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Evolution of sustainable product service system in the water management practice

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ABSTRACT

Water management is a complex interplay between climate changes, population growth, civilization, water scarcity and living environment. Today, the rising water crisis and water pollution control have prevailed to be the greatest challenge for the environmentalists and researchers. This has called for an integrated, coordinated and novel approach for the sustainable protection of water resources. In parallel to this development, the concept of "Sustainable Product Service System (SPSS)," an interconnection between the key management elements, particularly in relation to energy and carbon emission, water conservation, environmental preservation, and the associated water scarcity and pollution control has been adopted. The sustainability of water supply and management systems is a continuous process of cumulative learning, analysing, repetitive reviewing and updating of the services, quality of end products, system and resources requirement throughout the operations. With the aforementioned, the present work attempts to highlight the novel concept of SPSS and its implementation in different industries. This article reviews the historical evolution of SPSS practice in the water supply and consumption practice in response to the development needs and environmental alterations. The fundamental importance of data management and the network system in relation to the water footprint management tools and water conservation strategies is emphasized. The significance of the online management information is outlined, and the key challenges and future prospects of water resource management are elucidated.

Keywords: Environmental preservation; Sustainability; Sustainable product service system; Water management practice; Water resource

1. Introduction

The industrial revolution that began in Great Britain during the 16th and 17th century has induced dramatic changes to the transportation, mining, manufacturing and agriculture development worldwide. This revolution has triggered economic growth, rising living standards, resources depletion and has affected the ecological environment [1]. Meanwhile, the United Nations Environment Program (UNEP), the leading environmental authority which organizes the global environmental agenda and promotes the coherent implementation of the environmental dimension of sustainable development, has played a decisive role to develop good environmental governance, policies and specific guidelines on the transboundary air pollution and contamination of waterways [2]. Globalization, growing population, enforcement of environmental rules and regulations, and global awareness have placed a pressing need on governmental bodies and business proprietors to harmonize the environmental impacts during the production, consumption and services of goods [3]. Today, these industries have been transformed from material reduction and "end of pipe" quality control design into service-based industries. The shift from industrial economy to the service-based industry is known as functional economy, which represents the fulfillment of consumer's needs through the delivery of functions, instead of the end commodities [4].

Water has been described as the vital element to empower the natural movement of energy, materials and

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habitats. However, there is limited accessibility of drinking water among the 900 million populations worldwide [5], and the supply of safe household water is decreasing significantly. To overcome this water scarcity, water shortages and water pollution crisis, sound water resource management and urban planning must be given utmost importance to ensure the environmental, economic and social stability [6]. Sustainability can be defined as the ability to withstand and conserve for system continuity [7]. Shokohyar et al. [8] proposed sustainability as the ability to fulfill the growing demands with the least resources and emissions. Life cycle considerations, co-production processes, knowledge management and actor networks are the predominant factors affecting the sustainability [9,10]. Accordingly, the concept of sustainable product service system (SPSS) has been viewed as a new evolution which integrates services and products to reduce environmental impacts, and improve the product service system (PSS) design [8], with the novel concept model of "collaborative consumption" and "sharing economy," that benefits both consumers and service providers [11]. SPSS is the sustainable method to manufacture products or services throughout its course of life [12]. It simply means to complement physical products to non-physical services. Today, the successful implementation of SPSS in the water management practice has been witnessed by researchers, consumers and governing bodies, with dramatic improvement in the water domain [13]. Within this framework, this review article reports the applicability of SPSS in the water management systems. The concept of SPSS, and the wide-scale applications in the hydrological management and network systems, water resources online information, indicators, tools and philosophy were outlined. The major challenges and future prospects related to the water pollution issues were discussed. The successful examples, notably focus in the United States, Italy, Sweden, Netherlands, Australia, China and Vietnam were highlighted to familiarize the readers regarding the knowledge deficiency in this area.

