Comparative Analysis with Global Trends for Performance Assessment System in Water Demand Management of Different WASA's

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Certificate

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I **Komal Naeem** certify that this research work titled "Comparative Analysis with Global Trends for Performance Assessment System in Water Demand Management of Different WASAs" is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

Komal Naeem

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Dedication

Dedicated to my exceptional parents and adored siblings whose tremendous support and cooperation led me to this wonderful accomplishment.

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I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which You setup in my mind to improve it. Indeed, I could have done nothing without Your priceless help and guidance. Whosoever helped me throughout the course of my thesis, whether my parents or any other individual was Your will, so indeed none be worthy of praise but You.

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Copyright Statement

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List of Acronyms

ADB	Asian Development Bank
RDA	Rawalpindi Development Authority
RWASA	Rawalpindi Water &Sanitation Agency
FWASA	Faisalabad Water &Sanitation Agency
IMF	International Monetary Fund
IUWM	Integrated Urban Water Management
L/c/d	Liters per capita per day
MAF	Million Acre Feet
MGD	Million Gallons per Day
NRW	Non-revenue water
O&M	Operation & Maintenance
OECD	Organization for Economic Co-operation and Development
PCRWR	Pakistan Council of Research in Water Resources
UN	United Nations
WHO	World Health Organization
PCA	Principal Component Analysis
WAPDA	Water and Power Development Authority
WB	World Bank

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ABSTRACT

The issue of water scarcity is growing globally including Pakistan with the increasing trend of urbanization. Analysis of various performance indicators can help two folds; first, it will help in understanding the growth and efficiency so far, second, to predict estimates for future planning. This study has performed a comparative analysis between Rawalpindi (RWASA) and Faisalabad (FWASA) Water & Sanitation Agency using ten years' data of various performance indicators (for instance, total water supply, total water demand, deficit of supply, water supply charges, expenditures for operation and maintenance, pay and allowances, deficit in terms of revenue generation, etc.). Descriptive analysis has been performed to check the overall trend and tendencies in various indicators. Independent sample t-test showed a significant difference of average growth over the years on fourteen indicators while four indicators showed statistically insignificant difference. Simple linear regression modelling has been used to predict the growth of performance indicators with respect to time for each station. For various developed models, 7 showed a strong linear relationship for RWASA and 8 for FWASA. The development of the multiple linear regression model has been avoided due to multi-collinearity. To deal with the problem of multicollinearity and dimension reduction of the indicators, principal component analysis (PCA) has been performed. PCA favours for three principal components (PCs) for each station having Eigen values greater than 1 and cumulative variations of 90%. The principal component scores have been calculated. The results of the study are useful for planning and management of water resources of different Water & Sanitation Agencies.

CHAPTER 1

INTRODUCTION

1.1 Background

Undoubtedly drinking water is a key requirement for the existence of life on earth planet, but in different regions of the world, water scarcity has been increased in the last few decades (Pedro-Monzonís et al., 2015). From the world's total water supply of about 332.5 million mi^3 of water, over 97% of earth's water is saline and remaining freshwater resources are about 3%. Of all out fresh water, more than 68 percent is secured up as ice and ice sheets. Another 30 percent of freshwater is in the ground and leaves 1% for use in the form of lakes rivers and swamps (Black, 2016). This situation leads to water-stressed conditions and has the potential for drought and water scarcity. Water scarcity has become a global issue like climate change, poverty and depletion of non-renewable energy sources. But due to an exponential decrease in water availability, this issue has become the world's prime concern (Postel, 2014).

The issue of water scarcity is growing with the increasing trend of urbanization mostly people have migrated from rural to urban areas, which led to suppress the urban resources. Yet the advantages of city life are not available to all. Further raised population influx, inadequate and poor services for residents and outdated urban planning models have caused disempowerment of majority of new arrivals into slum areas and informal settlements that are the root cause of urban poverty and worst inequality and compromising efforts to attain a sustainable water supply system (Watkins, 2006).

There are many other factors also which are badly affecting water supply like the haphazard expansion of population around cities, inefficient billing system, socio-economic issues (free water), illegal connections of water supply, non-revision of a tariff, no metering system, water distribution and transport losses etc. Hence the problem of water scarcity in urban areas is real and irrefutable.

In 2000, 150 million individuals lived in urban areas confronting lasting water shortfall, where the per capita water supply was under 100 L/day. Right around 900 million individuals lived in urban areas that confronted occasional water shortfall, where water supply dropped below 100L/C/day for at least 30 days per annum. By 2050, these numbers are expected to increase to 1 billion and 3.1 billion individuals, respectively. Almost 33% of the total population – and over a portion of the 6 billion urban occupants predicted by 2050 – will confront basic water deficiencies in their urban communities. Additionally, about 500 million individuals are at present living in areas where water utilization has exceeded the local available water resources which are renewable by a factor of two. Non-renewable resources like fossil groundwater are being utilized in the most assailable areas of the world, yet those assets likewise diminish at a speedy pace. Thus, those vulnerable areas are currently exceptionally dependent on water provision from other areas that have plenty amount of water (Barlow, 2017). Almost 1.7 billion people are living in the basin of the rivers which further causes desiccation of rivers, groundwater diminution, and ecosystem deterioration.

Now the management of water resources is a major concern for the world. The provision of adequate clean water is the main goal of water management, which includes the sustainable use of water, wastewater management, and better sanitation services (Connor, 2015). In the developed region of the world reception of the water is adequate. But further amelioration of water management is required which includes advanced infrastructure, improved water quality, climate impacts, and political interests for water are interests (Clarke, 2013).

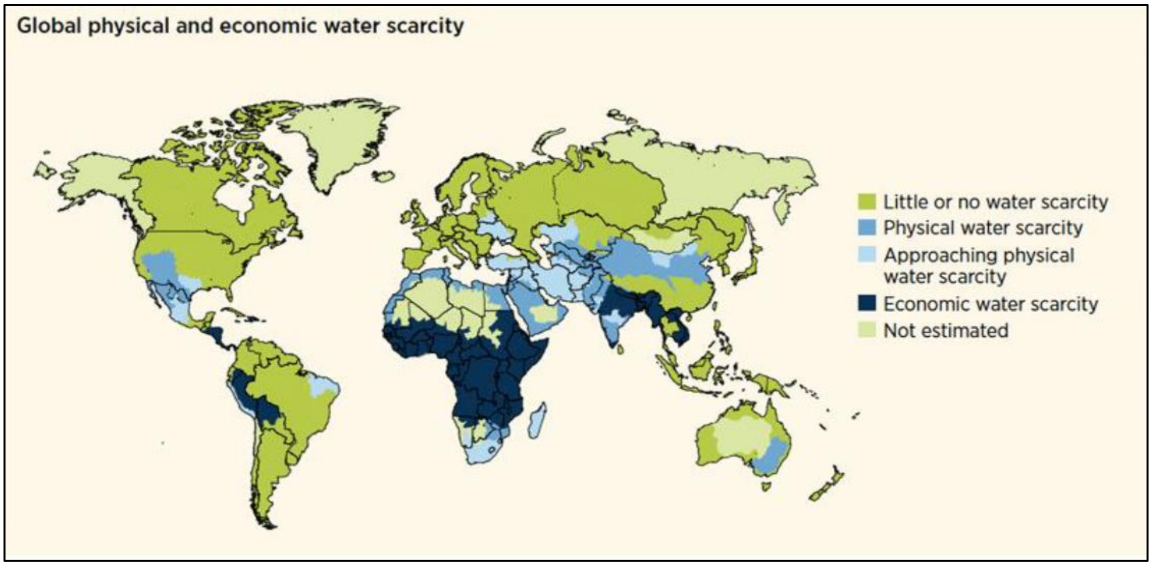

Figure 1: Global Physical and Economic Water Scarcity Map by UN

An ongoing water shortage map shared by the UN appears in figure 1, whereby parts of Pakistan lies under the zones featured as 'Physical water shortage' and 'moving toward the physical water shortage'(DESA, 2016). A report by UNDP has featured the approaching water shortfall that anticipates Pakistan soon and has become a serious menace to the country's stability. As indicated by this report, the specialists have asserted that by 2025, most of the areas will face a severe water shortfall (UN-Water and UNICEF, 2012). This issue was featured by the Pakistan Council of Research in Water Resources (PCRWR) in 2017. The Pakistani Water and Power Development Authority have expressed that strategies for Water storage and management policies are fictional which further accelerated the problem of water scarcity in our country. Pakistan had reached up to the mark of the "water stress line" In 1990 but no proper action was taken to mitigate the situation which became the root cause of crossing that stress line at 2005 (Ahmed et al., 2019).

This problem is aggravated because of increasing competition for resources and shortfall will continue to increase with time. Factors that are responsible for the growing saturation of resources are population size, modern living standards, and increased demand for clean water. This situation will become more worsen in the future because of unstoppable urbanization trends, industrialization, and unsustainable patterns of using fresh water in the agriculture sector as well. Under all these scenarios, current need of an hour is to focus on better management of water resources and give an estimation of the resources to give strategic policies to cope up with the upcoming water shortfall.

1.2 Problem Statement

Globally Pakistan has been positioned fourth, as far as the pace of utilization of water because of reliance on its economy on agriculture. Pakistan has the most noteworthy rate of water consumption in the world which implies the amount of clean water in cubic meters that is used per unit of its GDP (Khattak et al., 2011). This shows the degree of reliance Pakistan has on freshwater for the development and advancement of its economy. International Monetary Fund (IMF) has just articulated Pakistan as the third most water-stressed country universally which is in accordance with the reports given by the World Bank (Hoekstra and Mekonnen, 2016).

