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Sustainability in Urban Water Systems

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27.1 Introduction
Involving a large number of stakeholders and a high degree of complexity has made the management of urban water systems a challenging task. Significant growth of urban population and the dramatic increase in water demand in recent years have exacerbated the management problem in recent years. The introduction of sustainable development and sustainability concepts in the late 1980s has inspired water scientists and experts to initiate a new scientific branch in the context of urban water management called “sustainable urban water management (SUWM).”

SUWM aims to promote the use of technologies and practices able to preserve scarce resources for the future generations while providing water and sanitation for the current users at affordable costs and without significant environmental damages to vital ecosystems. Thus, those urban water systems that fulfill sustainability requirements at expected levels may be called “sustainable urban water systems.”

This chapter aims to provide readers with practical information on the basic concepts commonly discussed in the context of SUWM and sustainable urban water systems. To achieve this objective, first, different components of urban water systems and their functions in the life of urban residents are reviewed. Then, different perspectives on the meaning of sustainability and sustainable development concepts and the objectives of sustainable urban water systems are evaluated. Next, a brief review of conventional methods applied to appraise the sustainability of urban water systems including sustainability assessment methods and sustainability indicators (SIs) is presented. Finally, some experiences in implementing SUWM around the world are described, and the remaining issues in the context of SUWM are addressed.

27.1.1 Urban Water Systems
Sustaining an acceptable standard of living in urban areas requires a variety of public services such as water, energy, and transportation. Urban water systems are among those infrastructures, which serve a key role in ensuring the human health and the well-being of urban dwellers. Urban water systems include water supply system, wastewater collection and treatment system, and urban drainage. Water supply systems extract water from its source and convey it to a treatment plant in which raw water is purified and made suitable for use. Treated water is distributed via pipe networks to consumers (e.g., households, small industries) in order to satisfy their need to water for drinking, washing, etc. Wastewater collection systems convey wastewater generated by domestic and nondomestic consumers to the disposal sites. In some cases, a treatment plant exists in which wastewater is treated in order to reclaim water and nutrients for further uses such as landscape irrigation and fertilizer production. Urban drainage has the function of collecting stormwater to prevent flooding and protect the public from unhygienic conditions.
The systems described earlier are known as “conventional urban water systems” and primarily refer to the centralized and large-scale nature of these systems. Conventional urban water systems have been utilized for years in more developed parts of the world; however, a majority of urban residents in less-developed countries has not yet enough access to water and sanitation, mainly due to explosive population growth, financial limitations, and poor institutional involvement. These systems have been widely criticized for employing low-efficient technologies and having adverse impacts on the environment. Thus, there is an increasing tendency toward employing alternative urban water systems wherever conventional systems are not affordable in terms of financial or natural resources.

Alternative urban water systems predominantly rely on distributed technologies and small-scale and decentralized infrastructures and aim to minimize the distance between the location of end use and water source. Furthermore, these systems are primarily built in a manner to use energy and raw materials more efficiently in comparison with conventional ones. Rainwater harvesting, on-site wastewater treatment systems, ecological sanitation, and water-sensitive urban design (WSUD) are some well-known types of alternative urban water systems. To obtain more information on these systems, one can see References 20, 40.

27.1.2 Sustainability: Debate on Definition

Rapid population growth and the overuse of natural resources that substantially occurred in the second half of the twentieth century have degraded the global environment significantly. They have also caused widespread concerns about having sufficient access to scarce resources (e.g., water, energy) in the future. In the last decades of the twentieth century, it was globally acknowledged that the adopted development policies that aim to maximize the economic benefits from exploited resources posed a serious threat to nature as well as to human health.

Primary efforts to introduce a more eco-friendly definition of development in order to progress toward a more sustainable future were made by IUCN et al. in the report called “1980 World Conservation Strategy.” In this report, sustainable development was defined based on three following objectives: “a) Maintenance of essential ecological processes and life support systems, b) Preservation of genetic diversity, and c) Sustainable utilization of species and the ecosystem.”

In 1987, the report entitled “Our Common Future” delivered by the World Commission on Environment and Development (WCED) was published in which sustainable development is defined as “a development that fulfills the needs of present generation without compromising the ability of the future generations to fulfill their basic needs.”

