the temptation to always strive for the greatest technical achievement or complexity currently possible") often still justifies a conception of creativity as "innovative, adventurous, unrestrained" rather than "tempered by responsibility" (Pacey, 1983).

A reading that pits creativity against responsibility is the result of the cultural context of the last quarter of the 20th century. It reflects a Manichaean stance on the limits of technological processes, characterised by numerous overlaps with the issue of energy supply. The limit, in fact, is a concept ignored by the intoxication of industrialisation in the 19th century, demonised by the myth of progress in the early 20th century, and emphasised by the orientation towards sustainability at the end of that century. Such a perspective seems reductive and inadequate to face the challenges of the contemporary world. There is a need for a less simplistic interpretation to resolve the dilemma of staying within or going beyond all limits, a key theoretical question of technological processes in the 21st century.

The ability to activate technological processes has given humans an increasingly dominant role over nature, setting in motion an inexorable trend that has culminated in the Anthropocene, an era in which the overall material output of human activities ("anthropogenic mass") exceeds all "natural biomass" (Elhacham *et al.*, 2020). Underlying the quantitative superiority of technological products over nature is an enduring qualitative aspect. As a matter of fact, the vast majority of such products, from ancestral artefacts to handicrafts or industrial products, find their raison d'être in the extension of what can be achieved naturally. The effect of overcoming limits establishes the premises of a deep-rooted opposition between nature and artifice, in that nature imposes limits, and artefacts overcome them.

The terms of this contraposition are consistent with the polysemic character of the concept of limit itself, and the density of its meaning in relation to human existence (Ialenti, 2023). The polysemy of the term 'limit' is reflected in the semantic ambivalence of overcoming limits achieved by technological processes. Overcoming natural limits enhances human potential, also leading to our miserable conditions, at least according to the world view recognisable in Judaism and Greek mythology, at the roots of Western culture. In this approach, the artefact is not forgiven because it is the result of disobedience that has upset the idyllic balance between man and nature envisaged by the supernatural will in creation. The Tree of Knowledge in Eden, through which Satan tempts the ancestors, may symbolise the essence of the technological process (the immaterial aspects). The tamed fire, used in metallurgy and stolen from Zeus by the Titan Prometheus to give to man, may symbolise the tangible essence of the product (the material aspects). Thus, overcoming natural limits is at the root of the demonisation of technology, which has manifested itself since the advent of the First Industrial Revolution, and is always associated with sudden innovations and the ethical controversies they generate. This demonisation has been counterbalanced by the glorification of technology as an all powerful panacea in constant evolution, bent on transcending all limits. Demonisation and glorification have underpinned an enduring conflict between nature and artifice.

It should be added that in the contemporary scenarios the very notion of limit as a factor originating in technological processes has become blurred, forcing its revision or replacement. Indeed, as noted in the last quarter of the last century, such processes have lost their essence as a tribute to human needs, and have loosened their connection to specific spatio-temporal contexts (Jonas, 1979). Moreover, recent and increasingly urgent technological developments, triggered by digitalisation, have brought about disruptive changes in production, management and gov-

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01 | The "Blue Marble". The iconic photograph of the Earth taken on 07/12/1972 by the Apollo 17 space mission, which demonstrated even to the uninitiated the finite nature and fragile balance of the planet inhabited by humans (https://www.nasa.gov/image-article/apollo-17-blue-marble/; General Permission Granted)

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ernance systems, but also in the cultural roots of the concepts of Time and Space (Castells, 2010), both of which are closely linked to the concept of limit. This highlights how the concept is being challenged by flows that displace places, and by an instantaneous "timeless time", which defies measurement. In order to move beyond the simplistic contrapositions that prevailed until the last century, and in search of a methodological renewal adequate to contemporary challenges, the concept of continuum can be used to flank or even replace that of limit. Rather than focusing on contraposition as a category of thought, the tendency today is to look at the connections that can be discerned, even between domains that retain a distinguishable identity. For example, the contraposition between rural and urban domains is now considered unsuitable for describing the contemporary reality studied by Human Geography (Dymitrow, 2018). The "urban-rural continuum" is proposed as a testbed for unitary approaches that constitute a methodological "bonding agent", which can be applied to any context, such as the bioclimatic approach (Germanà, 2021).

In line with this juxtaposition or replacement of the concept of limit with that of continuum, the opposition between nature and artifice also tends to change its connotations. In the case of technological products in particular, which are essentially artificial, there is now a tendency to focus on the natural component in terms of the raw materials and energy resources used in their production. But even more significant is the shortening of the distance between the natural and the artificial, which can be seen in technological advances in the most diverse fields of application (medicine, agriculture, materials science), and which has made the argument heuristic even in the theoretical field. The artificial-natural distinction is "conceptually and empirically problematic", and reality is seen as a set of "intertwined phenomena rather than phenomena that are merely natural or merely artificial" (DesRoches *et al.*, 2019).