World Bank has revealed that during the year 2000, Pakistan turned into a water-stressed country (1,700 cubic meters/capita/year). Pakistan is confronting vulnerable circumstances as water accessibility per capita has dwindled from 5000 cubic meters to 1500 cubic meters within a 50-year time span. Water shortage is characterized as yearly availability of water under 1000 cubic meters, so Pakistan has a high potential risk become a water scarce country by 2035 (Archer et al., 2010).

The water shortfall becomes common especially in metropolitan cities of Pakistan including Rawalpindi and Faisalabad. In Punjab Province, Faisalabad is considered a second-largest city with a population of 2.7 million in urban areas in 2015 and considered the third-largest city of Pakistan. The growth rate is about 1.8% per annum, with this calculation, the population is expected to raise up to 3.1 million & 4.1 million in 2023 & 2038 respectively. With this growing population, acquiring an adequate quantity of water supply for the city is difficult in terms of resource development and new infrastructure development. Faisalabad Development Authority is responsible for the provision of water & sanitation services in the city. The design capacity of existing water supply facilities fulfilled about 77% of the total water demand of the city that was 500,000 m^3/day (110 MGD) from total water demand of 777400 m^3/day (171 MGD), leaving a deficit of 277300 m^3/day (61 MGD) and results in a shortfall of current water supply. Detaining in water supply facilities development and inefficient management of water resources leads to less water supply coverage area. Only 60% of households have access to municipal water supply in the current service area. Private groundwater extraction is common, which is the main stumbling block to develop additional water source in the city.

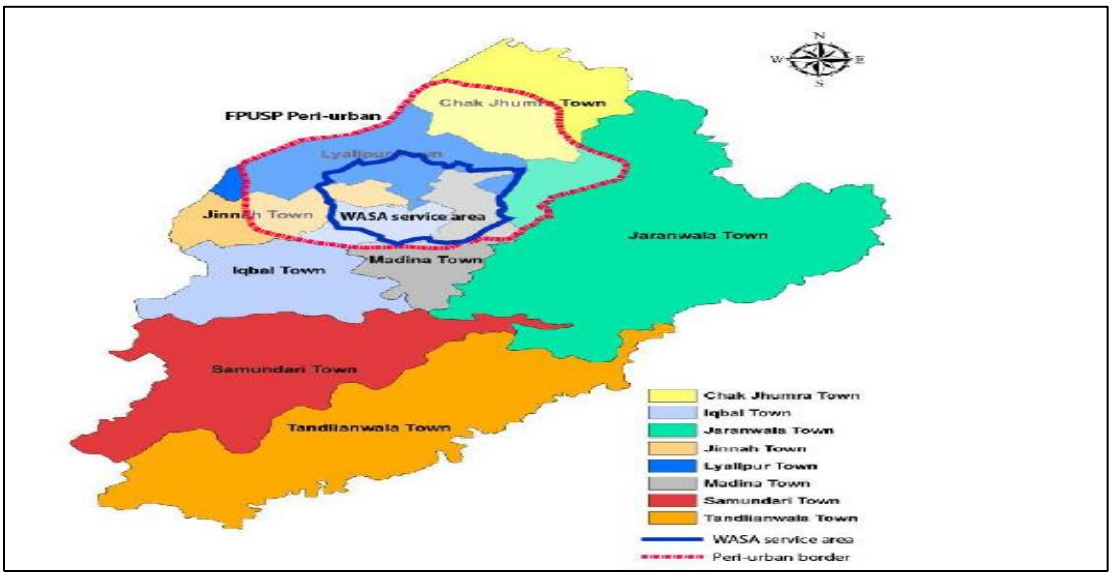

Figure2: Map Showing Faisalabad's Urban Areas

In Punjab province, Rawalpindi is also considered as a metropolitan city having a population of 2.1 Million in urban areas with a growth rate of about 1.86%. The Rawalpindi Development Authority is responsible for water & sanitation services in the city. RDA has coverage of about 1.6 million population currently which are residing in 46 union councils of the municipal corporation and 20 union councils of the district council.

Currently, the water demand in these areas is about 300044 m^3. While RDA is supplying water of 232000 m^3 and leaving a deficit of almost 68000 m^3 and it is continuously increasing with upcoming years due to the increasing population influx and uncontrolled migration of population towards the city. Water demand is endlessly increasing on a per capita basis while water resources are declining quantity and quality-wise as well.

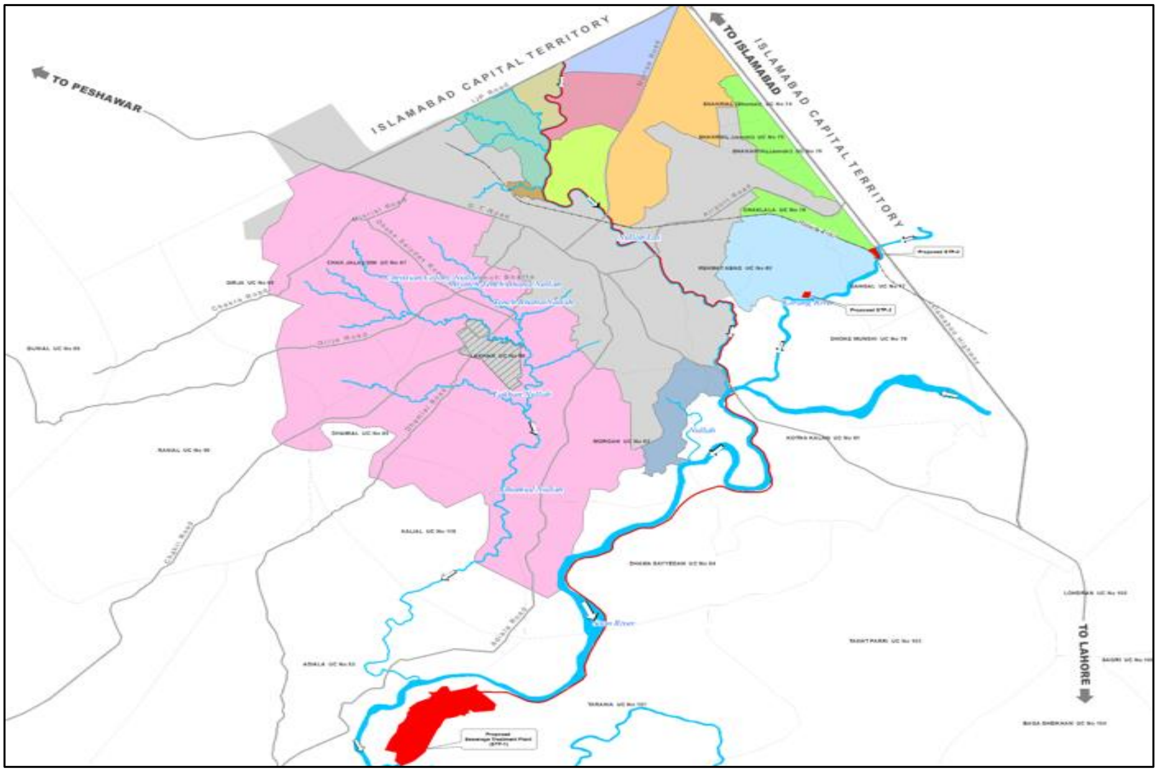

Figure 3: Map showing water supply system of Rawalpindi city

1.3 Research Questions?

1- What are water supply practices used around the globe are they sustainable or not?

2- What system for water supply is being used in Pakistan?

3- What gaps are found in the water supply system of Rawalpindi & Faisalabad?

4- What are the issues/constraints that affect the sustainable water supply of Rawalpindi and Faisalabad?

5- What are the major challenges that are faced by Faisalabad Water & Sanitation Agency and Rawalpindi Water & Sanitation Agency for coverage area and provision of adequate water supply?

6- Where we are lacking behind the world in water management? Is the metering system can enhance water demand management?

7- What methods can be used to check the efficiency of individual WASA?

8- Is water demand projection along with other management system projection help in making strategic use of resources to minimize the risk of water scarcity?

1.4 Research Objectives

- To investigate the best water practices used in both developed & developing countries in order to compare with local WASAs for defining performance indicators.
- To investigate the local water supply system & identify the gaps in the system by doing an in-depth statistical analysis.
- Compute reliable estimates to check the efficiency of the system, propose a framework for the output of the system by doing predicting modelling of indicators, and give recommendations for a sustainable water supply system.

1.5 Rationale of Study

This investigation planned for surveying the flow circumstance of water supply and management system with gaps related to its interest at present and in the years to go under the ebb and flow development procedures. Likewise, it targets concentrating the water supply arrangement of Rawalpindi and Faisalabad with regards to physical framework, the activity of the framework alongside its upkeep, and ultimately the water evaluating and metering component. The study planned to give a future projection of significant parameters regarding the water supply framework, upkeep, and evaluating current scenarios. Such a comprehensive report would realize an away from the declining water emergency in both cities by giving demand projections that will be quite helpful in making strategic policies for the efficient use of water resources. The ends and suggestions would be useful for the administration authorities so as to comprehend the significant issues regarding water supply management in upcoming years.