The concept of sustainable development incorporates the ecological values into the decision-making processes while recognizing the importance of human well-being and aiming to create a balance between the social, economic, and environmental goals of development. In this regard, sustainability might refer to a condition in which economic benefits and social welfare can be achieved within the carrying capacity of the environment. This “triple bottom line” (TBL) approach to the problem of sustainability was coined by Elkington referring to the “three Ps” (people, profit, and planet) or the principles of sustainability. Similarly to Elkington, Adams believes that sustainable development is built on the “three pillars” that are economic growth, environmental protection, and social progress.

Having different perceptions about sustainable development in different regions of the world has made it difficult to reach a global consensus about the objectives of this concept. Jeppsson et al. maintained that people in developed countries may consider population growth as the major threat to sustainable development, while in developing countries overconsumption may be recognized as the prime issue in the context of sustainable development.

Since the introduction of sustainable development in WCED, different experts and organizations have proposed various definitions of sustainability. Most of existing definitions are contextual and originated from the scientific background (e.g., urban planning, architecture, water resources, forestry).
of the individual or organization, which provides the definition. As water is in the center of development plans, water scientists have made ongoing efforts to define the concept of sustainability and incorporate it into the different levels of water resources planning and management.

A prevalent approach to define water resources systems sustainability is to pertain it to the performance of the system, while the sustainable development of the system is assumed as an ongoing process. In this regard, sustainability can be assessed in terms of different social, economic, environmental, and technical objectives. Loucks [33] defined water resources sustainability based on the three conventional performance indicators (i.e., reliability, resiliency, vulnerability) mostly applied for reservoir systems operation. Howard [28] suggested that the sustainability of water resources systems should be defined in terms of risk, and sustainable water resources systems are those that maintain acceptable risks over an unlimited time horizon. Mays [42] defined water resources sustainability as “the ability to use water in sufficient quantities and quality from the local to the global scale to meet the needs of humans and ecosystems for the present and the future to sustain life, and to protect humans from the damages brought about by natural and human-caused disasters that affect sustaining life.” Defining sustainability in terms of system’s performance has been criticized in a few studies. Voß et al. [59] indicated that “sustainability cannot be translated into a blueprint or a defined end state from which criteria could be derived and unambiguous decisions be taken to get there.” Bagheri and Hjorth [5] maintained that “sustainability is neither a state of the system to be increased or decreased, nor a static goal or target to be achieved.” In their opinion, one should monitor the systems’ progress using process indicators to ensure that sustainability requirements are achieved rather than measure the sustainability of the system by means of performance indicators [5].

27.1.3 Sustainable Urban Water Systems

Sustainable urban water systems are those that are designed and function along with the objectives of sustainable development. In addition to providing urban residents with basic needs such as water and sanitation, it is expected that a sustainable urban water system utilizes valuable resources efficiently and has minimal impact upon the environment. Different authors have attempted to describe “sustainable urban water system” or more generally “sustainable water resources systems” in their studies. An American Society of Civil Engineers (ASCE) Task Committee in their joint publication with UNESCO-IHP working group maintained that sustainable water resource systems are those “designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental, and hydrological integrity” [2]. Hellström et al. [27] stated that a sustainable urban water system as well as any of urban infrastructures should “1) move toward a nontoxic environment, 2) improve health and hygiene, 3) save human resources, 4) conserve natural resources, 5) save financial resources.” Marsalek et al. [40] suggested the following basic goals for sustainable urban water systems:

- The supply of safe and good-tasting potable water to the urban residents in an unlimited time horizon
- Collection and treatment of wastewater in order to protect the urban dwellers from diseases and the environment from adverse impacts
- Control, collection, conveyance, and quality improvement of urban runoff in order to protect the urban environment from flooding and pollution
- Reclamation, reuse, and recycling of water and nutrients for domestic or agricultural uses in case of water shortage

27.2 Tools and Methods

Sustainability assessment refers to a systematic process in which a given system is evaluated to gain knowledge about the performance of the system meeting the sustainability requirements. It can be
applied to rank the fields of activity, to provide suggestions to select appropriate technologies, and to identify solutions for implementing designed plans [49]. In this section, a brief review of tools and methods applied in the context of sustainability assessment of urban water systems is provided.