2. The concept of sustainable product service system

In 1987, "the need of development without compromising the ability of the future generation" has been firstly highlighted by United Nation (UN) World Commission of Environment and Development in the "Our Common Future" report [1]. In 1992, the concept of sustainable development was globally recognized, with nearly 180 of participating countries have agreed on the action plan, "Agenda 21" to measure different aspects of sustainable development at the UN conference on Environment and Development in Rio de Janeiro, Brazil [14]. In parallel to the environmental deterioration from the industrial revolution, the concept of functional economy was further established. Stahel [15] suggested that a functional economy strives on the management of present wealth by the optimized use of goods and services. It creates new pathways for the customized quality products instead of to produce a variety of standardized products. The path towards this development has directed researches towards the new design of sustainable and environmentally orientated products [16–18], and PSS was proposed to be the prominent key to achieve sustainability [19].

Goedkoop et al. [20] defined PSS as a marketable set of products and services capable to mutually fulfill the demands and necessities. The concept of PSS is to provide satisfaction rather than to produce single products, including insurance, guarantee, maintenance, product upgrade, repair services and refurbishment [21,22]. The proprietorship of the service orientated PSS belongs to producers or manufacturers, and customers would contribute specific charges for the particular services [18]. Mont [23] described SPSS as a unique system to manufacture products, network, services or supporting infrastructures to satisfy the customer's needs in a sustainable manner. The sustainability should include a qualitative change via transformation of traditional production and consumption techniques [24]. The definitions of SPSS concept according to different perspectives are given in Table 1.

The core value of the SPSS concept has been further widened to the manufacturing of durable products, reduction of energy consumption and preservation of environment, with the introduction of sustainable product service development (SPSD) [29] and sustainable product service design [9]. Roy [3] suggested that SPSS was developed to minimize the total waste generation during the utilization and end of life (EOL) phase, while Maxwell et al. [29] reported that SPSS was designed to fulfill the sustainable structure and standards in terms of social, economic or environmental development. Fig. 1 demonstrates the criteria for optimizing sustainability

Table 1
Definition of SPSS concept

The definition of SPSS from different perspectives	References
A business innovation strategy that offers a marketable mix of products and services jointly capable to fulfill clients' needs and/or wants, with higher added value and a smaller environmental impact as compared to the existing system or product.	[25]
A system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs, and have a lower environmental impact than traditional business models.	[17]
Products and services which can simultaneously fulfil people's needs and considerably reduce the use of materials and energy.	[26]
A product service system (PSS) is an integrated combination of products and services for optimal consumption.	[27]
PSS is a business model focuses toward the provision of a marketable set of products and services, specifically designed to be economically, socially and environmentally sustainable, with the final aim to fulfil the customer's needs.	[28]

in products and services, and Fig. 2 depicts the novel concept of SPSS. The features of SPSD concept have been developed in depth at the Imperial College London [12], and the practicability has been proven by a number of multinational companies. Hernández-Pardo et al. [30] also concluded that several small and medium enterprises have adopted the knowledge of SPSS to perform organizational changes and develop sustainable business practice. According to Luiten et al. [31] and Manzini et al. [32], the successful implementation of SPSS depends primarily on its effective software application, and information technology plays the pioneering role to initiate the SPSS design [8].

SPSS contributes to sustainability by materials reduction and energy preservation as suggested by Stahel [33] and Elsen [34], and it highlights the importance of shared services, product-life extension, demand management and maximum usage capacity [3]. Table 2 provides the multi-transdisciplinary applications of SPSS concept in different industries. Maxwell and van der Vorst [12] and Hernández-Pardo et al. [30] asserted the benefits of SPSS as cost saving for its services, creates new opportunity, generates higher innovation capacity, and provides better communication and flexible operation. The incorporation of SPSS in every level of organization would contribute to the improved quality of lifestyle, environmental management, cost reduction, higher flexibility, prolonged customer–supplier relationship and customer satisfaction [17]. Today, the aspiration of SPSS has been incorporated in a wide range of industry manifesto to develop a wise working system [9]. However, the full-scale implementation of SPSS is hampered by product mishandling, limited co-operation between end users with the manufacturers or service providers, unpreparedness to accept the tactical decisions, fluctuations in organizational structure and innovation in production and marketing strategies [17]. Most companies are reluctant to advocate environmental considerations into their production chain cycle due to the requirement of extra time, additional inspections and possibilities of lower profit margin [4]. Table 3 summarizes some of the successful implementations of SPSS concept.