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CHAPTER 2
LITERATURE REVIEW

2.1 Water Stress and Water Scarcity

According to (IWMI) clean water is the most fundamental need of people and almost 1.2 billion individuals don't have an approach to clean water (Gleick, 2014). According to the World Wildlife Federation that about two-third of the total world population could be facing water scarcity by 2025, because of freshwater reserves depleted at a faster pace (McDonnell, 2008). Furthermore, DESA has revealed that water demand will see a 40% increment by 2030 (DESA, 2016). At the same time, there is a projection of increment in the worldwide population to cross the 9 billion figure which will suppress water supply means (Connor, 2016). Lack of resources of clean water for people and their different needs describe the water scarcity concept. Because of the decreasing sources of clean water, the issue of water shortage is dynamically being distinguished as a fundamental concern in various countries (Alfano et al., 2015). 'Water stress index', is the most famous strategy utilized for estimating the degree of water shortage. This technique depends on the idea that water scarcity has been defined by the availability of all water resources for the number of inhabitants in a specific region or country. The water shortfall can be estimated as the volume of the fresh and renewable water available for each person every year. If the volume of renewable water is lower than 1,700 cubic meters/person/year in that particular country, then there is a water-stressed conditions in the country. If the volume of renewable water drops down to 1,000 cubic meters in that particular country that region is considered as water-scarce. And if it further dropped below 500 cubic meters, portrayed as the absolute water scarcity (Falkenmark, 2004).

About 50% of the population of the world is residing in urban areas, while 30% of inhabitants in urban areas are living in slums. There is an expected rise of the urban population up to 6.3 billion by 2050. According to reports 93% of the urban population live in the developing countries, out of which 40% will be residing in slum areas by 2030 as the urban population in Asia and Africa is well on the way to be multiplied by 2 at that point (Vidal, 2010). As the industrial and domestic water demand will be incremented to twofold by 2050. Resultantly competition among peri-urban, urban, and rural regions will most likely be escalated (Eliasson, 2015).

All these are the major reasons to manage water resources, inefficient way to cope up with this upcoming shortfall. Every country has various systems to manage water and sanitation system. Here are some case studies mentioned from developed as well as from developing regions.

2.2 Water Supply Management System Scenarios

2.2.1 Water supply management system of Spain

Water supply, sanitation system, and wastewater treatment in urban areas of Spain are governed by the municipality (articles 25 and 26 of Local Government Regulatory Law 7/1985, of 2 April). There are 8117 local government authorities and 8125 municipalities which empower concerns related to the provision of water services inside their metropolitan limits (Tortajada et al., 2019). The relevant paper gives an overview of pricing and non-pricing measures for the reduction of local water utilization at the household level in five urban regions in Spain. Questionnaires were sent to water utilities for efficiency analysis of organizations that give water benefits in the metropolitan territories of Barcelona and Seville, the urban communities of Malaga and Saragossa, and the locale of Madrid (Tortajada et al., 2019). About 67% of the administration of urban water management are run by Aguas de Barcelona (AGBAR) and Aqualia is privatized (González-Gómez et al., 2014).

In the five mentioned territories double taxes are applied, with fixed and variable charges. Every Spanish city has widely used this practice. Duties are applied, depending on individual household consumption levels in Madrid, Barcelona, and Saragossa, while in Malaga and Seville, water charges have been applied dependent on per capita water consumption at the household level (García-Rubio et al., 2015). Comparisons were made to estimate current and future water demand, which was a fundamental commitment. Directors from the utilities have been asked the effect of measures taken and implemented.

All territories that have implemented pricing and non-pricing measures to empower the proficient utilization of water and that decrease in per capita water utilization have been the after effect of times of draught season, went within specific cases by water limitations and estimating pricing and non-pricing measures. 15m^3/month water tariff volume has been selected for this is the reference volume that has been used in different investigations that have conducted in Spain (Melgarejo-Moreno et al., 2019). In every one of the five regions considered the utilities accept that non-pricing measures have greatly affected water utilization choices in comparison with estimating measures. This outcome coincides with past research. The level of water consumption has a direct relation with the price elasticity of water demand and demand elasticity has an inverse relation with income level (Melgarejo-Moreno et al., 2019).

2.2.2 Water demand projection (Australian scenario)

Development of water resource management is a key strategy for the precise forecast of water demand and to monitor the future water supply and demand balance to ensure appropriate water supplies to the individuals (Haque et al., 2013b). Through literature, it is evident that to model or forecast water demand Various sorts of models, such as regression, time series, and neutral artificial networks have been in practice. The Time series model is used for the estimation of water demands projection for a shorter time period model and neutral artificial networks are also used for shorter projection of water demand(Haque et al., 2013a). While for the longer projection of water demand, analysis based on regression typically multiple regression analysis has been used (Authority, 2009). Although the obvious accomplishment of multiple linear regression analysis in demonstrating water demand, the model has an issue of multicollinearity which is associated with variables having a high correlation (Rajab et al., 2012).

Since water demand relies upon numerous variables, for example, population, family size, precipitation, temperature, population age, water cost, and policies, a multicollinearity issue may emerge during the multiple regression model which may give rise to the mistaken estimation of future water demand (Franczyk and Chang, 2009). To keep away from the multicollinearity issue principal component regression analysis has been utilized in a few investigations which exhibited its capacity to eradicate the multicollinearity issue and to deliver better model outcomes. In any case, the use of principal component regression in water demand estimating is limited. Principal component regression has been used to gauge future water demand in the Blue Mountains Water Supply frameworks in New South Wales, Australia. Furthermore, it was discovered that the principal component regression model has the option to foresee future water demand with a higher level of precision and could diminish the issue of multicollinearity individually. The technique exhibited can be applied to different urban areas in Australia and in the world (Zhou et al., 2000).

2.2.3 Improved Urban Water Utility through Organization

Developing countries have common barriers to the provision of proficient water services in urban areas, which includes unclear responsibilities and roles of organizational design. A study was conducted of eleven urban water utilities overall completed by the World Bank in 2005 distinguished the accompanying key characteristics for the identification of well-performing parameters regarding water utilities (Kayaga et al., 2018). After that World Bank commissioned a comparative study in 2013 which includes the assessment of five efficient water utilities allocated in various parts of the world, including the alignment of management systems with their environmental strategies and organizational structures. These water utilities were divided as one city from Africa, one city from South East Asia, one city is from the mainland which is Europe, and the remaining were selected from the United Kingdom. A quality management system has been incorporated Which includes management structures, procedures, responsibilities, processes, management resources, and mechanisms to actualize the standards and activity lines expected to accomplish the quality objectives of an individual organization (Bach et al., 2014).

Another key factor is the establishment of efficient organizational design. That gives noteworthy high-performance culture development by using the strategy of careful allocation of resources (Connor et al., 2012). The focal point of OD is essentially the processes of internal business, while the water utilities performances are to a great extent influenced by the institutional and strategic environmental conditions in which they work According to extant literature there is a significant connection between private firms' performance and OD. We discovered numerous similarities in the OD of the five water utilities examined, which were all thought to be 'high-performing' by the World Bank's International Benchmarking Network for Water and Sanitation Utilities (IBNET) 2010 database (De Witte and Marques, 2010).

Documents and records are built up and kept up to give proof of effective operation and conformity of effective quality management systems. Lessons along these cities can be adaptable to organizational (re) design of water utilities, for their improved exhibition, subject to empowering factors in the individual organization's working condition (Berg, 2010).

2.3 Urban Water Supply Assessment System in India

Access to water and sanitation benefits in urban India is generally common, but little attention is being paid to equity of coverage, adequate provision of services, and quality of supply water. The absence of satisfactory and reliable data is a main obstacle in the urban water supply and sanitation system of India. This paper portrays the journey of 400 or more urban areas in two western streams of India from a simple paper-based framework to an online performance assessment framework. Performance Assessment System (PAS) is set up under the CEPT University as a research project, subsidized by the Bill and Melinda Gates Foundation. 5,000 to 5 million population is a range of these selected 400 or more urban areas of different sizes as well. Performance measurement framework (PMF) was developed for the accomplishment of the online system (Jaladhi et al., 2016) . Whose basic purpose is to develop a water and sanitation benchmark with an emphasis on a 'genuine' issue of developing countries. International benchmarking standards, previously conducted studies in India for benchmark development with the use of performance information at the base level were extensively reviewed in PMF development. International Benchmarking Network for Water and Sanitation Utilities has been used as reference (IBNET) Other organizations were American Water Works Association (AWWA) and the International Water Association (IWA) (Van den Berg and Danilenko, 2010). IBNET and AWWA give prepared formats and a web platform for the collection of data, analysis and investigation of results (Alegre et al., 2016).

But in India, where the population in a large proportion living in slum areas and where numerous urban areas rely upon on-site sanitation frameworks, direct application of these templates is doubtful. Hence, an online PAS, which is a demonstrated device, can be utilized as a monitoring framework for the different, recently launched government projects to gauge the visualized results. The Sustainable Development Goals (SDGs) as stated by the United Nations (UN) have a set of 17 major objectives with 169 targets and SDG 6 is to " provide sustainable water management and Guarantee accessibility of water and sanitation for all". Under this objective, there are targets. Target 6.2 is to " accomplish access to sufficient and impartial sanitation and cleanliness for all" This target is assessed through Indicator 6.2.1 determined as "what percentage of the population is utilizing safe sanitation services" (Water, 2016). The online module’s performance information is used for making better policy interventions. The exhibition data of the online module is utilized for better dynamic and approach intercession at the state level and to make improvement plans at the city level. When completely set up is being done, it may be utilized for both result checking and investment decisions (Jaladhi et al., 2016).

2.4 Pakistan’s Scenario

Water deficiencies, "cautions the South Asia researcher Anatol Lieven" present the best future risk to the reasonability of Pakistan as a state and a general public. While this affirmation might be exaggerated, one can barely question its basic reason Pakistan's water circumstance is very problematic. Water accessibility has dived from around 5,000 cubic meters (m^3) per capita in the mid-1950s to under 1,500 m^3 for each capita today. As per 2008 information from the Food and Agriculture Organization, Pakistan's aggregate water accessibility per capita positions dead toward the end in a rundown of 26 Asian nations, what's more, the United States. Pakistan is relied upon to become water rare (the country designated with yearly water accessibility beneath 1,000 m^3 for every capita) by 2035. However, a few specialists venture this may occur when 2020, if not prior. Faisal Khan of Hobart and William Smith Colleges depicts how awful arrangements, poor administration, and corruption affect water management. In 2007, Rawalpindi's Water and Sanitation Agency reported that 64 percent of the city drinking water supply contained human waste and utilized water and that 70 percent of the city's water supply lines were conveying sewage water to purchasers (Khan, 2009).