### 27.2.1 Sustainability Indicators

A prevalent approach to achieve a quantitative understanding of progress toward the objectives of sustainable urban water systems is to present the result of sustainability assessment studies by means of SIs. Indicators can be defined as “pieces of information, which summarize important properties, visualize phenomena of interest, quantify trends and communicate them to relevant target groups” [38]. The prime functions of indicators are “a) Assessing conditions and trends, b) Providing information for spatial comparison, c) Providing early warning information, d) Anticipating future conditions and trends” [24].

SIs can be utilized to provide information on to what extent the sustainability objectives have been accomplished; however, as the importance of different aspects of sustainability is determined by stakeholders, SIs cannot be measured in absolute terms [58]. A set of typical SIs applied to sustainability assessment of urban water systems can be found in References 6, 35. A variety of frameworks have been applied to develop and select SIs. Here, some SIs selection frameworks are introduced.

#### 27.2.1.1 Balanced Lists (Theme Frameworks)

Balanced lists (theme frameworks) are frameworks that categorize the SIs into separate groups by means of a TBL approach. They usually include the main aspects of sustainability, social, economic, and environmental, although in some cases other aspects such as technical and institutional are also considered [37]. Balanced lists were first adopted by the United Nations Commission on Sustainable Development (UNCSD) in their report “Indicators of Sustainable Development: Framework and Methodologies” published in 1996 to suggest a first list of 134 SIs. The indicators were considered to be employed by different countries in the decision-making process of development and to create an opportunity for international comparisons [54]. Balanced lists have been widely used to evaluate the sustainability of urban water systems [27,35].

#### 27.2.1.2 Pressure–State–Response Framework

Pressure–state–response (PSR) is an environmental assessment framework developed by the Organization of Economic Cooperation for Development (OECD) in the early 1990s, and a first set of PSR indicators were introduced in the report entitled “Towards sustainable development: Environmental indicators” [45]. In PSR, SIs are developed about a specific problem and categorized into pressure, state, and response groups. Pressure indicators refer to environmental pressures caused by human activities and degrade the environment through emissions and the depletion of natural resources. State indicators describe the current state of the environment, which is threatened by human activities in terms of quality and quantity of natural resources. Response indicators provide information about the response of human society to environmental damages. For instance, if low water quality of a given river due to the discharge of untreated industrial wastewater is considered as the problem, the volume of discharged wastewater, the concentration of heavy metals in the river, and the number of industrial factories that treat their wastewater before discharging it into the river can be considered as pressure, state, and response indicators, respectively.

#### 27.2.1.3 Driving Force–Pressure–State–Impact–Response Framework

Driving force–pressure–state–impact–response (DPSIR) is a modified version of PSR framework developed by adding two new indicator groups (i.e., driving force, impact) to PSR indicators. DPSIR has been adopted by the European Environmental Agency (EEA) and the European Statistical Office (Eurostat) with the aim of monitoring the state of the environment in the European Union (EU) countries [17].
It adopts a cause and effect approach to provide an understanding of the relations between emissions and impacts [37]. Driving force indicators refer to the hydrologic and socioeconomic factors, which indirectly exert stress on the environment such as population growth and climatic condition. Impact indicators describe the socioeconomic impact of a degraded environment such as poverty and unemployment. For instance, for a given river, in addition to discharge of untreated industrial wastewater (pressure), low precipitation and high level of evaporation (driving forces) can diminish the quality of water. Furthermore, waterborne diseases, which spread in residential areas in vicinity of the river due to the drinking of polluted water, are an example of impact indicators.

27.2.2 Sustainability Assessment Methods

A variety of system analysis methods has been applied to assess the sustainability of urban water systems. Beck [7] defined system analysis as “The procedure and corpus of methods for providing support and guidance in the systematic analysis of decision-making problems. It may involve the development and use of mathematical models and is often associated with the notion of optimal solutions to problems.” Some well-known and conventional system analysis methods applied in the context of sustainability assessment of urban water systems are cost–benefit analysis (CBA), life cycle costing (LCC), life cycle assessment (LCA), material flow analysis (MFA), exergy analysis, microbial risk assessment (MRA), and multi-criteria analysis (MCA). Here, LCA, MRA, and MCA are introduced, and the application of these methods in sustainability assessment studies is reviewed.