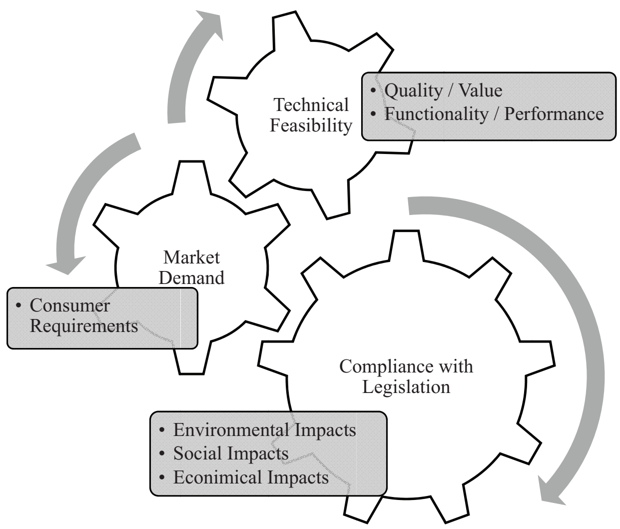

Fig. 1. The criteria for optimizing sustainability in products and services.

3. Historical development of water management

Water management is an integrated initiative undertaken to achieve sustainable water supply, water pollution control, public health protection, waterway security and conservation of ecosystem [35]. Other than physical, chemical and biological transformations, water management system has been recognized to be the symbol of civilization. Historically, the first stone filled dam was constructed in Memphis, Egypt, as early as 4,000 BC. Till 2,500 BC, a canal for potable water was built, and between the rivers of Tigris and Euphrates, the canals were competently designed to distinctively testify the glories of Mesopotamia. In the cities of Harappa and Mohenjo-daro, canals for irrigation, water wheels and damming of river flow were constructed around 1,100 BC. During the civilization of Huang Ho river valley, an impeccable operational dam

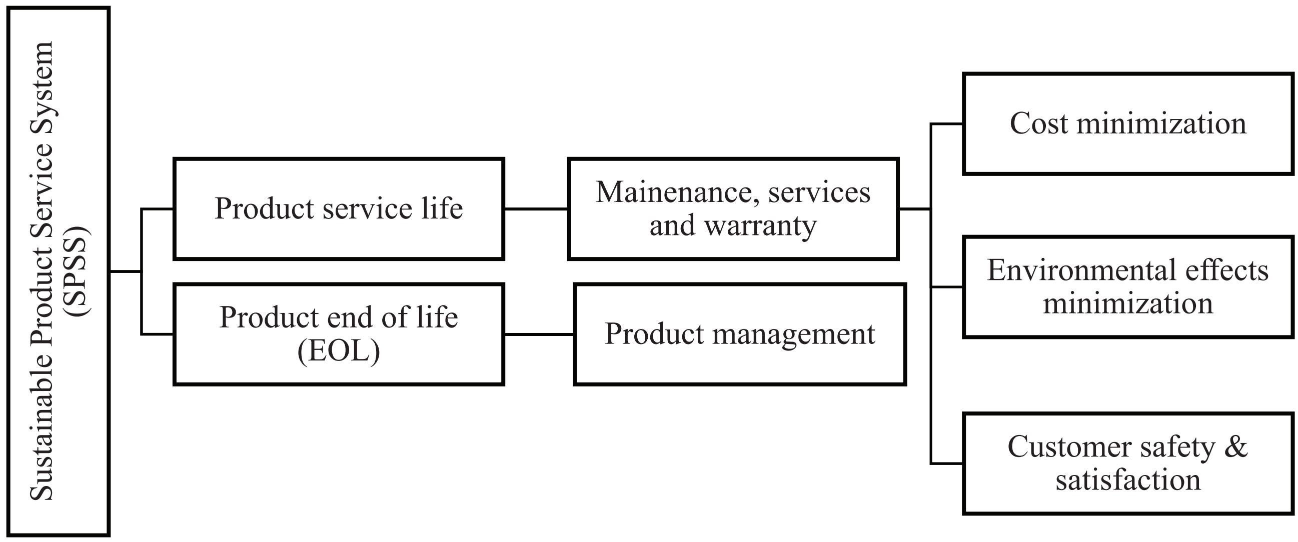

Fig. 2. The concept of sustainable product service system.