Also, in 2008, the Pakistan Council for Scientific Research established that in excess of 2,000,000 individuals in Peshawar drink contaminated water. A significant driver of these conditions is the scarcity of urban wastewater treatment. While these issues distress every Pakistani city, some urban regions are influenced more than others and in various ways. (Wescoat Jr, 2009) of the Massachusetts Institute of Technology, brings up that the nation's urban water frameworks work in a totally different atmosphere, fluctuate in social and regular terms, and serve diverse modern economies "in various civil and commonplace institutional settings".

CHAPTER 3

MATERIAL AND METHODS

3.1 Background and Current Water Situation of Study Areas

Coming towards the water scenario of selected metropolitan city Faisalabad, for provision of water and sanitation services within the premises of Faisalabad water and sanitation agency WASA is responsible which is working under Faisalabad Development Authority FDA.

3.1.1 Outline of WASA-F's Operations

The real status of WASA F's activity for waterworks, sewerage/seepage works, and money related conditions are outlined underneath.

3.1.2 Outline of water supply works of WASA-F

The total number of household units in Faisalabad City is 400,000, the number of households in the WASA-F Service Area is 250,000 and the total number of household connections to the WASA-F Service Area is 113,000. Having a water supply from WASA of 6 hours (2 hours' x 3 times). WASA-F has Designed intake Water consumption volume from Groundwater is 427,000 (m^3/day) and the actual amount of water intake from groundwater is 209,000 (m^3/day). From surface water resources FWASA has designed a surface intake capacity of 73,000 m^3/day, but the actual surface intake is 31,000 m^3/day. FWASA has designed Water supply volume of 500,000 m^3/day and the actual water supply volume is 240,000 m^3/day. For the treatment of water, they have slow sand filtration and rapid sand filtration having a capacity of 28,000 m^3/day & 45,000 m^3/day respectively. While currently, their actual treatment capacity is about 11,000 m^3/day & 20,000 m^3/day respectively. Only a disinfection facility is mostly used for bulk water supply in the city having a designed capacity of 427,000 m^3/day and currently, 209,000m^3/day water is disinfected.

3.1.3 Outline of water supply facilities of WASA-F

Faisalabad's major source of water is groundwater and for the uptake of water from the ground, WASA-F has installed mega tube wells around different well fields. 25 Tube Wells are installed in the Chenab Well - field, 25 are installed in the JBC Well - field and 28 tube wells are installed in the RBC Well - field. WASA-F further owned pumping stations named Chenab line with a capacity of 16-32Cusec having a Booster of 7 Cusecs and distribution of 10 Cusecs. Another pumping station is also under WASA-F named JBC line 15-37 Cusec having Booster of 4 Cusecs & distribution of 5 Cusecs. FWASA has 3 slow sand filtration water treatment plants having a capacity of 7000-12800 m^3/day and 1 rapid sand filtration plant with a capacity of 45500 m^3/day. FWASA has calculated its distribution pipe length (km), it has 101 Arterial mains of 400 mm-1,600 mm diameter and 1309 Secondary & tertiary lines having a diameter of 75 mm-300 mm. Further FWASA has 33 Ground Reservoirs (GR) and 42 Over Head Reservoirs.

3.1.4 Outline of the financial condition of WASA-F

FWASA has two types of tariff collection system as it has collected 28% of revenues from the residential area on the basis of flat rates. While for commercial and industrial sector FWASA has a metered system as well as flat rates and revenue collection efficiency is 75-80% in this sector. WASAs budget for Receipt and Expenditure is predominantly characterized into Non-Development and Development. Receipt in Development incorporates; 1) ordinary government activities and 2) monetary budgetary help through outside multilateral awards. Developmental expenditures are the capital venture under the improvement programs. Receipt in Non-Development, additionally viewed as Operational Receipt, incorporates 1) water supply and sewerage income 2) Grants, sponsorships and transfers 3) other income. Use in Non-Development, additionally viewed as Operating

Expenditure, is made out of 1) pay remittances, 2) water supply & sewerage electricity costs 3) fix upkeep costs and 4) other expenses.

3.2 Present Condition of Water Resources in Faisalabad

3.2.1 Current scenario of groundwater resources

Chenab tubewells have been yielding water a long time since beginning their tasks. The groundwater level in the encompassing zones has fallen 20 m at the most extreme, because of over intake of water for a long haul period. Changes in the groundwater level in the JBC Well Field recognized after the beginning of office activity show extreme groundwater intake, prompting the declining water level about one meter for each year persistently until 2015. Along with GBC, around Jaranwala and Satiana have a high density of the current wells, and in this manner not have many advancement possibilities. The current wells are dispersed in the territories between and in the region of these towns, along with GBC, probably permit further improvement. The capability of groundwater sources is outlined as moderately low.

3.2.2 Existing condition of surface water resources

In spite of the fact that water system waterways (JBC, RBC, and GBC) have a stable water stream, for the most part, the accessible measure of water has been yet insufficient to meet the necessary measure of water for the water system. Waterway terminations happen once every year for channel maintenance. A typical closing period is around three weeks and at some point, more.

3.2.3 Present condition of Chenab river

The water stream of the Chenab River is controlled at an upstream barrage. Thus, no water is released at the time of barely any months a year. This regular stream may potentially divert the waterway course where the water streams. The intake point is found in the more remote water system waterways. As an elective intake point, WAPDA plans to develop Chiniot Dam situated approximately 40 km a long way from the city.

3.2.4 Reasons for water shortfall

The declining water level in groundwater happens due to inordinate water pumping. The potential for new improvement is low. There are waterway shutting periods that are no stream in water system trenches brought about by support. Laws and guidelines are being produced for water supply and sewerage works. In any case, the implementation of laws and guidelines is as of now extremely less.

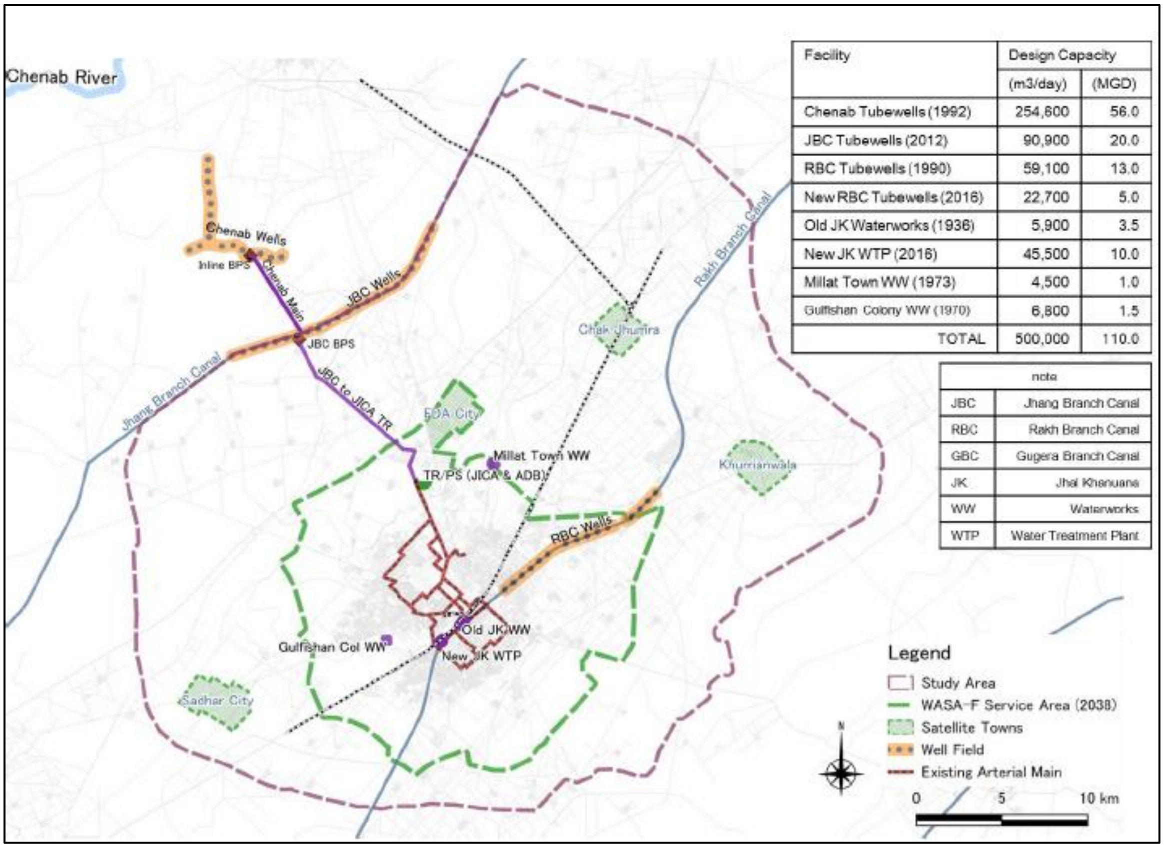

Figure 4: Existing Water Supply Facilities of Faisalabad

3.3 Scenario of Rawalpindi

Now Coming towards water second selected metropolitan city Rawalpindi for provision of water and sanitation services within the premises of Rawalpindi water and sanitation agency WASA is responsible which is working under the Rawalpindi Development Authority RDA. The major objectives of RWASA for water supply are the Provision of safe drinking water and improved sanitation facilities and the Development and exploitation of additional water sources to cater for future needs. The following map shows RWASA jurisdiction areas.