27.2.2.1 Life Cycle Assessment

LCA is a process in which “the environmental effects associated with any given activity from initial gathering of raw materials from the earth (petroleum, crops, ores, etc.) to the point at which all materials are returned to the earth are evaluated” [16]. In recent decades, LCA methodologies have been developed, and the global use of LCA has been promoted through the scientific work of organizations such as the Society of Environmental Toxicology and Chemistry (SETAC), International Standardization Organization (ISO), and the United Nations Environmental Program (UNEP) [26]. Currently, the LCA methodology is being standardized by ISO within the framework of ISO14000 series [31]. LCA includes the four following steps [26]:

- **Goal and scope definition**: Goal and scope definition refers to formulating the objectives of the study in terms of a question, a specific application, etc., and determining the spatial and temporal coverage of the study, respectively.
- **Inventory analysis**: It is a process in which the input and output flows of the product system through its life cycle including the use of raw materials, energy, water, and emissions into the air, soil, and water are quantified.
- **Impact assessment**: In this phase, inventory data are associated with specific environmental impacts in order to achieve an understanding of these impacts.
- **Interpretation**: This is the final phase of LCA in which the soundness and robustness of results are evaluated.

LCA has been widely employed to assess the sustainability of urban water systems [36,38,39].

27.2.2.2 Microbial Risk Assessment

Urban water systems can potentially pose threats on humans’ health due to a variety of reasons such as discharge of untreated wastewater to water bodies or accidental spills of stormwater [19]. Therefore, estimating the level of microbial risk associated with urban water systems in terms of quantitative measures is a matter of vital importance. A systematic framework to assess the risks of human disease posed by pathogens was first developed by Craun et al. [15]. MRA is an analytical method that aims to measure the disease risk associated with exposure to pathogenic microorganisms [20]. It involves the application
of dose response functions—which define the relationship between the number of pathogens consumed and the likelihood of infection—in order to predict the degree of risk from an exposure in terms of a probability of infection [20]. MRA has been used to assess the sustainability of urban water systems in various real case studies such as the comparison of two wastewater treatment system alternatives in Sydney, Australia, and Hammarby Sjöstad, Sweden, by Fane [19] and Ashbolt et al. [3], respectively.

### 27.2.2.3 Multicriteria Analysis

MCA is a type of integrated assessment (IA) tools primarily applied in situations when there are competing criteria [43]. The main advantage of MCA is that sustainability criteria and indicators can be quantified in quite different units without the need for converting all criteria into monetary units. Furthermore, by means of MCA, different social, economic, and environmental indicators can be weighted and combined in order to provide an integrated perspective of sustainability. Multi-criteria decision-making methods (MCDMs) are a group of MCA methodologies designed to facilitate the process of decision-making for human and to provide optimum solutions for multi-criteria problems using rational principles and mathematical formulations. MCDMs are usually categorized into multi-objective decision-making methods (MODMs) and multi-attribute decision-making methods (MADMs). The latter is used to select the best alternative among a variety of alternatives with regard to different criteria, while the former is basically designed to find the optimum solution of a mathematical function in a given decision space. Goal programming (GP) and compromise programming (CP) are some conventional MODMs, and analytic hierarchical process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Elimination Le Choix Traduisant la REalité (ELECTRE), and Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) are some typical MADMs. In the context of sustainability assessment of urban water systems, MADMs have been widely used to integrate the results of different sustainability assessment methods and produce a sustainability index [31,35].

### 27.3 Implementing Sustainable Urban Water Management

One of essential prerequisites to accomplish the objectives of sustainable urban water systems is a sustainable practice for managing these systems. SUWM can be described as “integrated and biophysical systems, which consider social, economic, environmental and political contexts, provision of water for ecological and human uses, and a long-term perspective” [57]. In this section, some experiences of implementing SUWM are described.

#### 27.3.1 SWITCH: Toward the City of the Future

Sustainable Water Management Improves Tomorrow’s Cities Health (SWITCH) was an EU-funded research program implemented and co-funded by a consortium of 33 partners from 15 countries over the period 2006 to 2011. The main objective of SWITCH program was to accommodate the change toward more SUWM in the “city of the future” [58]. To achieve this objective, integrated urban water management (IUWM) was selected as the management practice.