Areas of permanence of the concept of limit

If the limit as a factor giving rise to technological processes is in many ways a problematic concept, there are areas in which it is still fundamental today. A first area is the implementation of technological processes, which at all phases must deal with a varied set of limits, both material (resources) and immaterial (skills), which influence it, even to the point of impeding it in extreme cases. The detachment of technologies from the spatio-temporal contingent and dematerialisation are factors that tend to make the limitations affecting technological processes less easily identifiable. However, the incentive to go beyond the limits continues to be an important lever for technological innovation, pushing for more effective solutions in many respects (materials, resources and time required; achievable performance), with important consequences for the final product, as countless examples in varied application fields demonstrate.

A second area can be found in the explicit emphasis on the concept of limit that the orientation towards sustainability has placed since its inception in the last quarter of the 20th century, from the need for awareness of the "Limits to Growth" (Meadows *et al.*, 1972), to the definition of the maximum tolerable limit of global warming (UNCC, 2016).

Precisely, the awareness of the limits of natural non-renewable resources, previously considered inexhaustible (Fig. 01), helped to initiate this orientation, undermining the production paradigm consolidated with the advent of industrialisation, geared towards unlimited development, and upholding the principle of circular production. The aim is to reduce to zero the extraction of raw materials from nature, and the production of emissions and waste from processing and post-consumption.

The concept of limit in this case is well defined by objective data, which unfortunately show that the proliferation of institutional efforts, policy documents and scientific advances in recent decades have not significantly affected the trend of the global economy. Indeed, it continues to apply voracious production models that largely exceed the limits of resource reproducibility. The "circularity gap" is widening globally as the date of global "Earth Overshoot Day" continues to be anticipated. The alternative of secondary materials has fallen by 21% in five years, reaching only 7.2% of production in 2023, and «in the last six years alone we have consumed over half a trillion tonnes of materials – almost as much as in the whole of the 20th century» (Circle Economy, 2024).

Even at the other end of the linear production, the limit retains a role of precise guidance, both in reducing waste (by monitoring the "National recycling rate", the sole indicator of target 12.5 of the SDGs, to "significantly reduce the generation of

02 | As a technological tool, Icarus' artificial wings could only function at a safe distance from the humidity of the sea and from the heat of the sun (Germanà, 2025). Bas-relief "The Fall of Icarus", dated 17th century, Musée Antoine Vivenel, Compiègne, France (Public Domain)

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waste through prevention, reduction, recycling and reuse"), and in setting a limit on emissions of greenhouse gases, known to be responsible for Climate Change (CC).

Using the concept of limit, the transition from alarm bells to death knell for the planet is rapid, as demonstrated by the "Planetary Boundaries Framework" approach, a set of scientifically determined values to delineate the safety zone, as opposed to the uncertainty zone and the danger zone, with respect to nine major categories of human-environment impacts on the natural balance known in the Holocene (Rockström *et al.*, 2009). In such a framework, the concept of limit inevitably proves divisive. Indeed, in the CC approach, for example, it opens a gulf between denialism (which fuels indifference) and catastrophism (which fuels 'eco-anxiety'), both attitudes that justify inaction.

The search for CC mitigation and adaptation strategies goes beyond this gulf, in a realistic and action-oriented perspective. Unlike mitigation actions (which are considered preventive, because they aim to reduce the causes of CC and will not prove decisive in the short to medium term), the adaptation actions (which take into account the inevitable transformation of climate scenarios and tend to mitigate their effects) quickly raised the issue of their limits, in terms of environmental-physical, economic, and technological dimensions (Adger *et al.*, 2009, p. 337). Based on the recognition that adaptation can only be limited, and taking into account the multiplicity of actors and the complex variability of factors affecting adaptation, a distinction has been made between "hard" limits, that do not change, and "soft" limits, which may change over time (Klein, 2014; IPCC, 2023). In particular, soft limits change because they are "largely associated with human systems and are primarily influenced by a range of socio-economic, cultural and biophysical constraints" (Thomas *et al.,* 2021).

Beyond or within the uncertain continuum

The dilemma of whether to go beyond or stay within limits has proved to be a misleading one for contemporary technological processes. The very concept of limits is problematic. As a matter of fact, quantifying thresholds reduces the complexity of phenomena and produces segmentations rather than the interconnections that are needed today (Butera, 2021).

Awareness of limits and the need to stay within them underpinned the hypothesis of sustainable development, which the inertia of the previous economic-productive paradigm, based

03 | The turtle pushed by a sail is the symbol used during the Renaissance to depict the motto Festina lente. Fresco by Lorenzo Sabadini dated 1565, Palazzo Vecchio Firenze. Creative

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on industry/consumerism pairing, proved to be a mirage on a global scale in just a few decades. Rethinking the concept of limits can help avoid overly ambitious goals, and the inaction of catastrophism or denialism, setting the scene to proceed (according to the Latin motto *Festina lente*, without delay but with caution) (Fig. 03) with small steps, «pushing for measures that are flexible and can be progressively adapted to changes in the scale of the problems and in public understanding of the situation» (Bardi, 2011).

The deepening of the limits of CC adaptation is a theme that has led to the replacement of "incremental adaptation" with "transformational adaptation", which imposes a systemic reorganisation and revision of goals and values (Klein, 2014). The same result leads us to consider technological processes within an imperfect definition, finding support in the uncertain continuum represented by the appropriate time and extent, within which Icarus' artificial wings could have worked (Fig. 02).

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