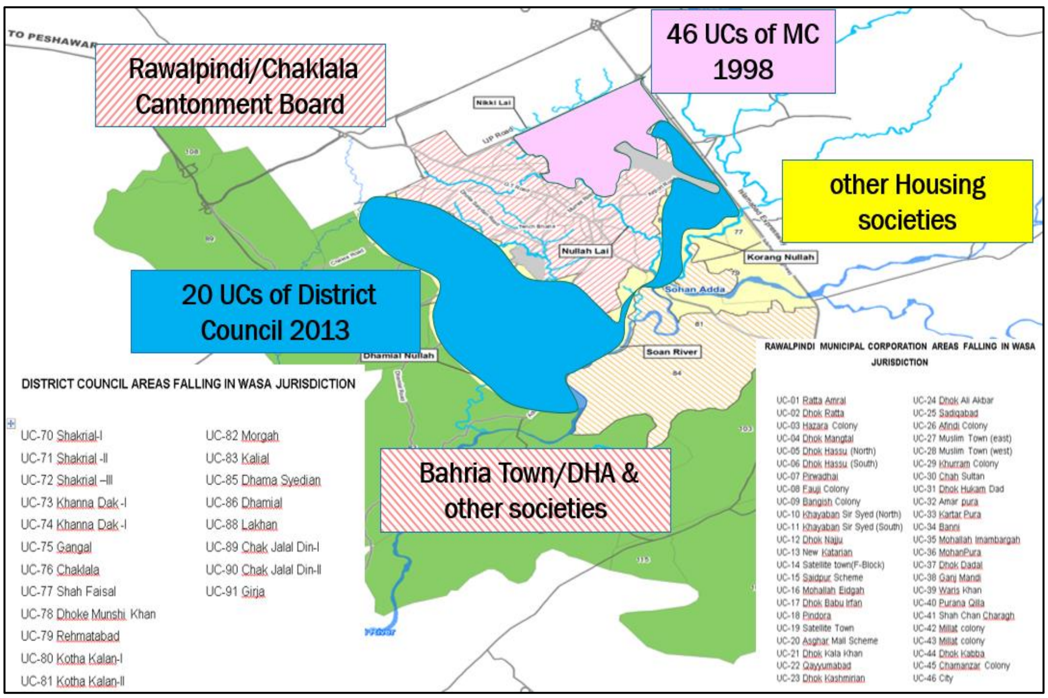

Figure 5: RWASA Water Service Area

3.3.1 Outline of water supply facilities of WASA-R

RWASA has 1.6 million people that are living in their coverage area at present. Their coverage area constitutes 46 UCs Municipal Corporation and 20 UCs District Council. RWASA has a total of 132,592 water consumers and of which 118,791 are domestic consumers and 13,801 are commercial consumers. At present, Rawalpindi Water and Sanitation Agency (RWASA) jurisdiction area is having water demand of 304600 m^3/day (67 MGD) of water. Surface water supplies originate from Rawal Dam and Khanpur Dam, which the groundwater supply originates from 362 profound tube wells. Rawal Dam supplies 104560 m^3/day (23 MGD) against the introduced limit of 127290 m^3/day (28 MGD). Khanpur Dam supplies 27276 m^3/day (6 MGD) against a designation of 66372 m^3/day (14.6 MGD) because of a lack of water in Khanpur Reservoir. The introduced limit of the store is 231850 m^3/day (51 MGD). Profound tube wells at present work for the most extreme stockpile at 172751 m^3/day (38 MGD). And they have a deficit of about (15 MGD) at present.

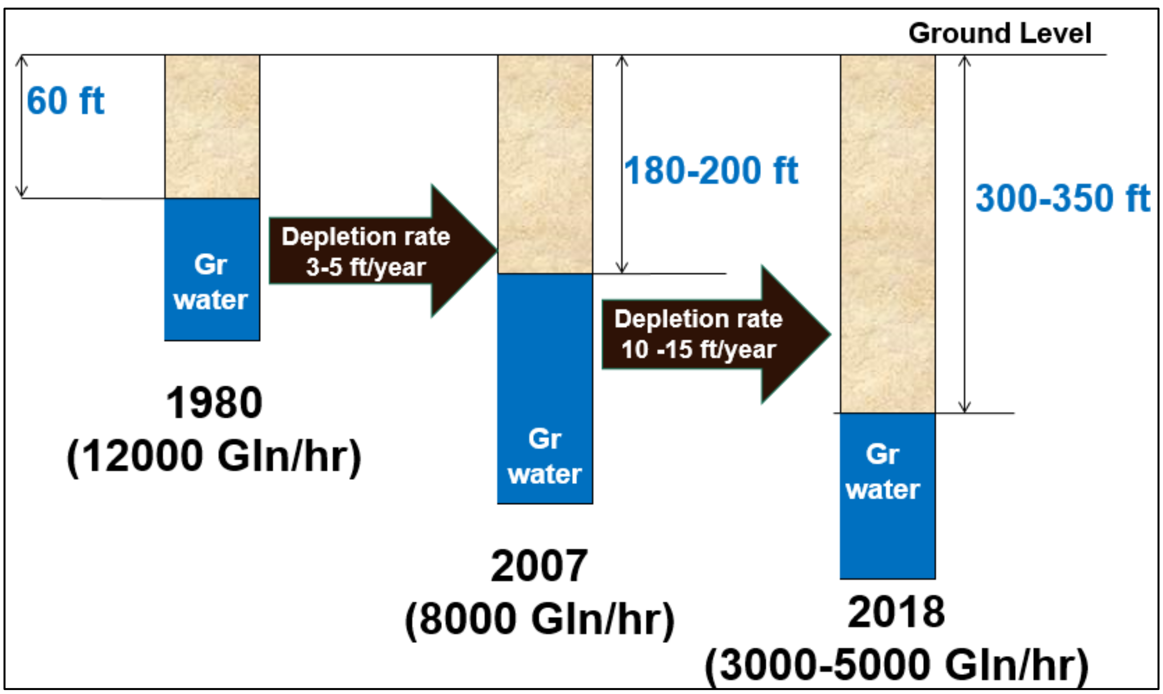

Figure 6: Declining trend of Ground Water Table of Rawalpindi

Groundwater has deprived a lot on the premises of Rawalpindi as the water table reaches from 60 ft. to 180-200 ft. In the year 2007 it further goes on depleting to 300-350 ft in the year 2018. As it clearly shows in the picture this groundwater continuously dwindles due to excessive intake of water from the ground in the future as well.

3.3.2 Outline of the financial condition of WASA-R

Two types of tariff systems are being used for revenue collection in WASA-R. Which includes Metered Bulk Supply Tariff and Unmetered Domestic Supply Tariff. Consumers are isolated into various classes depending on the size of the plot/house they have to pay the tariff on flat rates. Commercial Supply Tariff un-metered Consumers are isolated into various classifications depending on the kind of business and utilization of water. The financial condition of WASA-R is also affected by these tariff types. Until 2010 the RWASA was alright in money-related self-manageability, yet at that point, the water prices were frozen at the 2009 rates. From that point forward because of inflation and different variables, the activity/upkeep costs have nearly multiplied, however, duty has not expanded. The majority of RWASA's income is currently expended in compensations and vitality costs (tube wells and treatment offices) and little is left for upkeep/ improvement of the existing framework. RWASA major revenue sources are Domestic/commercial consumers Fee, Bulk consumers fee, including MES, NARC, NIH, Pak Railway, new water connection fee, water tanker fee, tender fee, UIP Tax share, Miscellaneous income, and Enlistment fee. And their major expenditures constitute Water treatment plant costs, Operation & maintenance costs, system & design costs, pay & allowances, contingency costs, and different loans and grants that are returnable to banks.

3.4 Data Collection:

3.4.1 Collection of primary data

The collection of data is one of the key tasks in any study to represent the real essence of results-focused to be achieved. For the collection of required data questionnaire was prepared. Which includes significant parameters regarding water supply management to check the efficiency of individual WASA. This questionnaire was sent to FWASA and RWASA. They provided data of the last 10 years, according to parameters asked for them. And that data is analyzed by various statistical methods, collection and analysis of data played a major role in understanding the current situation of the study area in terms of water availability and future scenarios as well. primary data covered a significant part of this study. The questionnaire includes the following parameters.

Design Criteria Regarding Water Distribution System
1-What are the major sources of water supply in the city?
2- How much is total supply of water?
3. total demand of water (per capita)
4-How much deficit of supply occurs yearly i-e gap between supply and demand?
5-what is water demand growth rate
6-what type of Treatment system is installed at the source and at consumers end?
7-Total flow rate and peak hour demand?
8- what is Water pipeline sizing criteria and materials used in manufacturing?
9- Flexibility of supply system w.r.t future extensions (future planned projects their capacities and completion)
Economic Aspects
1-how much Recovery of tariff from Water Supply Arrears?
2- what are Infrastructure Charges?
3-what are the Water Supply and Sewerage Receipts?
4-how much Recovery is being done through Sourcing of Illegal Connections?
5-how much Recovery is being done through Sourcing from Chronic Defaulter?
6- how much revenue is collected from Property Tax Share?
7-what are the sources of Other Income?
8-Is there any P.F.C. Award Share from City District Government?
9-what is Annual lease amount for land and auction of wastewater?
10- Income from Mobile Phone Companies by leasing roofs of OHRs and from hiring of Crane and Fork Lifter?
11- what are the Share of Departmental Charges from development Schemes and income from investment on different projects?
12-Income on investment/Deposit
13-what are the sources of Miscellaneous Incomes?

