

# Emerging Technologies

Subjects: Management | Engineering, Industrial | Others

Contributor: Andrzej Magruk

According to G. Veletsianos, from a general point of view, an emerging technology is “a new tool with promising potential”. However, an emerging technology is generally defined according to the field in which it is analyzed. B.R. Martin describes an emerging technology as a technology the use of which will benefit many sectors of the economy and/or society. Other important characteristics of emerging technology, according to D. Rotolo, D. Hicks and B. R. Martin, include radical novelty, relatively fast growth, coherence, and prominent impact. Which refers to the crucial following contexts: aspect of future time, anticipation, uncertainty and Industry 4.0. the following definition of an emerging technology has been created by the author – „*Emerging technology in Industry 4.0 is a technology the development of which, from today's point of view, is uncertain and not obvious, but through complex anticipatory research, it is possible to identify its potential radical impact in selected areas, e.g., social, technological, economic, scientific.*”

Keywords: uncertainty ; knowledge ; foreknowledge ; emerging technologies ; futures studies ; foresight methods

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## 1. Background

Emerging technologies in the context of industrial development 4.0 are burdened by some of the greatest potential uncertainties, especially with regard to their technological evolution and market acceptance, but also by the lack of definition of their boundaries <sup>[1]</sup>.

According to N. Pidgeon, we are currently confronted with the increasingly complex and, at the same time, uncertain and unpredictable nature of technological risks, as well as the need to control emerging technologies before their final application<sup>[2]</sup>.

The complexity of the development of emerging technologies at an early stage of research may lead to unintended consequences, such as systemic errors<sup>[2]</sup>. The aim of avoiding such undesirable phenomena is a forward-looking, systemic analysis of the aforementioned technological development in the form of foresight research. One of the main advantages of the foresight methodology is its set of numerous research methods, which can be used in very different contexts and configurations. These combinations should be based on an appropriate mix of complementary approaches and methods, which synergistically may be able to cope with inherent uncertainties and potential disruptions<sup>[3]</sup>.

## 2. Importance of Emerging Technology

B.R. Martin describes an emerging technology as a technology the use of which will benefit many sectors of the economy and/or society<sup>[4]</sup>. L. Porter, J.D. Roessner, X-Y. Jin and N.C. Newman define emerging technologies in the next 15 years as those that can have a significant impact on the economy<sup>[5]</sup>. B.C. Stahl identifies emerging technologies as those that have the potential to gain social validity in the next 10 to 15 years<sup>[6]</sup>. According to N. Corrocher, F. Malerba and F. Montobbio, the development of emerging technologies refers to technical, institutional and social changes<sup>[7]</sup>. This may have unintended consequences that increase uncertainty and ambiguity. Other important characteristics of emerging technology, according to D. Rotolo, D. Hicks and B. R. Martin, include radical novelty, relatively fast growth, coherence, and prominent impact<sup>[8]</sup>. M. Halaweh, on the other hand, lists the following attributes of an emerging technology: uncertainty, network effect, costs, unobvious impact, availability. These are not yet fully investigated<sup>[9]</sup>. According to Veletsianos, an emerging technology<sup>[10]</sup>: (a) may or may not be a new technology (depending on the context, an emerging technology may appear in one context, i.e., place, domain, or application, even though it is considered to exist in another<sup>[9]</sup>); (b) can be described as an evolving organism that exists in a state of “coming to being” and experience hype cycles; (c) satisfies the “not yet” criteria of not yet being fully understood and not yet being fully researched; (d) is potentially disruptive, but its potential is mostly unfulfilled. There is no final consensus-based definition of emerging technology due to different research perspectives, which in turn may lead to misinterpreting this term <sup>[8],[9]</sup>. The only certain feature—as R. Srinivasan has shown—of an emerging technology is the high degree of uncertainty associated with it<sup>[11]</sup>. This is due to the specificity of an emerging technology, whereby its future development is not based on well-

established knowledge and is therefore difficult to estimate<sup>[6],[12]</sup>. Furthermore, the uncertainty of emerging technology development refers, as M. Halaweh points out, to many variables, the values of which are unknown, unpredictable or unstable. This fact has a strong connection with the specificity of the future per se, which, according to K. Cuhls<sup>[13]</sup> and others <sup>[14][15][16]</sup>, is unknown and unpredictable; however, broad, general directions can be reasonably guessed or anticipated by foresight studies.

One of the overriding aims of anticipation activities should be the identification, comprehension and management of uncertainty. Situations of uncertainty—in terms of foresight—are those wherein it is impossible to predict what impact the decision will have, but different outcomes for these impacts can be anticipated<sup>[17]</sup>. In this process it could be very useful to explore different types of futures (of the development of emerging technologies) in their relationship with knowledge and foreknowledge ranges.

According to B. Martin (on the basis of M. Godet and De Jouvenel), there is always more than one possibility; therefore, foresight looks—in a systematic process—into the several alternative futures of science, technology, economy and society by using very rich and flexible research methodology. One aim of exploring these uncertain but possible future options is to identify areas of strategic research and the emerging technologies<sup>[4]</sup>.

Despite the fact that an emergence phenomenon relates to the process of creating, or becoming important and visible, it should be remembered that the most important area of emerging technology analysis should be the future of its development, which, from the point of view of its radical novelty, is characterized by a high degree of uncertainty. Uncertainty is one of the key starting points for many different studies focusing on the role of technological development expectations<sup>[8]</sup>.

One of the characteristics of contemporary technological and economic development is the increasing importance of uncertainty<sup>[18]</sup>.

For further time horizons, especially in complex systems such as Industry 4.0, uncertainty increases and deepens, while the predictability of the development of the studied phenomena decreases. This results from, among other things, the complexity of the features, structures and behaviors of the analyzed systems, which usually go beyond the area observed and verified by the available knowledge, both subjectively and objectively.

Uncertainty also arises in the process of forming emerging technologies. This is due to the non-linear and multifactorial development of such technologies, and because, from today's point of view, work on them is still in progress.

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