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RETHINKING THE ROLE OF GREY LITERATURE IN THE FOURTH INDUSTRIAL REVOLUTION

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Abstract

The world is at the dawn of a new industrial revolution that will fundamentally change the way we live and work. Many consider this the Fourth Industrial Revolution (4IR). While the First Industrial Revolution (1IR) mechanized production using water and steam power, the second one brought mass production using electric power, and the third one was characterized by automation and digitization, mainly using electronics and information technology.

The 4IR is building upon the third one, but the difference, and its main contribution, is the fusion of technologies that are blurring the lines between the physical, digital, and biological worlds. This is further enhanced by the emerging progress of technology in fields such as quantum computing, machine learning, artificial intelligence, robotics, virtual assistants, the Internet of Things, self-driving cars, drones, 3-D printing, nanotechnology, biotechnology, traffic and security monitoring systems, and renewable energy. This paper examines the potential impact of the emerging 4IR on grey literature (GL) and is based on analysis of the most prevalent current trends and developments in “cyber-physical systems” that connect machines, computers and people. It will examine the need to rethink the definition of GL, its creation and publication types, processing, sustainability and usability. Given the magnitude of the potential impact of the 4IR on GL, the question is what challenges the 4IR will pose to GL managers. One could assume that the acquisition of new knowledge and skills, and the revamping of existing processes and methods will be necessary. Becoming aware of this new phenomenon is only the beginning. It needs to be followed up by professional development and adequate training. Finally, the job of GL professionals will be to promote and publicize the usefulness and importance of GL, not only in their daily work, but also in research and science.

Keywords
Grey Literature; Industrial Revolution; Information Technology; Information Management

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Introduction
The last 230 years, known as the '*industrial age*', started with the use of steam-powered machines in textile production and the introduction of the first mechanical loom in 1784. The introduction in 1870 of electrical energy, mass production and assembly lines marked the transition to the 2IR. The second half of the 20th century, brought us computers and electronics, which for many indicated the 3IR. Their massive spread was brought about by an increase in speed and functionality, along with a decrease in price and size. Machines became interconnected, were able to 'talk' to each other, and could do many jobs previously reserved only for people. For many, the introduction of these cyber-physical systems marked the beginning of a new era, the Fourth Industrial Revolution.

Although the 4IR is building upon the 3IR, the difference, and its main contribution, is the fusion of technologies that is blurring the lines between the physical, digital, and biological worlds. The 4IR already connects billions of people through powerful communication networks and smart mobile devices, offering access to an immense amount of data and information through high-speed internet access and unlimited storage. This affects our lives, our identities and the way we govern our societies, manufacture products and deliver services.

All of this is further enhanced by the emerging progress of technology in fields such as quantum computing, machine learning and artificial intelligence, robotics, virtual assistants, the Internet of Things, self-driving cars and drones, 3-D printing, nanotechnology, biotechnology, traffic and security monitoring systems, and renewable energy.

This paper examines the potential impact of the emerging 4IR on GL and it is based on analysis of the most prevalent current trends and developments in "cyber-physical systems" that connect machines, computers and people. It does that by looking into the historical content of the 4IR, the various terms used for the same concept, the basic pillars of 4IR and its overall impact on the way we manufacture products, manage companies and processes, and run our daily lives. It will examine the need to rethink the definition of GL, the creation and types of GL, processing, sustainability and usability. Given the magnitude of the potential impact, the question is what challenges the 4IR will pose to GL managers. It can only be assumed that it will demand the acquisition of new knowledge and skills, and the revamping of existing processes and methods. Becoming aware of this new phenomenon is only the beginning. It needs to be followed up by professional development and adequate training of GL users. Finally, the job of GL professionals will be to promote and publicize the usefulness and importance of GL, not only in their daily work, but also in research and information science.

In conclusion, the paper summarizes the future of GL, its volume and formats, a possible new definition refocusing on quality, intellectual property, curation and sustainability, the need for increased knowledge and visibility, and its improved relevance to our work.

History of Industrial Revolutions

Around 230 years ago, the world progressed from the agricultural to the industrial age (IA). During the ***agricultural age***, wealth came from the land and farming. With the introduction of technology, namely water mills, hydraulics, steam engines and coal, the agricultural age gave ground to a more superior industrial age that no longer depended on the land. The IA started with the use of steam-powered machines in textile production and the introduction of the first mechanical loom in 1784, which marked the birth of the factory. This became known as the ***First Industrial Revolution***. Power from water ran all the machinery in mills that were placed near rivers and streams. This was a great improvement, however, limited mobility, together with the need for a steady flow of water, became a limiting factor for development. The introduction of steam engines, which used coal, was the turning point in revolutionizing the production of iron, railroads, textiles, and the printing press.