14-Is there any Grant from GOP allotted to WASA or from District Government?
15- how much revenue is generated from Tender Fee/Enlistment Fee and through Establishment?
16- what amount of expenditures are on Pay & Allowances and for Other benefits for Employees?
17-what are the Electricity expenses for Water Supply
18- what are the Operation and Maintenance Expenses of water supply system?
19- what are the POL Expenses Of Vehicles and Repair Of Vehicles & Travelling Expenses?
20-what are other expenses including Expenses On Office Facilities, Electricity & Gas For Offices, Legal & Audit Fee and Procurement & Stores?
21- what is surplus/deficit in terms of the gap between revenues and expenditures?

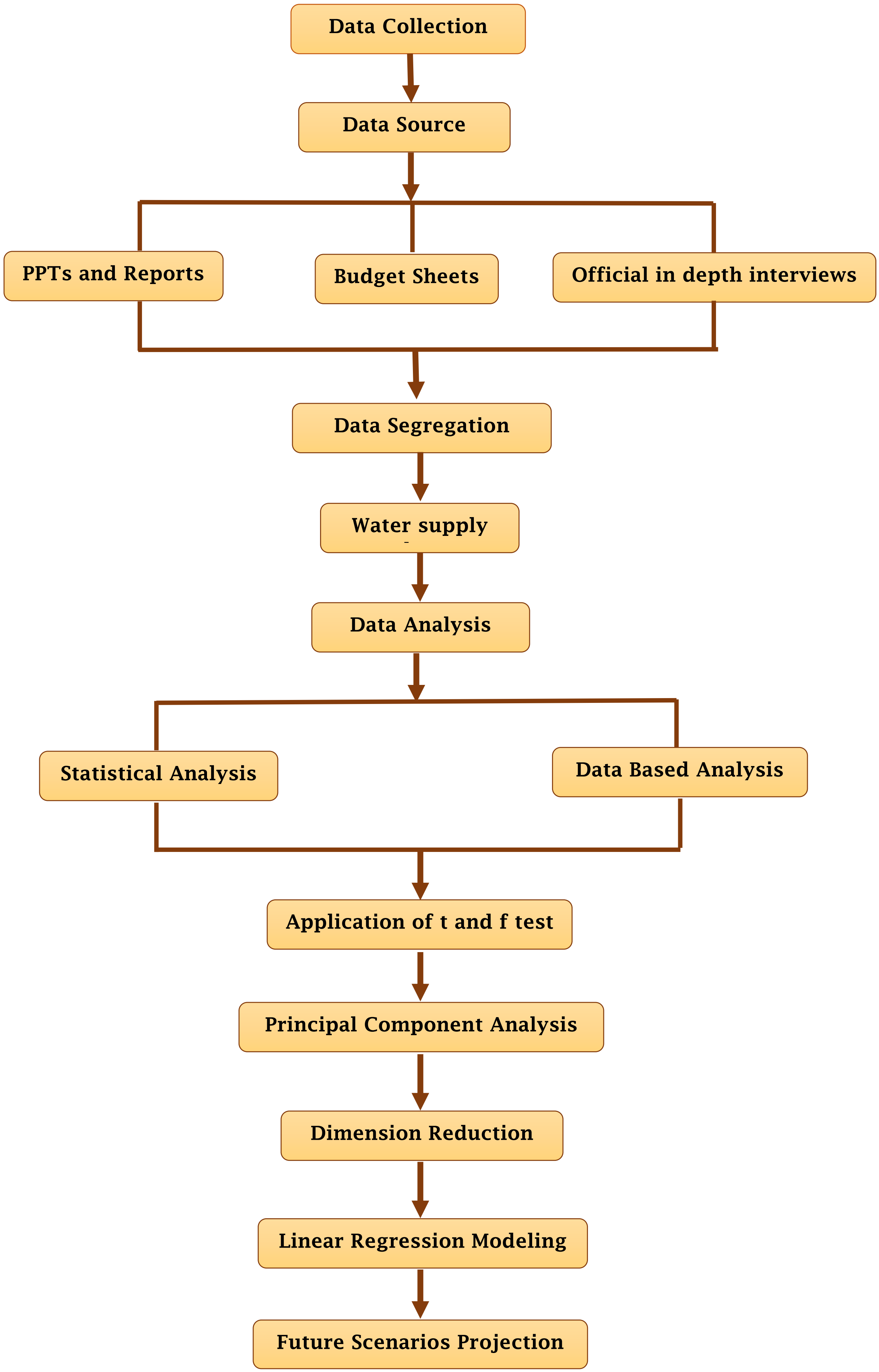

Figure 7: Flowchart showing the methodology used during this study

3.4.2 Regression Analysis

Regression Analysis is a factual procedure for assessing the relationship among factors. It incorporates numerous systems for examining and modelling several variables, it explains the relationship between dependent value and one or more independent values. Regression Analysis helps in seeing by changing the independent variables how the dependent variable varies. The simple linear regression model equation is written as

$$y_i = \beta_0 + \beta_j x_i + \varepsilon_i \qquad \text{(i)}$$

where "y" is response that is dependent variable, β0 is the dependent variable mean which is intercept when x is considered as zero, βj is slope (change in dependent variable **y** w.r.t **x**) or response variation about the mean can be explained by regression coefficients and ε_i (Random part). This regression analysis is set of strategies dependent on an "n" sample having order sets $(x_i y_i)$, where i= 1, 2, 3,…., n, for assessing and making derivations on the coefficients of regression, where multiple independent values of regression coefficient are denoted by j=1,2,3,… .,n. These assessments would then be able to be utilized to evaluate dependent variables having mean values for specific value of x. Different diagnostics checks have been utilized to survey the nature of the created model(s) and its resultant gauges, for example t-test, f-test, R-squared and Adjusted R-Squared **3.4.2** (Sanli et al., 2005).

3.4.3 R-Square

Variances found in the dependent variable is determined by **R2** that is predictable form of new independent variable. It is statistical process, utilized in the point of view of factual models with the reason for either the expectation of future results or the testing of speculations based on the related data. The purpose of **R2** is testing hypothesis on the basis of given information and give prediction of future consequences. It gives the proportion of exactness of observed results as given by the model. 0 to 1 is the range of **R2 value**. The value of **R2** is determined by

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}} \quad \text{(ii)}$$

whereas the sum of Square of residuals (SS_{res}) is determined by

$$SS_{res} = \sum_i (y_i - f_i)^2 \quad \text{(iii)}$$

whereas the total sum of Square (SS_{tot}) is determined by

$$SS_{tot} = \sum_i (y_i - \overline{y}) \quad \text{(iv)}$$

3.4.4 Adjusted R-Square

The purpose of adjusted R2 is to determine the variation found in the dependent variable that is caused by predicting variables by adjusting the amount of terms in statistical model. The formula of adjusted R^2 is given as

$$R^2_{\text{Adjusted}} = 1 - \frac{(1-R^2)(N-1)}{N-p-1} \quad \text{(i)}$$

where "R^2" denotes sample R squared value, "p" value is showing number of predictors and total sample size is denoted by "N".

3.4.5 t- test

t test is hypothetical test of statistics, in which t distribution is followed under null hypothesis. This test is used to check difference found between the two data sets. For the application of this test value of scaling term and normal distribution should be known. Scaling term can be substituted by making an estimate on the basis of given data if it is unknown. t test is being performed to assess regression coefficients significance individually.

Formula for t value calculation is written below

$$t = \frac{M_x - M_y}{\sqrt{\frac{S_x^2}{n_x} + \frac{s_y^2}{n_y}}} \quad \text{(i)}$$

$$S^2 = \frac{\sum(x-M)^2}{n-1} \quad \text{(ii)}$$

Where mean is denoted by "M", score per group is denoted by "n" and individual score is represented by x.

3.4.6 F-test

It is a statistical test based on hypothesis, in which F-distribution is followed under the null hypothesis. Usually statistical models comparison has done by F test. It is also used for model identification that fits best on population of sample data. model adequacy has been assessed by F-test. The value of F-test is stated as ratio of two observation's variances which could lead to estimation of data sets.

$$F_{value} = \frac{\sigma_1^2}{\sigma_2^2} \quad \text{(i)}$$

σ^2 is showing variance and formula of variance is given by

$$\sigma^2 = \frac{\sum(x-x)^2}{n-1} \quad \text{(ii)}$$

3.4.7 Linear Regression Model

Validation and approval of linear regression model for the better estimation of resultant, data should have specific assumptions that are required to be achieved by using statistical methods. This study proposes a comprehensive analysis, in the field of hydrology for the prediction of the water supply management system, Formal statistical tests have been used to validate CLRM related assumptions. There is only one independent variable in simple linear regression and in multiple linear regression there are multiple independent variables. For the application of the multiple linear regression model, there must not exit strong linear relationship between the independent variables otherwise it will cause the problem of Multicollinearity. Which refers to a situation in which two or more independent variables are highly linearly correlated. The range of multicollinearity is between -1 to +1. If a specific value deviates from centre zero, it has a probability of multicollinearity. If a specific value of a data set has correlation value is close to -1 or 1 with a p value of less than 0.05 it has a strong linear relationship. And if a specific value has Pearson correlation value closer to -1 or 1 but it has a p value greater than 0.05 then that value did not give strong correlation.