IUWM is a popular version of SUWM applied to urban water systems around the world especially in Europe and Australia. The word “integrated” implies the integration of different aspects of urban water management such as supply and demand, sources and sinks, scale, and considering urban water systems to be a whole system rather than separate entities [41]. van der Steen and Howe [58] put forward a hypothesis that “design and management of the urban water system based on analysis and optimization of the entire urban water system (infrastructure and human organizations, water supply, sanitation, stormwater, etc.) will lead to more sustainable solutions than optimization of separate elements of the system.” Mays [41] outlined two reasons for applying IUWM to urban water systems. First, different components of urban water systems (water supply, wastewater, stormwater system) are naturally
connected through the hydrological cycle, and, second, the real advantages can be realized through the integrated management of these systems rather than independent action.

The SWITCH program consisted of three main parts [58]:

- **Learning alliances**: They were based on this proposition that in case of dealing with complex situations, a group of people working interactively are more likely to reach better solutions than talented individuals working separately [12]. Learning alliances were established in “SWITCH cities” including Accra, Alexandria, Beijing, Belo Horizonte, Birmingham, Cali, Hamburg, Lima, Lodz, Tel Aviv, and Zaragoza.

- **Action research**: It involved implementing IUWM in terms of real case studies in “SWITCH cities.”

- **Multiple-way learning**: This refers to this premise that through the implementation of case studies, urban water experts and managers from European countries and developing countries can share their knowledge and learn from each other.

Details about the results of implemented case studies can be found in Reference 12.

### 27.3.2 Integrated Resources Planning: An Australian Approach

Integrated Resources Planning (IRP) or the so-called least-cost planning [29] is “a process of planning services in a way that ensures the efficient and sustainable management of water, energy, or other resources” [22]. IRP involves making detailed demand forecasts, producing a large number of alternatives, assessing demand-side and supply-side alternatives equally, and deciding how to fill the demand–supply gap at least cost while recognizing the sustainability requirements [22]. Within a project undertaken by the Institute of Sustainable Futures (ISF), University of Technology Sydney (UTS) for the Water Services Association of Australia (WSAA), an IRP framework for urban water management was developed [52]. The key principles of the IRP framework are as follows [52]:

- **Water service provision**: It recognizes that what is important to customers is the services required (e.g., healthy and adequate water for drinking, bathing) and not the water itself.

- **Detailed demand forecasting**: This principle involves disaggregating the water demand through an end-use analysis, which enables demand forecasting as well as determining the water conservation potential.

- **Consideration of a broad spectrum of viable options that satisfy service needs**: It recognizes that the objectives of IRP can be achieved through a wide range of options such as water reuse and supply augmentation.

- **Comparison of options using a common metric, boundary, and assumptions**: To ensure that water services are supplied to society at the lowest cost, IRP adopts a common monetary unit (net present value) to assess all options.

- **A participatory process**: As urban water systems interact with different parts of the environment and society, and involve a multitude of individuals with various preferences, IRP recognizes the importance of stakeholder participation at particular levels of the planning process in order to incorporate diverse needs and values into final decisions.

- **Adaptive management**: This principle emphasizes that IRP is a continuous learning process in which plans are developed, put into action, and evaluated iteratively.

### 27.3.3 Soft Path for Water: Canadian Experiences

The term “soft path” was first introduced by Lovins [34] to describe “soft path for energy.” Lovins [34] maintained that people do not actually need energy resources such as electricity and oil, but they require the services provided by these resources. Wolff and Gleick [61] adopted the soft path approach to develop
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the concept of “soft path for water.” They believed that in addition to the conventional “hard” path that primarily relies on centralized infrastructures and decision-making and adopts supply-side management practices, there is a soft path to meet water-related needs by conserving water more efficiently and matching the water services to consumers’ diverse needs [61]. This approach is called “soft path” because it primarily relies on human creativity to find solutions for water-related problems—“working with nature rather than attempting to overcome it” [8]. The soft path for water or the so-called water soft path primarily relies on following principles [9]:

- **To resolve the water supply–demand gaps from the demand side:** This principle emphasizes that before adding any new water supply sources to the existing system, it should be ensured that all feasible water conservation efforts have been made.

- **To match the quality of the water supplied to the required quality by end users:** This principle that is also known as “water quality cascading” [20] recognizes that most-important needs to water such as drinking should be satisfied by high-quality water and less-important needs such as washing should be met by lower qualities.

