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REVIEW ARTICLE

Industrial revolution 4.0 in water supply, wastewater and stormwater management: opportunities, challenges, and impacts

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ABSTRACT

Industrial Revolution 4.0 (IR 4.0) is the revolution that promotes customized and flexible mass production technologies in automation and manufacturing processes. The application of industrial revolution 4.0, such as the Internet of Things (IoT), Cyber-Physical System (CPS), and big data, are used in the water industry to provide better water quality, accurate real-time data, etc. This paper compiles IR 4.0 technology applications, advantages, disadvantages, impacts, and challenges in the water sector, including water supply, wastewater treatment, and stormwater management. It is found that the current water industry is facing a few challenges, such as managing water services, balancing water costs with energy prices, maintaining aging water and wastewater infrastructure, and environmental issues. However, with the application of numerous IR 4.0 innovations, all the challenges can be solved or minimized. Meanwhile, the advantages and impacts of adopting IR 4.0 in water industries are thoroughly discussed. Despite the numerous advantages of IR 4.0, significant drawbacks have restricted the adoption of IR 4.0 in the water industry. The high start-up cost, reluctance, uncertainty, and problems of adopting IR 4.0 are some key challenges that need to be addressed. Generally, IR 4.0 provides more benefits to the community as it helps improve the water system's performance and efficiencies and creates a more sustainable environment.

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KEYWORDS
Industrial revolution; artificial; intelligence; water

1. Introduction

The industrial revolution (IR) is a process of change from agrarian-based structures to machines and manufacturing or a complete transitional shift in the economic and social networks of the current community due to technologically advancing alternatives that improve efficiency. The first industrial revolution (IR 1.0) began in 1784, focusing on the mechanization of manufacturing with the introduction of water and steam power. A Scottish inventor named James Watts came up with a sustainable version of the steam engine [1]. After Watt's innovation, many industries applied his invention for their purposes, such as using steam engines to process yarn in a cotton mill, mechanized farming, and steam trains that eventually led to railroad connections. This revolution is known as The Age of Mechanical Production [1].

In the 1870s, more inventions emerged alongside scientific discoveries, such as electricity, chemical fertilizers, and gasoline-powered engines. Then the second industrial revolution (IR 2.0), known as The Age of Science and Mass Production, was started in 1879, using electrical power for mass production assembly [1]. Many people left their rural homes to search for job opportunities in cities, which eventually sparked urbanization in bigger towns and led to the beginning of a modern world.

IR 3.0 was introduced in 1970 and focuses on digital technologies and Information Technology, using Internet Access to do a human's work using Programmable logic controllers (PLC), hence earning the name The Digital Revolution [2]. The digital age brought 1950 global communication, thus enabling supply chains and business opportunities to reach a global range.

IR 4.0 started in 2011 to transform modern society and innovation with advancements in digitization, automation, data analysis, and interconnectivity to drive the economy. The primary function of IR 4.0 is to

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integrate physical production with technological operation using intelligent digital technology to exchange information, trigger actions and control each other without human intervention [2]. It ensures that machines operate autonomously or collaborate with humans to create a customer-oriented production field that constantly maintains it.

The main components of IR 4.0 are Cyber-physical systems, The Internet of things (IoT), Cloud computing, and Cognitive computing. IR 4.0 calls for a more comprehensive, interconnected, and holistic approach to manufacturing. The implementation of large-scale machine-to-machine communication (M2M) and the Internet of Things (IoT) will enable the industry's world to become more automated, with better communication and monitoring and intelligent machines that can analyze and diagnose problems without the need for human interaction [3]. With IR 4.0, implementing big data, IoT, and artificial intelligence, machines can analyze and communicate faster than humans, increasing production.

IR 4.0 physically connects to digital and enables better cooperation and access between departments, partners, suppliers, products, and employees. The factories will become more efficient, more productive, and less wasteful and save costs due to smart machines' support, getting more intelligent when accessing more data. Thus, IR 4.0 enables business owners to better monitor and understand all aspects of their operations and use instantaneous information to increase efficiency, optimize processes, and drive development [3]. Besides, networks of interconnectivity allow larger stores of data that can be shared between engineers and scientists to obtain information. The chronology of industrial revolutions is presented in Figure 1.

Over the years, only a few review articles have focused on the application of IR 4.0 in the water industry. It is critical for the new generation of civil engineers to know and understand where to apply IR 4.0 in the water industry. Furthermore, it is critical to understand the impact and challenges faced in the water industry and how IR 4.0 helps analyze the challenges we are currently facing in the water industry. Hence, this paper summarises the benefits, drawbacks, consequences, and problems of IR 4.0 technology application in the water sector, including water supply, wastewater, and stormwater management.

2. Research and review method

The systematic literature review (SLR) recommended by Kitchenham and Charters [4] is the foundation for this work's research and review methodology. Three primary methods of SLR are (i) planning the review; (ii) carrying out the review; and (iii) reporting the review, as presented in Figure 2.

Research questions (RQ) are developed based on the applications, impacts, advantages, disadvantages, and challenges of IR 4.0 in the water industry. The following Research Questions (RQs) and motivations for this literature have been developed to achieve this goal, as shown in Table 1. The basis for this research process is the identification and analysis of IR 4.0's current applications in the water industry. It examines the impacts, strengths, and weaknesses of adopting IR 4.0 in the water industry. Meanwhile, it foresees the challenges in implementing IR 4.0 in the water sector.

2.1. Data sources

The defined research questions can surely aid in narrowing and refining the study and looking for published publications in relevant domains based on the given

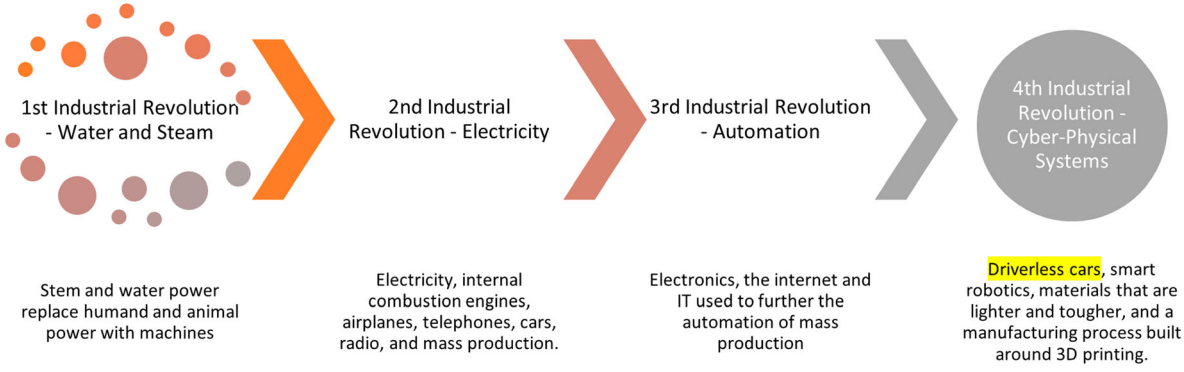

Figure 1. Chronological overview of the industrial revolutions.