3.4.8 Principal component analysis

(Matteson and Tsay, 2017) describes a notable system utilized right now the PCA. It is a multivariate numerical instrument which changes the arrangement of uncorrelated factors. These uncorrelated factors are called parts of the components of correlated factors. The PCs are linear combinations of the original correlated variables in a way that they aggregate of the variances are identical for both the first original variables and new uncorrelated variables. The key rationale behind the PCA is the dimension reduction and transformation of data sets and leads to independent and significant coordinates of WASAs parameters with respect to water supply and management rather than mutually dependent coordinates. Principal component analysis changes the first informational index of n factors which is original data and they are correlated values as well, among themselves to different degrees to another informational index containing n number of uncorrelated principle components (PCs). The PCs are succession from the most elevated variance to the least one. The foremost PC clarifies the most elevated variance in the data and the next second PC describes the next highest variance found in data and the manner continuous to all n principle components.

The estimations of the considerable number of PCs can be acquired by a similar condition as Equations 1 and 2. These two conditions are for PC 1 and PC 2. Despite the fact that the quantity of PCs and original correlated variables are equivalent, ordinarily the greater part of the variance in the informational index can be clarified by the initial not many PCs that can be utilized to represent the first original values (Abdul-Wahab et al., 2005). This aide in the reduction of the dimensionality found in first correlated original data.

$$PC1 = a_{11}x_1 + a_{12}x_2 + \cdots a_{1n}x_n = \sum_{j=1}^{n} a_{1j}x_j \quad \text{(i)}$$

$$PC2 = a_{21}x_1 + a_{22}x_2 + \cdots a_{2n}x_n = \sum_{j=1}^{n} a_{2j}x_j \quad \text{(ii)}$$

$$PC3 = a_{31}x_1 + a_{32}x_2 + \cdots a_{3n}x_n = \sum_{j=1}^{n} a_{3j}x_j \quad \text{(iii)}$$

$$PCn = a_{n1}x_1 + a_{n}x_2 + \cdots a_{n}x_n = \sum_{j=1}^{n} a_{nj}x_j \quad \text{(iv)}$$

Where $x_1 x_2 \dots x_n$ are the first original variables in the informational data sets and a_{jj} are the eigenvectors.

The eigenvalues are considered as variances of the PCs and the coefficients a_{jj} are the eigenvectors extricated from the covariance or matrix having correlation of the informational data sets. The eigenvalues of the data grid can be determined by Equation 3 as demonstrated as follows

$$|C - \lambda| = 0 \quad \text{(v)}$$

Where C is representing the covariance matrix, λ is considered as the eigenvalue and I is the identity matrix.

The PC coefficients or the weights of the variables in the PC are then calculated by Equation 4

$$|C - \lambda| a_{jj} = 0 \quad \text{(vi)}$$

Because of contrasts in the units used in the study, variables having correlation matrix were utilized to acquire eigenvalues and eigenvectors. The eigenvectors are multiplied by the square base of the eigenvalues to produce a $n \times n$ grid of coefficients, which are called variable loadings. Principle components are represented by these loadings. Moreover, the product sum of original variables values and variable loadings form component scores which are new data set values. These scores can be utilized in the various direct conditions as new factors to foresee the future water request. These scores can be used in forecasting future scenario of water supply and management in the form of multiple linear equations. After principal component analysis simple regression analysis has been performed.

CHAPTER 4
RESULTS & DISCUSSOIN

4.1 Rawalpindi Water Supply and Management System

For the estimation of gaps present between water supply and water demand as per million population under the RWASA coverage area cumulative trend lines have been drawn on the latest ten-year data. And the difference between water supply and water demand is shown on the graph as a deficit. Details of the graph are explained below

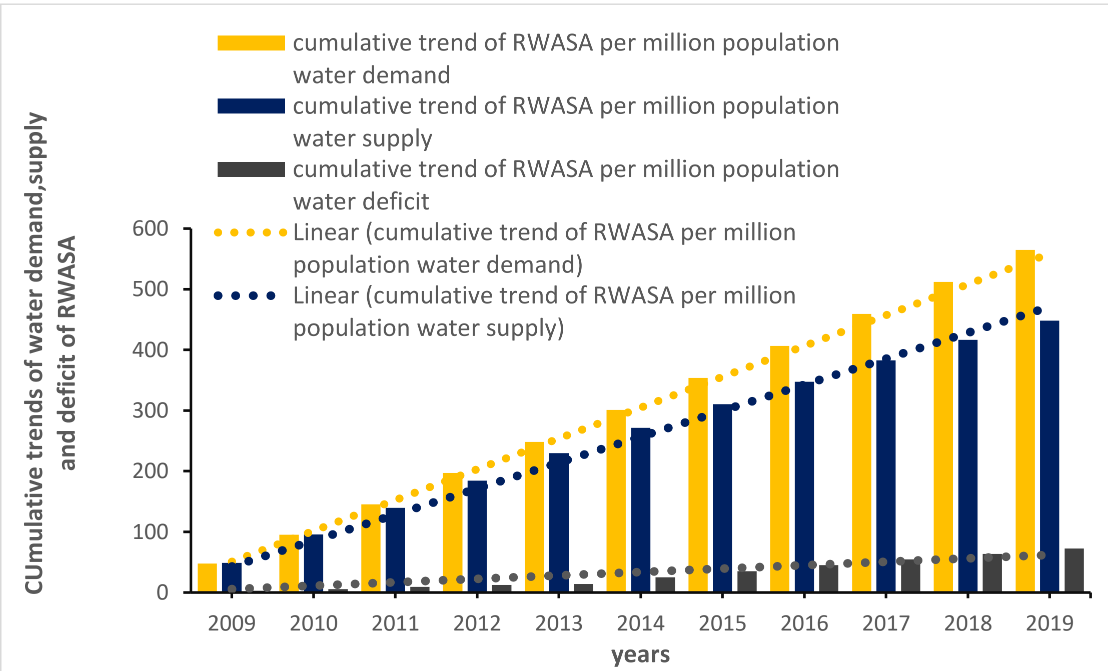

Figure 8: Cumulative trends of water demand, supply and deficit of RWASA

According to data given by the RWASA water demand as per million population has been increased from 213700 m^3/day to 236400 m^3/day (47 MGD - 52 MGD) due to increased living standards within the latest ten-year time span. While per million supply rate has been dropped from 218200 m^3/day to 145500 m^3/day (48 MGD - 32 MGD) the reason behind that is the haphazard increment of urban population and the increased competition of resources. And for the total current 1.6 million RWASA jurisdiction population water supply is about 231850 m^3/day (51 MGD). The total water demand of 1.6 million population is 300000 m^3/day (66 MGD) leaving the deficit of 68191 m^3/day (15 MGD). Cumulative trend lines have been drawn on the data and their pattern showed the following results. water demand trend line is being coincided with the cumulatively added values it means that water demand is according to population. While water supply cumulative value trend line is lower than the water demand graph and also water supply trend line is being deviated from the cumulative value which has described that water supply should be more than the current one otherwise the deficit will be increased in the upcoming years. Similarly, in previous years' deficit values are beneath the trend line which means deficit was comparatively less, but the current deficit has been increased as the values are deviating from an average line in an upward way.

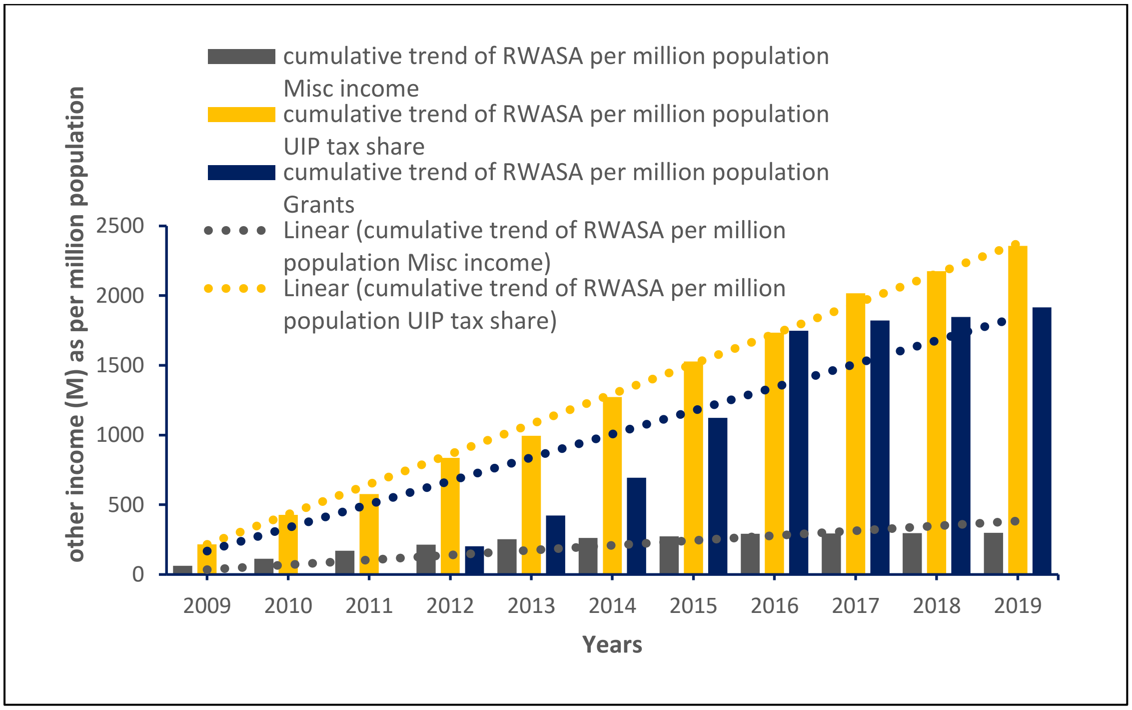

Figure 8: Other Income (million) as per million population of RWASA

The trend line of miscellaneous income has been shown that cumulative values are coinciding with the average line in the initial years in an upward direction. But with increasing year share of miscellaneous income has dropped as per million populations because the population is growing at a faster rate than the resources. But the cumulative trend in urban immovable property tax share has made a progressive increase in revenues of RWASA. The cumulative trend of grants has been described that 2009-2011 no subsidies or grants are given to RWASA from the government of Punjab. But after that subsidies, loans and grants have been provided and it has been increased with upcoming years in order to cope up with functional expenditures and for developmental projects.