The introduction of electrical energy, mass production, conveyer belts and assembly lines, which started in 1870, marked the transition to the ***Second Industrial Revolution***. Steel and petroleum became the major products that changed or enabled many other improvements and developments in transportation, construction, lightning, communication, and new materials such as plastic. The 2IR, also known as the ‘Technological Revolution’, lasted until the start of World War I in 1914.

The second half of the 20th century, brought us computers and electronics, which resulted in the digital automation of production using automation and IT. This, for many, indicated the ***Third Industrial Revolution***. It is often called the computer or digital revolution because it was catalysed by the development of semiconductors, mainframe computing (1960s), personal computing (1970s-1980s), and the Internet (1990s). (Schwab, 2016). The introduction of industrial robots and robotics affected factories and industrial production.

It should be noted that there are some authors that do not accept the difference between the third and the fourth industrial revolutions, categorizing them both under the Third Industrial Revolution (e.g. Rifkin, J. 2011; Anderson, 2012; Dosi, 2013).

The increase in speed and functionality and the speed of computers, along with a decrease in price and size, brought us to a stage where machines became easily interconnected, ‘talking’ to each other, ‘talking’ to humans, and doing many jobs previously reserved only for people. For many, the introduction of ‘Cyber-Physical Systems’ (CPS) marked the beginning of a new era, the era of the ***Fourth Industrial Revolution***. Robots, intelligence, automatons, the reduction of human labour and mediation via tools, appliances, machines, industrial automation and office automation are becoming widespread (Bloem et al., 2014). Highly intelligent CPS can autonomously perform end-to-end activities along the value chain.

Figure 1 visually represents the historical time-line of the industrial revolutions, listing the basic characteristic elements, while, at the same time, indicating the degree of complexity.

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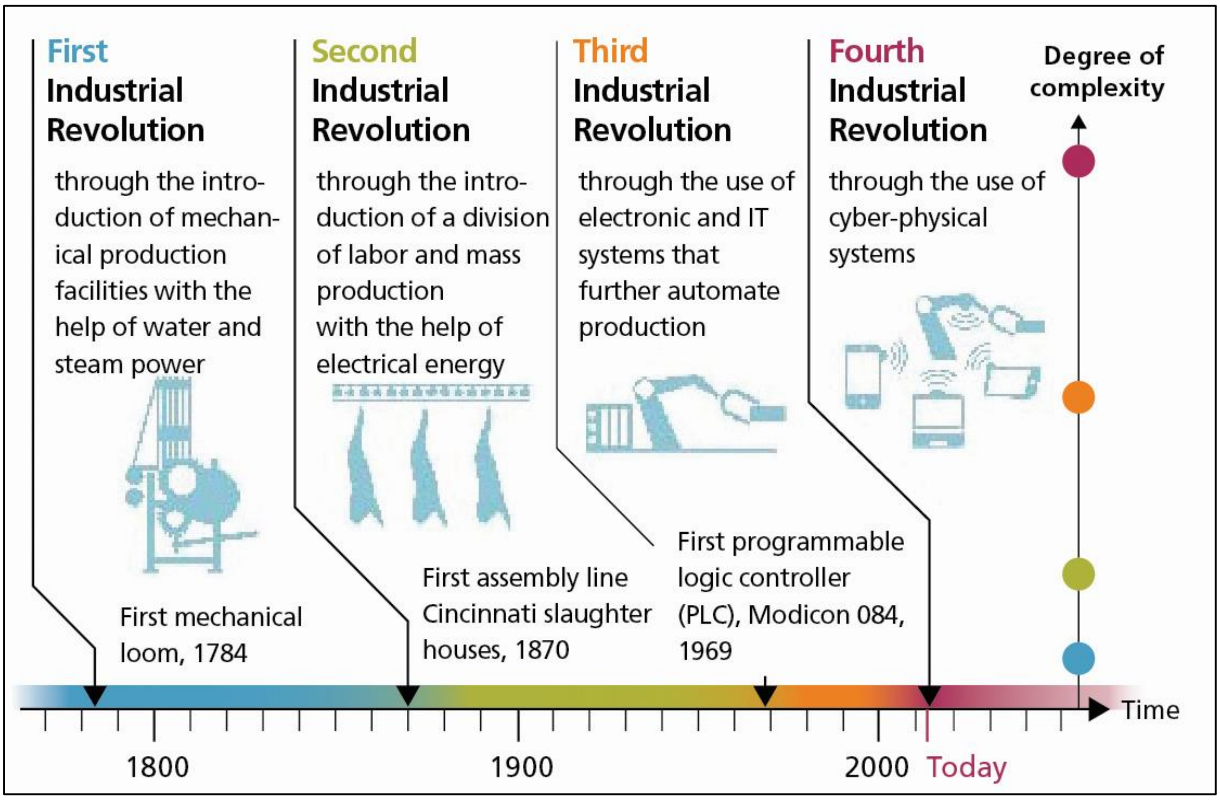