Table 2
The multi-transdisciplinary applications of SPSS concept in different industries

Organization	SPSS strategy	References
Xerox Corporation	Leases the application of photocopiers. Xerox took up the mission of "Waste-Free Company," to remanufacture and recycle old copiers.	[3]
Interface	Leases the usage of carpet tiles. The old broken tiles are remanufactured, and included as the lease fee.	
Qurrent	Developed a new software and service system that enables self solid waste management. A website was established through which members could analyze their energy production and consumption.	[4]
EGO (Ecologico Guardaroba)	Created a system whereby ladies can share dresses to a restricted number of women. Users pay for an annual subscription fees, and EGO provides the washing and maintenance services of the dresses.	
Clear Channel Outdoor, Smartbike	Bike sharing system whereby users can rent bikes on per minute basis. The company manages the service and maintenance of the bikes.	
IBM	Introduced a new system in which an equipment can be easily repaired or upgraded to extend its lifespan and could be returned at the end of its life (EOL) phase.	[8]
Toshiba	Customer can purchase products with different warranty agreements using the provided financial services.	
Dell	Adopted the concept of maintenance, repair, reuse and recycling to reduce the amount of energy and resources required during the production.	
Sony	Consider upgradeability while developing their products. These products are refurbished at the EOL phase by their global centers.	
Diddi & Gori	Supply and install textile flooring that is widely used by the retailers during trade fairs and exhibitions. The cost of raw material is heavily reduced by the recovery of fiber in the textile, leading to overall price reduction.	[21]
Klüber	Developed a service which analyzes the effectiveness of sewage treatment and aerosol treatment plant. A mobile laboratory has been designed to accurately evaluate the performance of the lubricants applied, and their environmental impacts.	
Allegrini	Manufactures phosphorus free products which contain renewable ingredients from palm and coconut oil, potatoes, corn, rice and vegetable glycerine. Reduces raw material consumption and production processes, contributing to landfill reduction of waste generation.	
AMG	Produce hot water from methane and solar energy. Customer will not be billed for methane consumption as hot water itself is sold as the product. Customer pays for the maintenance service for equipments being accounted for by AMG.	

system was built by Emperor Yu as a control measure from flood, and between 312 BC and 455 AD, more than 200 aqueducts were constructed in Rome [36,37]. Water management played a key role to signify the growth of civilizations, and till today, good water management practice is a great measurement to represent the extent of development of a country.

4. Integration of SPSS in the water management system

One of the greatest challenges of the 21st century is the sustainable management of water resources. It is an integrated activity undertaken to achieve reliable water supply, hygienic collection, public health protection, water security, intragenerational and intergenerational equity, and a demonstrable long-term living environment [38]. It has been estimated that over 400 million developing population are facing severe water shortages for the simplest latrines, and unsafe water and poor sanitation are the primary causes for a variety of waterborne diseases [13]. The health threats associated with the inadequate water supply, loss of productivity of the workforce and poor sanitation level have eventually brought into the focus and planned actions to ensure the strategic and effective management of water resources. This blue print design would be jointly established, in parallel to the sustainable development of economic, social and environment. The most prominent benchmarks are the specific legislations, Water Framework Directive (WFD), Directive 2000/60/EC adopted by the European Union (EU),

Table 3
Some of the successful implementations of SPSS concept

Research area	Brief content	References
Bicycle usage	The case study of traditional bicycle sale vs. public bicycle rental system was elucidated to outline lopsided advantages for the latter option.	[1]
United Kingdom construction and manufacturing sectors	Addresses the challenges with the huge generation of waste electrical, and electronic equipment though a waste prevention assessment has been identified	[16]
Small medium enterprise (SME)	The concept of SPSS has not been implemented in business ventures but in projects related to SME.	[18]
Leather manufacturing industries	Highlighted the incompatibility of design and agreed that SPSS was useful to improve the performance of the industry.	[30]

and "Lei das Águas" (Water Law), Law No. 9.433/97 enforced in Brazil [39]. The initiation of the water management policies and practice from different angle has assisted a deeper understanding for the decision makers, and the public to integrate the concept of SPSS in the water resource management framework.