- **Backcasting rather than forecasting:** Backcasting starts from the desired future and works backward in order to identify the “soft paths” that connect that future to the existing situation. In this regard, the main aim of planning is not to find where current routes will take the system but how the objectives of the system can be attained.

A framework for water soft path analysis was developed by Friends of the Earth, Canada. The following steps should be taken to carry out the framework [10]:

- **Identify water services:** The first step is to make a list including all services provided by water for consumers (drinking, bathing, washing, etc.) and calculate how much water is used by each service. In this step, feasible alternatives for water conservation are also evaluated.

- **Create a “business-as-usual scenario”:** This step involves creating a scenario in which rates of water withdrawals and uses grow through the time scope of the study assuming that the size of the population and of the economy has normal growth.

- **Review water supply options:** In this step, all current water supply sources (surface water, groundwater, etc.) are identified and evaluated to determine if any are being excessively used or diminished. All new water supply sources, which threaten ecological, social, and cultural values, should be rejected.

- **Establish a desired future scenario:** In a desired future scenario, both sources and uses of water should be sustainable in the target year. In this step, effective communication with stakeholders may be beneficial in order to identify more desirable options for the future. At least two scenarios should be created for the future. In one scenario, possible cost-effective modifications should be investigated. It encompasses a multitude of policy options to make water services cost-effective for both water users and water service providers. In the second scenario, cost-effective changes should be integrated with major changes in consumers’ behavior, growth rates, and the economic structure of the society. Furthermore, solutions to implement water quality cascading should be sought in this scenario.

- **Ensure desired future scenarios are sustainable:** This step involves examining the desired future scenarios to ensure the sustainability of the supply–demand can be met. Making adjustments to the scenarios is likely if any of them suffers from weaknesses that prevent them to fulfill the expected goals.

- **Adjust for expected effects of climate change:** In this step, the impacts of climate change on water resources as well as human activities should be incorporated into the future scenarios.

- **Backcast from the desired future to the actual present:** This step involves developing multiple soft paths by designing policies and programs that connect the desired future to the current situation. In other words, it should be determined what actions are required to be done to achieve the desired future.
Friends of the Earth, Canada, in cooperation with research teams from three Canadian universities (University of Victoria, Acadia University, and University of Waterloo) implemented the water soft path analysis framework in three case studies at different spatial scales including a generalized urban area, a composite watershed, and a province [10]. The case studies were conducted mainly to try out the framework, not to obtain instantly practical results [10]. More details about the results of the case studies and guidelines on conducting a water soft path analysis can be found in Reference 11.

27.4 Sustainable Urban Water Management: Remaining Issues

A large number of research studies have been implemented in the context of SUWM; however, the following issues required to be addressed more in future studies:

1. Impact of climate change on urban water systems: With regard to ongoing trends of greenhouse gases (GHGs) emission, climate change becomes inevitable. It creates several impacts on urban water cycle that result in urban flash floods and significant changes in the amount of urban water supply and demand [32]. In the Fourth World Water Forum held in March 2006, the Cooperative Programme on Water and Climate (CPWC) remarked that risks posed by climate change are not adequately addressed in the development and management plans of the water sector [41]. Mays [41] contended that global climate change has received inadequate attention in urban water management even in highly developed parts of the world such as the United States. A useful approach to deal with this challenge is to adjust the results of urban water planning models with regard to perceived impacts of climate change. Some important information on the implication of climate change for urban water supplies and water demand can be found in Fane et al. [21].

2. Need for a paradigm shift in dealing with the problem of sustainability: By a review on methods and tools applied for sustainability assessment of urban water systems, one can realize that “hard systems thinking” approach has been primarily adopted in previous studies. The word “hard systems thinking” first used in Checkland [13] describes “an approach to real world problems in which an objective or end-to-be-achieved can be taken as given.” In this way, there is a desired state and a present state, and the final objective is selecting the best way of getting from the present state to the desired state [13]. Decision-making based on the hard system thinking approach basically involves selecting a choice among a clearly defined set of options for action [46]. MCA is a typical example of analytical methods that strongly relies on the hard systems thinking approach and primarily has been used to find an optimum alternative for a given urban water system from a sustainability perspective.