Figure 1 History of industrial revolutions (DFKI)

Definition of the Fourth Industrial Revolution

There are a number of similar terms and corresponding definitions used to describe this new period of industrial development. Some of the most popular are Industry 4.0, the second machine age, the Fourth Industrial Revolution, smart factory, Industry X.0, and digital workplace.

The term ***Industry 4.0*** originates from Germany's 2011 Hannover Fair. It was a project of the German government to promote the computerization and innovation of manufacturing, in particular the reorganization of the global value chains. The essence of Industry 4.0 lies in a modern and modular structured factory, where physical processes are controlled by cyber physical systems that create a virtual world for making decentralized decisions.

The Second Machine Age indicates a stage when digital technologies (e.g. hardware, software and networks) are becoming more sophisticated and integrated and are transforming societies and the global economy. According to Erik Brynjolfsson & Andrew McAfee (2014), the world is at an inflection point where the effect of these digital technologies will manifest with 'full force' through automation and the making of 'unprecedented things'.

Professor Klaus Schwab, founder and Executive Chairman of the World Economic Forum, is the creator and the strongest proponent of studying the phenomena and using the term ***Fourth Industrial Revolution***. He believes that we are at the beginning of a revolution that is fundamentally changing the way we live, work and relate to one another. A range of new technologies that are fusing the physical, digital and biological worlds characterizes this new revolution, affecting all disciplines, economies and industries, and even challenging ideas about what it means to be human. (Klaus Schwab 2016).

The ***Smart Factory*** or ***Smart Manufacturing***[1] is an environment where machinery and equipment are able to improve processes through automation and self-optimization. ‘Smart’, because of the combination of production, information, communication technologies, sensors, motors and robotics, connecting the ‘shop floor’ to the ‘top floor’.

Accenture[2] favors the term ***Industry X.0***, the cyber-physical production system that combines communications, IT, data and physical elements. Machines “talk” to products and other machines, objects deliver decision-critical data, and information is processed and distributed in real time resulting in profound changes to the entire industrial ecosystem.

Gartner[3], another major world consulting company, talks about the ***Digital Workplace*** which enables new, more effective ways of working; raises employee engagement and agility; and exploits consumer-oriented styles and technologies.

The Pillars of the Fourth Industrial Revolution

Just as there are many takes on the definition itself, there are also many opinions about the main pillars of the 4IR. Klaus Schwab talks about three groups of pillars or drivers, namely physical, digital and biological, with each one of them having related products and innovations. The World Economic Forum talks about 13 signs of the Fourth Industrial Revolution[4]. The European Union talks about ‘Nine Pillars of Industry 4.0’[5], while the United Arab Emirates launched an unprecedented six-pillar plan to prepare for the Fourth Industrial Revolution[6].

Figure 2 lists some of the major drivers and pillars of the 4IR. It includes big data, artificial intelligence and machine learning, real-time analysis, robots, sensors, nanotechnology, 3D printing, Internet of Things, numerous smart devices, cyber security and visualization. The most important and fundamental of these are probably processing power, communication speed, artificial intelligence, augmented reality, and robotics.

[1] The National Institute of Standards and Technology (NIST) defines Smart Manufacturing as systems that are “fully-integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs.”