The conceptual framework of SPSS could be generally divided into three major levels: the top level of design process, the middle level of design methods and techniques, and the bottom level of supporting data and knowledge [40]. The top level of design process consists of four major parts, namely PSS requirements identification and analysis, technical attributes and conflict resolving, PSS modularization, and PSS configuration and concept selection. The middle level of design methods includes specific design methods and techniques to support the SPSS design process, and the bottom level of information and knowledge support is the necessary input data. The successful implementation of SPSS framework requires the necessary input of product life cycle information, knowledge of requirements mapping and conflict resolving, data of service process and resource, and library of SPSS module. These supporting data are essential to assure that the valuable outputs from one phase have been organized wisely to support the mechanism of the SPSS system. Today, SPSS has found wide application in the water management practice by the integration of new innovative elements, efficient resource management, saving energy consumption, health and safety protection, lower operation cost and value added products.

4.1. The development of water resource management indicator, tools and management philosophy

The concept of sustainability is integrated as a guide for the protection, preservation or restoration of natural environment [41]. In 2004, a case study of uplifting an abandoned quarry to a wastewater treatment plant has been presented by Siracusa and La Rosa [42] in Catania, Italy, using the "emery analysis." The analysis evaluated the economic and environmental aspects of traditional water treatment system. A series of modifications were proposed towards a sustainable urban wastewater management system. Effluents at the vacant quarry were collected in a number of ponds to create a leisure park for hiking, bird watching and fishing. A lagoon was proposed to be built inside the uninhibited quarry, where the treated water was pumped to the lagoon through a pump system. This highly treated water, also known as reclaimed water, was deemed as an excellent source for landscape irrigation, and useful for agricultural and industrial use. This study highlighted the concept of rehabilitation, preservation and successful management of environment. The transformation of an open dump site to an environmentally and aesthetically useful treatment plant had been enumerated.

Similarly, the integrated water resource management (IWRM) philosophy was suggested by Warner et al. [5] to be the ideal window of opportunity to overcome water-related problems. The IWRM approach includes knowledge extension beyond professional water expert on water management at the local communities. Fertilization has been suggested to be the best supplementation to irrigation, during the non-rainy and sensitive crop seasons. The study defended water requirements for rice and fish cultivations, and encouraged wide-scale algae production for fishery in the marine system. The philosophy of IWRM is based on the triangle of sustainability to visualize the different value orientations to overcome water-related boundaries and mandate. The triangle of sustainability in one of its many incarnation is depicted in Fig. 3.

The application of sustainable development indicators (SDI) as a measure to improve sustainability in Swedish water system has been reported by Palme and Tillman [14]. Field studies were conducted in Uppsala, Boras and Stockholm Water Company (SWC) from April 2004 till March 2006. The sustainability in urban water systems could be achieved by the introduction of SDI in future planning and decision makings. The incorporation of environmental management system (EMS) was suggested for accounting and reporting purposes to deeply improve the business performance. The authors encouraged the exertion of gentle, persistent and practical changes to completely examine the environmental cause–effect chains in regard to the social sustainability.

Concurrently, Stakhiv and Stewart [43] have pointed out the major drawbacks associated with general circulation model that does not provide relevant information, essential in decision makings. The sustainability of ecosystem, economy and hydrological cycle is affected by the climate change, flash flood, storm surge, landslide and all water-linked systems. This had placed a rising pressure on the ecosystem, food chain and land use. The researchers have, therefore, introduced the application of regional climate model as a

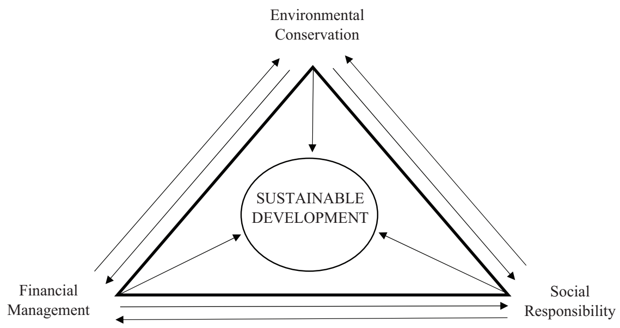

Fig. 3. The triangle of sustainability (in one of its many incarnations).

hydrological tool to improve the water management system, and identified the need of meteorological data in various application of hydrological analysis. The necessity for real-time information and considerations on the deviations and robustness during the data surveillance, monitoring and assessment ought to be highlighted. In a broader context, better governance, knowledge, information sharing, economical and building resilience in relation to the ongoing water changes should be addressed.