Adopting the hard systems thinking approach to assess the sustainability of socioeconomic systems such as urban water systems has drawn criticism in a few studies [5,59]. Socioeconomic systems basically consist of a large number of interactions and feedback loops makes them show complex and nonlinear behavior. Regarding this fact, adopting conventional linear approaches such as the hard systems thinking approach is logically not the most effective way to deal with the problems lie in such complicated nonlinear systems. In contrast with the hard system thinking approach, there is a “soft system thinking” approach. Soft systems thinking or soft systems methodology is “an action-oriented process of inquiry into problematic situations in which users learn their way from finding out about the situation, to taking action to improve it” [14]. Sushil [51] asserted that adopting the paradigm of “learning”—which is the basis of “soft systems thinking” approach—is a more appropriate tool to systematically study and evaluate complex socioeconomic systems in comparison to the paradigm of “optimization.” This premise implies a paradigm shift in dealing with management problems. One of soft system thinking-based concepts that has gained renowned attention in the context of natural resources management is “social learning.” Pahl-Wostl and Hare [47] described the social learning as “an ongoing learning and negotiation process where a high priority is given to questions of communication, perspective sharing and development of adaptive group strategies for problem solving.” Few studies have been conducted using the social learning concept to deal with
the problem of sustainability in urban water systems \[4,48\]. Bagheri and Hjorth \[4\] employed system dynamics methodology and the social learning concept to propose a framework for monitoring the progress of complex systems toward sustainable development and examined it in a case study for the urban water system of Tehran. Adopting the social learning concept to make the sustainable urban water systems workable seems a wise choice; however, a good deal of work is required to be done in order to fortify the position of the this concepts in urban water management.

3. Capacity development in academic institutions, governmental and private organizations, and society: Capacity development or capacity building is “the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time” \[55\]. It requires to be addressed at three interrelated levels as the following \[53\]:

a. Individual level: In this level, capacity development involves providing the conditions under which government officials are able to initiate an ongoing process of learning, acquire new knowledge and skills, and use them in new ways.

b. Institutional level: In this level, capacity development primarily focuses on modernizing systems and processes.

c. Societal level: In this level, capacity development aims to create a more interactive practice of public administration that learns from actions as well as feedbacks received from the public.

Considerable pilot studies and research projects have been conducted to promote the application of sustainable practices of urban water management; however, sustainability and its objectives in urban water sector are not still fully acknowledged by water users and service providers in different parts of the world particularly in developing countries. A reason for this shortcoming may be poor capacity development in academic institutions, governmental and private organizations, and society. In a study conducted at the Regional Center on Urban Water Management (RCUWM) based in Tehran, Iran, in order to assess the problems of urban water management in the Middle East and Central Asia countries, it was remarked that there is an urgent need for capacity building of staff in these countries, and thus high priority should be given to training and capacity building for sustainability \[23\]. In a discussion paper provided by the UNEP, the following strategies are proposed to increase the effectiveness of capacity building for sustainable development: “a) Identifying needs and building on existing capacities, b) Being clear about the objectives, c) Using a wide range of capacity building approaches, d) Target the right people to build a critical mass, e) Making the training-of-trainers approach work, f) Institutionalizing capacity building programme at regional and national level” \[56\].

27.5 Summary and Conclusions

In this chapter, a concise review on main topics in the context of sustainability in urban water systems was presented. After a brief introduction of urban water systems and their functions, existing visions on sustainability definition and the objectives of sustainable urban water systems were reviewed. Then, conventional tools and methods applied for sustainability assessment of urban water systems were discussed, and good practices of SUWM around the world were described. Finally, this chapter addressed some important issues that need to be discussed in future studies.

Sustainability principles in urban water systems have been established well in terms of definitions, conceptual frameworks, and analytical methodologies during the past decades; however, considerable efforts are required to make these principles work in the real world. Regarding this reality that roughly 1.1 billion people lack safe drinking water, about 2.6 billion do not have access to adequate sanitation, and between 2 and 5 million people die annually from water-related diseases \[25\], sustainability objectives in urban water systems are still far from being reached in a global scale. To facilitate the progress toward the sustainable development of urban water systems, considerable emphasis should be placed on developing mechanisms to involve stakeholders in the decision-making processes of urban water
systems that enable them to communicate their visions and share their knowledge and more importantly to learn interactively from their decisions.

References