[2] Accenture PLC is a global professional services company providing a range of strategy, consulting, digital, technology & operations services and solutions. www.accenture.com

[3] Gartner, Inc. is one of the world's leading research and advisory companies. The company helps business leaders across all major functions in every industry and enterprise size with the objective insights they need to make the right decisions. www.gartner.com

[4] https://goo.gl/pyCK8m

[5] https://goo.gl/ZwzVm1

[6] https://goo.gl/BtzyJF

Figure 2: The Fourth Industrial Revolution pillars

The General Impact of the Fourth Industrial Revolution

The prediction is that the impact of the 4IR will be felt by all parts of society and through all of its activities and it will not be a small tremor. Every single activity and every industry will be affected in some way. The three main activities that will be impacted are:

- The way we manufacture products;
- The way we manage processes and companies;
- The way we run our personal lives.

The impact of the 4IR on the way we manufacture products is already present in many of the leading factories and production facilities. The impact can be noticed through:

- Reduced manual labour;
- Increased use of robots, sensors, artificial intelligence (AI) and machine learning;
- Automated supply chain management;
- Reduced level of stock;
- Stronger link between customer demands and production;
- Highly individualized and personalized products.

The impact on the way processes and companies will be managed is still not perfectly clear, although some indications are already present. They include:

- Horizontal and vertical integration through companies and entire industries;
- Removal of organizational silos, insistence on self-run and self-managed teams, building the 'system of systems';
- Real-time monitoring and planning;
- Introduction of 'lean concepts' (i.e. eliminating anything useless) ;
- Fast response to change and quick delivery using Agile;
- From reactive to predictive mode of operation and management.

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The impact of the 4IR on the way we run our personal lives will be manifested in some, or even all, of the following ways:

- The appearance of the almost omnipresent Internet of Things, including our households;
- The use of smart phones, need for constant communication and danger of spying; threats to our private lives through unauthorized use of security cameras and surveillance equipment;
- Unpredictable growth of society's poor and rich parts;
- Shopping and retail industry (e.g. use of drones and already present online shopping);
- Work environment (remote/mobile work; 24/7 availability);
- Education (e.g. MOOCs, training for jobs vs. training for skills);
- The open access movement (e.g. the role of intellectual property, open science, crowd sourcing).

"The challenges are as daunting as the opportunities are compelling. We must have a comprehensive and globally shared understanding of how technology is changing our lives and that of future generations, transforming the economic, social, ecological and cultural contexts in which we live." (Schwab, 2016).

Impact of the 4IR on the Grey Literature Concept

A valid question to ask is one about the current use and the importance of GL, not as a source of information, but rather as a topic of research itself. In other words, is GL still a subject of scientific study and research? A quick look through ScienceDirect[7] using the phrase "grey literature", results in 7,459 hits. As Figure 3 shows, the number of articles that either deal with or mention GL had a steady rise in the last 9 years, from only 253 references in 2009 to over a thousand in 2017. The two articles listed for 2018 are still in print. This is a good indication that interest is still there and that further exploration of the future and the role of GL is still valuable.

There have been many attempts to describe the concept of GL and to assign it a proper definition. The results achieved while doing this tell us that GL is much easier to ***describe*** than to ***define*** (Schöpfel, 2010).

Figure 1: ScienceDirect search results

[7] http://www.sciencedirect.com/

The 12th International Conference on Grey Literature (GL12), held in Prague in 2010, came up with the following definition:

> *"Grey literature stands for manifold document types produced on all levels of government, academics, business and industry in print and electronic formats that are protected by intellectual property rights, of sufficient quality to be collected and preserved by library holdings or institutional repositories, but not controlled by commercial publishers, i.e., where publishing is not the primary activity of the producing body".* (Farace, D. and Schöpfel, J., 2010).

Thanks to the hard work of the Prague definition authors, Dr. Farace and Dr. Schöpfel, in promoting grey literature and related research, and to the work done by GreyNet International[8], this definition is most widely accepted and followed.

Another interesting attempt to add an additional 'modern' twist to the definition of GL was to look at it from the perspective of traditional publishing, which usually goes through a peer-review process. Accordingly, GL is regarded as ***"****the diverse and heterogeneous body of material that is made public outside, and not subject to, traditional academic peer-review processes****"***. (Adams at al. 2016).

Although this definition brings into focus an interesting aspect of GL, it is very limiting, especially taking into consideration new challenges brought about by the IR.

The current concept of GL, as stated in the Prague definition, still has some challenges, especially from the 4IR perspective. The main challenges relate to multiple types of originators; humans and machines, volume and type, and the speed of GL creation. Therefore, the focus of the GL definition needs to shift more to quality, intellectual property, curation and sustainability. In its current form, the definition risks becoming obsolete due to its inability to differentiate GL from other types of documents.