The dynamic changes of the Dutch water supply companies with their competitors, and the domestic end users have been analyzed using a conceptual tool by Hegger et al. [44]. An inventory of current innovations in the concomitant changes of consumer–provider relationships, and in the water consumption practice was presented. The newly developed conceptual tool was applied to distinguish between the upstream vs. downstream, and core vs. non-core processes or innovations. Discussions and consultation with marketing professionals were conducted to identify the potential empirical research activities and new roles of water supply management. Data analysis concluded that service providers in the Dutch water supply sector are inclined towards consumer-inclusive innovation strategies, specifically at the downstream of the water chain. The concept of ecological modernization of domestic water consumption practice, including the importance of "solid and sustainable" functions of the water providers has been highlighted.

Meanwhile, Lee and Tansel [24] have proposed the amendment of life cycle analysis (LCA) to evaluate the demands, emission and environmental impacts of residential water for home appliances. Three water-related processes, namely, water supply, wastewater treatment and life cycle of water conservation appliances were examined using the economic input–output life cycle assessment (EIO-LCA) tool. The EIO-LCA model was developed by Green Design Institute at Carnegie Mellon University (2008) to estimate the relative emission and demands from monetary activities, and the supply chain. The energy consumption, greenhouse gas emission and lifespan of several appliances were determined. Water usage from home appliances showed the greatest impact on water supply. The findings concluded that the sustainable water demand and urban planning should be achieved by water conservation practice, while water using home appliances should be retrofitted into environmentally friendly design for optimal lifespan of the products.

The need for urban water conservation was recognized by Makki et al. [45], who developed a quantitative and qualitative research design for 200 households in South East Queensland, Australia. A series of questionnaire surveys, smart metering measurement, diaries and household water stock inventory have been carried out to identify the major contributors to residential water consumption. Water flow data were collected by smart metering technique, while 2 weeks water usage was recorded and analyzed using the Trace Wizard software. The study reported that shower end use was the highest indoor consumption category, much higher than those required for sanitary purpose. The newly established model enabled large data samples to be identified over a long period of time, and was useful for the prediction of other residential end users. The model could be applied as a variable tool to assist policy makers and water technology proprietors to implement better targeted water conservation strategies.

In Macao, the need for sustainable water footprint in the gaming industry, also known as the gambling industry was evaluated by Li and Chen [46]. As the richest region in Asia, Macao has been suffering from long-term water crisis. The water usage to the domestic, industrial and recreational purposes throughout the country is predominantly imported from the mainland China. A hybrid method of bottom-up and top-down approach for water footprint was applied to determine the energy requirement of the water footprint management, with operating inputs, labor, commission and goods purchased as the input data, and virtual water embodied in each input (VWi) was calculated by multiplying the monetary costs (MCi) with the corresponding intensity. The resulting data indicated that the use of indirect water was dozens of times larger than the direct water. These findings do not support the opinion that service sectors are small water consumers. The gaming industry has the obligation to look into matters that impact water resources, and proceeds by conducting appropriate strategies to manage its commodities and services in a more sustainable manner. Government and stake holders should not be misled by looking at the direct water used by an industry, with strong emphasis devoted to the consumption of virtual water. The reduction methods can be adopted, especially in the form of electricity or in the use of energy efficient products, to prevent water losses for a sustainable future.

Accordingly, the concept of sustainable product service efficiency has been proposed by Chou et al. [47] to explore the relationship between product-service value and the sustainability impact. Product-service integration and social value in its solution that is required in SPSS was merged with the idea of eco-efficiency to interpret the relationship of sustainable product service (SPS) efficiency derived as:

$$\text{SPS efficiency} = \text{Product} - \text{Service value}/\text{Sustainability impact} \quad (1)$$

with customer and employees perception is referred to the product-service value and product, while delivery and use of product/services is implied as the sustainability impact. The optimal efficiency could be achieved at the highest product-service value with the lowest sustainability. Employee perception is emphasized to ensure the stability of sustainable product-service efficiency, and the foresight of the company's policy. Weakness and PSS performances in different factors, indicators and categories should be recognized to fully interpret the sustainable product-service efficiency.

4.2. Hydrological data management software and network systems

Over the years, the rising dependency on water resources, and the growing environmental pollution have accelerated the necessity for specific monitoring systems and data archives for water resources review and hydrological system [48]. The requirement of these additional software or network systems is to ascertain the long-term storage of water-related information, particularly among the legislators and decision makers [49]. Hydrological cycle has been conventionally managed by the construction of canals, irrigation systems and dams [50]. These traditional management techniques are usually inappropriate for larger flowstreams that require continuous recording of larger data sets for a long period of time. In this perspective, Rodda et al. [51] have proposed the applicability of World Hydrological Cycle Observing System (WHYCOS), and the attractive and cost-effective form of worldwide network key stations, linked by satellite for the accurate measurement of river flow, water quality variables, air temperature, wind speed, humidity and radiation. WHYCOS with the incorporation of geostationary satellites such as Meteosat together with the segment of telecommunication system of the world weather watch, global climate observing system and GEMS Water Quality was capable to combat water crisis, focusing firstly in Africa.

Similarly, Wolf and William [52] have acknowledged the worldwide usefulness of GEONETCast, a near real-time global environmental information delivery system which transmits products and services; in situ, airborne and space-based observation through communication satellites. The key features of GEONETCast are data collection, management, and distribution hubs to accept, process, prioritize and schedule incoming data or products. The area targeted by GEONETCast are natural and human-induced hazards, water management, weather, environment, health, ecosystem management, climate change, sustainable agriculture, environmental related energy issue, and desertification and biodiversity. Today, GEONETCast has broadened its coverage globally. The system has extended its application among national specialized centers, universities and end users for various planning.

For wise management of hydrological data, the scientific workflow tool, Kepler based service was recommended by Guru et al. [53] with its own run-time engine, and different models of grid cell computation to support grid and web-based services. Kepler is capable to work efficiently with its high flexibility, and enables the application of advance analytical tools such as R scripts, Matlab expression, statistical tool and Globus. The new introduction of this scientific tool will enhance latest scientific knowledge discovery for the sustainable management of hydrological difficulties. Meanwhile, a water-related information system has been established by Klinger et al. [54] for the advance development of Mekong Delta (WISDOM). The system serves as a data storage to support project planning and decision makings for different water management applications. The representation state transfer (REST) was incorporated in WISDOM to allow more information and search of relevant database by organizations or governmental institutions. The researchers have envisaged the implementation of REST into two levels: Level 1 was designed for visualization, and Level 2 highlighted the intersection between the relevant datasets. The development promoted a better data processing towards a decision support system.

Ernest et al. [55] have further developed a rule-based decision support tool integrated with geographic information system (GIS) for optimal planning of sensor network in the drinking water system. EPANET, a public domain software package developed by the United States Environmental Protection Agency (EPA) was applied for the hydraulic simulation, monitoring of water quality and establishment of water distribution models. The contamination scenario was duly arranged to mimic the actual conditions, and EPANET was integrated into the GIS platform. This software provides a knowledge enhancement to answer the specific difficulties that require specific consultations.

4.3. The establishment of water resources online information

Following the huge losses and disastrous damages to the residential, industrial, agricultural, commercial and public properties by the Red River Flood tragedy in 1997, at the cities of Fargo, Grand Forks and Winnipeg and several towns within North Dakota, Minnesota and the region of Manitoba, the Red River Basin Disaster Information Network (RRBDIN) was developed for the sustainable management of floodplains within the Red River Basin [56]. The sustainable management system provides the most up-to-date information required for decision making in floodplain management, disaster relief and formulation of mitigation strategies. Parallel to the concept of SPSS, RRBDIN was envisioned as the online data accessible to individuals and organizations responsible for the sustainability of water management around the Red River Basin.

The Sustainable Site Initiative (SITES) was commenced by the American Society of Chemical Engineer, Environmental and Water Resource Institute in 2009 to address the issues related to sustainability of site design [57]. The establishment focused on the development of hydrology, soils, vegetation, materials, human health and well-being. According to the design, stormwater management, pollutant removal, water reuses, restoration of waterway, preservation of natural wetland, and riparian floodplains were the main concern in the hydrological domain. With the assistance, guidelines and performance benchmarks provided by SITES, a reliable structure was readily available for engineers, landscape architects, environmental designers and other professionals to reassess their design methods and integrate sustainable practice in their current projects.