A proposed new definition, which might help meet some of the above-mentioned challenges, regards GL as *any recorded, referable and sustainable data or information resource of current or future value, made publically available without a traditional peer-review process.*

Impact of the 4IR on Grey Literature Types

Let us examine just one of the facets of GL – its multitude of types and formats. Even a quick look at papers written about GL dealing with various formats and types, suggests a great variety. Figure 4 is a short list of possible types. However, a more complete list is available at the GreyNet International website[9]. It lists over 150 document types specific to GL.

[8] **http://www.greynet.org/**
[9] **http://www.greynet.org/greysourceindex/documenttypes.html**

Bibliographies	Rejected manuscripts	Publications from NGOs and consulting firms
Discussion papers	Un-submitted manuscripts	Videos
Newsletters	Conference abstracts	Wiki articles
PowerPoint presentations	Book chapters	Emails
Program evaluation reports	Personal correspondence	Blogs and social media
Technical notes	Newsletters	Data sets
Publications from governmental agencies	Informal communications	Committee reports
Reports to funding agencies	Census data	Working papers
Unpublished reports	Pre-prints	Company reports
Dissertations	Standards	Catalogues
Policy documents	Patents	Speeches
	Webinars	Reports on websites

Figure 2: Types of grey literature

In order to illustrate the challenges already faced by GL, or that could bel faced with the progression of the 4IR, we will examine only one GL type, namely ‘data set’. This type typically includes a tremendous amount of data and information coming from the Internet of Things (IoT), the Internet of Everything (IoE), the Industrial Internet of Things (IIoT), Machine to Machine communication (M2M), self-driven cars, robots, sensors, security systems, and surveillance cameras. Estimates for the number of connected devices vary by billions. Gartner says some 20 billion by 2020. Allied Business Intelligence says more than 30 billion, Nelson Research says 100 billion, Intel says 200 billion, and International Data Co. says 212 billion. Such a huge number of devices, generating tons of data, mostly in an unstructured form, represents a considerable challenge for GL researchers, practitioners and managers.

Impact of the 4IR on Grey Literature Processing

Wayne Balta, Vice President of the IBM Corporation, in his presentation regarding IBM’s concept of ‘smarter planet’ and the role of big data and sustainability (Balta, 2014), talks about three defining attributes that arise from the foundation of data. According to him, the world is becoming:

- **Instrumented** (ability to measure, sense, and see the exact condition of everything);
- **Interconnected** (people, systems and objects can communicate and interact with each other);
- **Intelligent** (we can respond to changes quickly and accurately, and get better results by predicting and optimizing for future events).

As pointed out by John Naisbitt[10], “We have for the first time an economy based on a key resource [Information] that is not only renewable, but self-generating. Running out of it is not a problem, but drowning in it is”. He went further to stress that, “We are drowning in information but starved for knowledge“. Following on Naisbitt’s thoughts, Wayne Balta developed a system of Four Vs of big data, which is important as well in understanding the role of GL.