5. Challenges and future prospects

For decades, the complexities of hydrological challenges and water-related problems have been simulated using different scientific models. The development has expanded from satellites, in situ sensors, observation system to data management tools, with the application of cyberinfrastructure-driven workflow [55]. In Australia, it has been reported that there is a hindrance in data sharing, as the hydrological information gathered by 260 major organizations are stored in different methods or standards, which could delay the compilation system and analysis process. The successful implementation of scientific workflow tool and software has enabled a better management of the hydrological information. Accordingly, standardization of techniques or tools for information and data storage was suggested to improve the transparency and auditability of the hydrology data in the water domain.

Accomplishment of the technology-based entrepreneurship depends largely on the attitudes of decision makers, as suggested by Preston [58], and radical innovations should be pursued continuously by the management team. To integrate SPSS in the current water management practice, an organization must be prepared to accept changes (organizational structure, monetary, mindset of the employees or end users) on the new system, and to ensure the practicality of the incorporated management. Unreadiness and refusal to adapt to the current changing technologies by the decision makers in the management teams would certainly trap themselves in the old ways of thinking to endure great losses.

Additionally, it is crucial to balance the economic development with the societal and environmental consequences. The life concept of "save the earth and make money too" was suggested by Tierney [59] to outline the imbalance between economic growth rate, pitiable environmental outcome and inequitable social effects. Although a growing trend of LCA, eco-design protocols and cleaner production tools to ensure the sustainability of environmental well-being has been witnessed, the rising demand has forced even the greenest industries at the height of success to face with the harsh realities of the consumer market. Water management related industries must consider the needs of the market, the economic well-being of the industry, and minimize environmental impact caused by the undertaken decisions. Accordingly, Foran et al. [60] recommended that the evolution of data management plays a vital role to maintain the sustainability and continual improvement of the water domain. Systematic data entry, standardized hydrological reporting parameters, and online data availability may create a platform for various group of people to discuss water-related matters, and enable a better compilation of water-related information. Therefore, the integration of SPSS into the operational gridlock is expected to accelerate a great progress for the collection, interpretation, dissemination and storage of the hydrological information.

Within the water service providers, the integration of good governance between the public water operators, communities, trade unions, industrial partners, and other key players pertaining to water management practice is essential for the preservation of water quality standard, reduction of water shortage, greener products and greener production [61]. Additionally, knowledge and education must be disseminated between the general population to ensure that sustainable principles of water management are promoted and defended. Investments in research, developing water resource management plan, and projects that protect water quality and quantities must be actively developed, with special emphasis devoted to the monitoring and inspection perspective. A typical example is the initiation of National Water Commission, by the Australian government that has encouraged the public participation in the water management practice and decision making through the National Water Initiative. The profound knowledge of the Indigenous people on water, management and biodiversity has compelled all states within the Commonwealth of Australia to involve directly in the establishment of water planning, Indigenous rights, social spiritual and customary objective, and water access [62].

6. Conclusion

To date, the ascending growth of water crisis and environmental pollution have reduced the accessibility to safe water supply for domestic and industrial applications. The rising environmental awareness among the community and business developers has compelled profound water management and urban planning to be given utmost importance, to ensure the environmental, economic and social stability. This development of meteorological information system, accessibility to online data bank and commencement of World Water Day would signify the extent of societal involvement in regards to water management. Accordingly, the evolution of SPSS in the hydrology domain has offered the advantages of accurate and consistent data monitoring, reliable reduction of resource flow, energy conservation, lower waste generation, new innovation of water management system, overall cost reduction and preservation of hydrological cycles. The major hindrance to develop sustainable water management system could be attributed to the limited data storage and computation tools, low acceptability and monetary consideration. Therefore, the establishment of SPSS pertaining to the water management practice and development, and contextualizing strategies should be integrated efficiently to ensure that these concerted efforts are not only superficial in its impacts. Ultimately, full co-operation and joint venture between different parties ranging from the ground users, industrial partners, policy practitioners, governmental agencies, non-governmental organizations to the decision makers is a directive motivation for the successive implementation of SPSS practice.

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