[10] https://en.wikipedia.org/wiki/John_Naisbitt

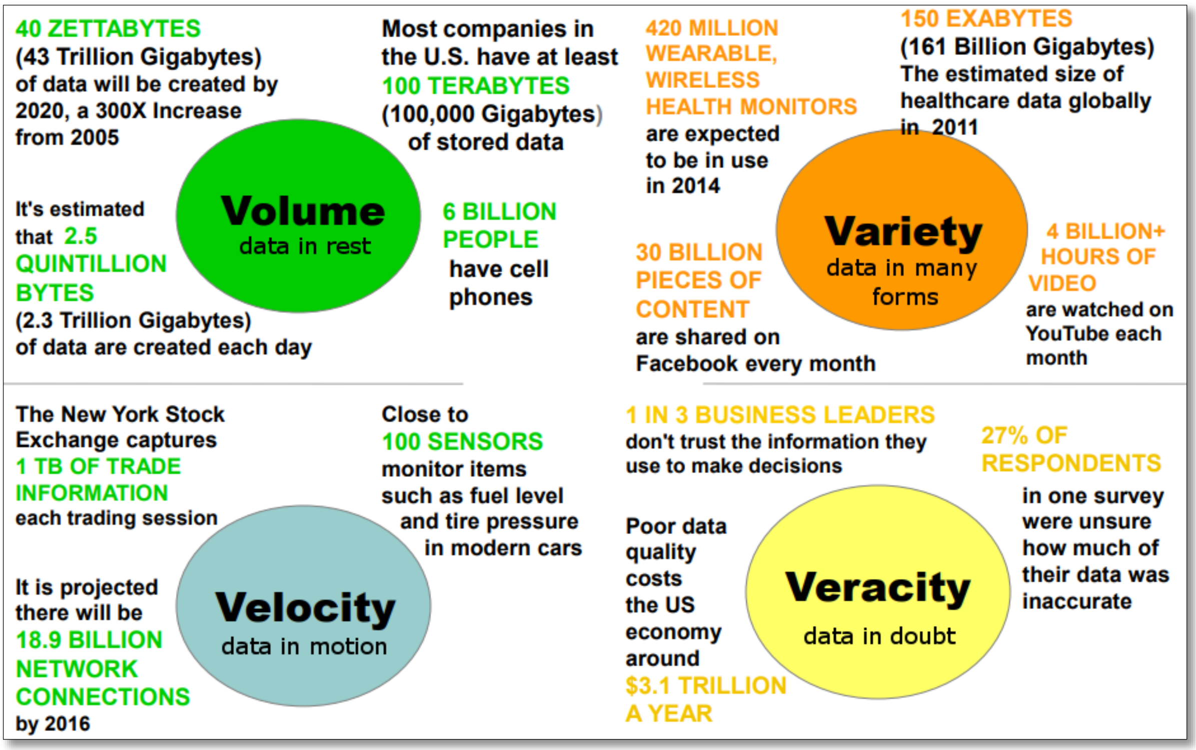

Figure 3: Big data (Source IBM, Balta, 2014)

Impact of the 4IR on Grey Literature Sustainability

The above-mentioned four Vs are also important for the long-term sustainability of GL. The Oxford dictionary defines sustainability as "the ability to be maintained at a certain rate or level."[11] However, the most famous definition comes from the Brundtland Report (1992) that states "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainability of GL can be examined from three main aspects:

- **Environmental/technical**
  - Long-term preservation; organization and management; operability;
- **Economic/Financial**
  - Level and duration of support; Return on Investment (ROI); future value;
- **Social/Organizational**
  - Audience; information ownership & governance; freedom of access to information.

Each of the aspects mentioned here represents, by itself, a research topic. For this paper, it should be sufficient to note that sustainability represents the biggest challenge to the existence and future use of grey literature. Without functional sustainability, there will hardly be future for GL.

[11] https://goo.gl/OAW1JT

Impact of 4IR on Grey Literature Usability

Closely connected to sustainability is GL usability. Designing the means, tools and methodologies for the future use of GL could become a breaking point for further industrial and social interest and in investing additional efforts to secure, process and maintain GL repositories. If its future usability cannot be guaranteed, there will not be much concentrated effort to do anything with it the present. Therefore, the question of usability needs to be examined from the following angles:

- **Tools for analysis**
  - Old vs. new tools and technology; different software functionality, concepts, expectations; dynamic vs. static information and documents;
- **Visualization**
  - 2-D and 3-D; virtual and augmented reality; requirement levels and technical skills;
- **Intellectual property**
  - Over protectionism; open access and open science; doubts about IP helping development, health, innovation;
- **Privacy**
  - Protection of sensitive personal information; CCTV cameras in public; social media photos.

Tools for future processing, analysis and presentation of GL, especially data and data sets, are a breaking point for its long-term sustainability and usability. However, intellectual property and rising concerns regarding privacy protection could also become major determining factors for the future of GL.

Conclusion

In the last few decades, developments in information technology have had an immense impact on the way we manage information in general, and on the way we create, disseminate and use GL. Based on the review of the 4IR and the related developments already in place, it can be concluded that GL will not disappear in the future, that its volume will probably experience exponential growth, and that the number of GL types will increase.

Taking into consideration the volume and speed of GL creation, there seems to be a need to revisit the old definition of GL by refocusing on quality, intellectual property, curation, sustainability and usability. The most important, and probably the most critical step, is to differentiate GL from other document types so that proper attention can be focused on relevant GL issues and solutions.

In order to increase knowledge, visibility and relevance of GL, more work needs to be done on theoretical research and practical applications; on the development of proper training courses and tutorials; on establishing cooperation with data and information specialists, librarians and archivists; on promotion; and on efforts to demonstrate the value of properly managed GL collections.

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