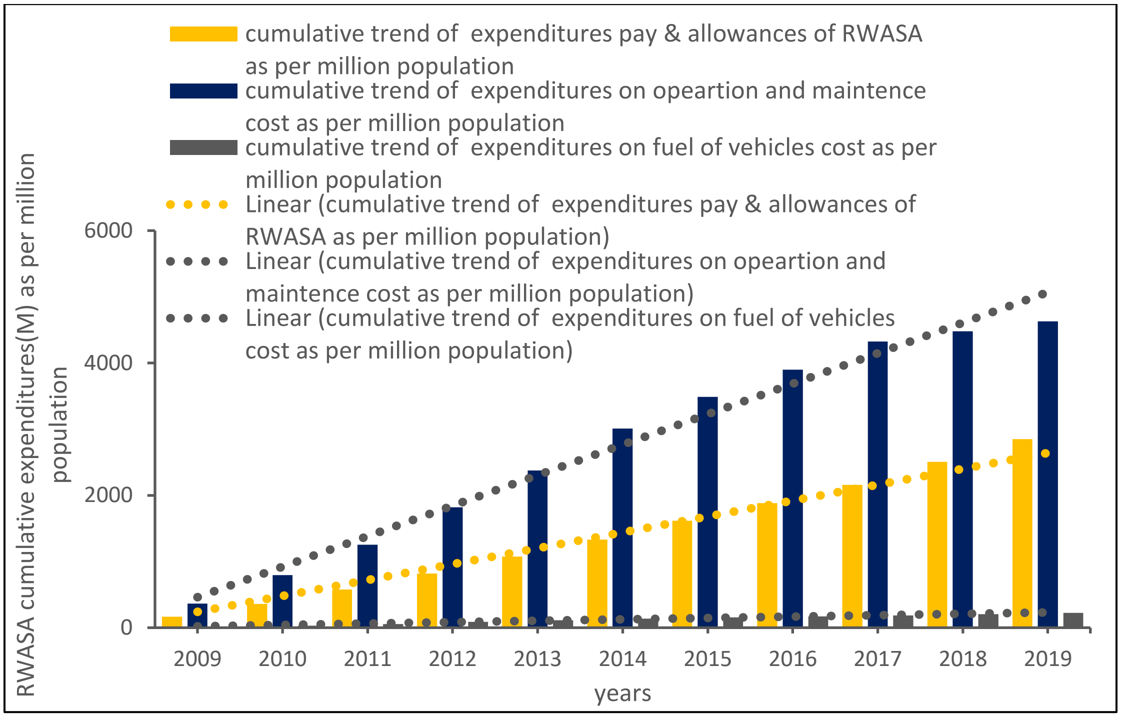

Figure 9: RWASA cumulative expenditures(million) as per million population

Cumulative trend of expenditures on pay and allowances, operation and maintenance and expenditures on vehicles fuel have been plotted on graph. They have increasing trend with each passing year because these factors have direct relation with increment in provision of water services.

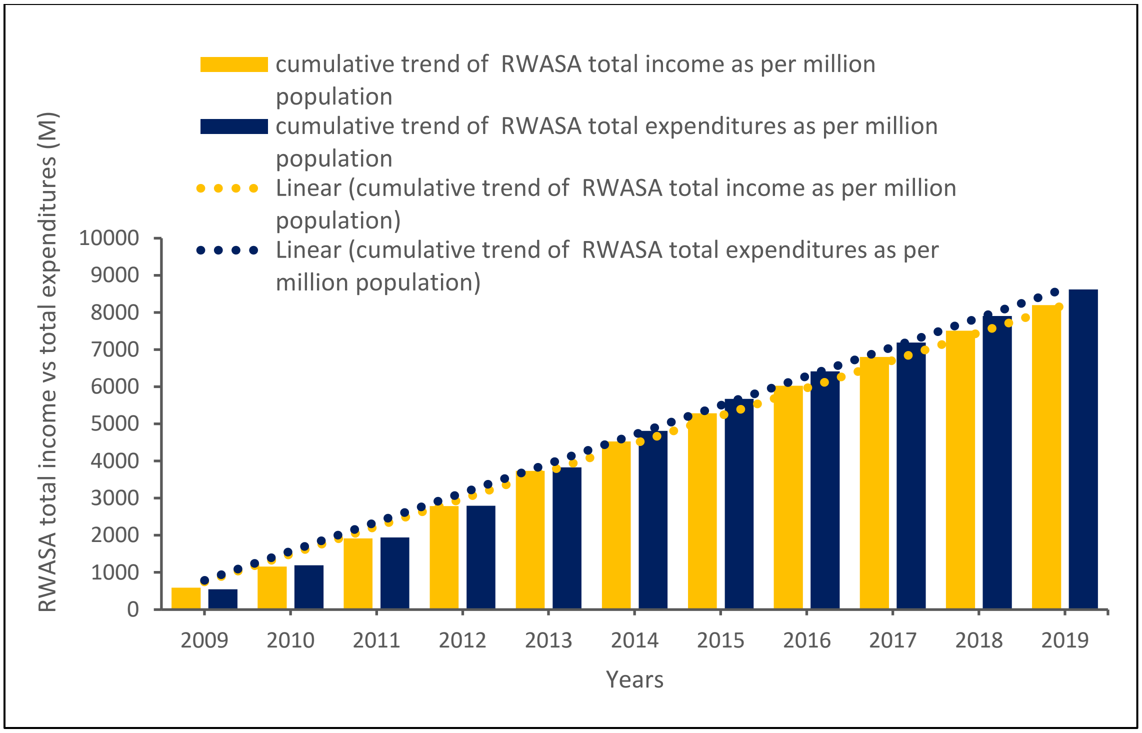

Figure 10: RWASA total income vs total expenditures (million)

Cumulative trend lines of total revenues generated and total expenditures are described in the graph. This shows that the total expenditures trend line has been slightly higher as compared to total revenues of RWASA leaving the deficit of income. As the total income of RWASA from per million population was 586 million in 2009 and has increased up to 687 million in 2019, while the expenditures have increased from 547 million to 709 million for providing the services to one million population. Similarly, a slightly higher expenditure trend was found between 2000-2019.

4.2 Faisalabad Water Supply and Management System

For the estimation of gaps present between water supply and water demand as per million population under the FWASA coverage area cumulative trend lines have been drawn on the latest ten-year data. And the difference between water supply and water demand is plotted on the graph as a deficit. Details of the graph are explained below

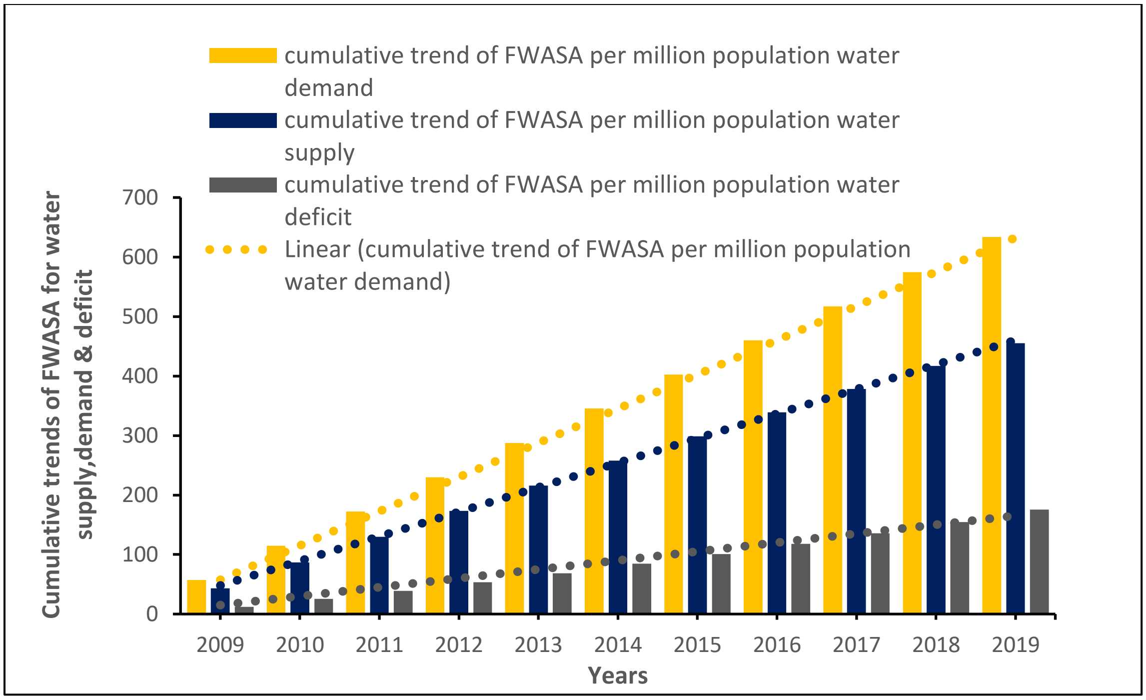

Figure 11: Cumulative trends of FWASA for water supply, demand & deficit

According to data given by the FWASA water demand as per million population has been increased from 259000 m^3/day to 268200 m^3/day (57 MGD - 59 MGD) due to increased living standards within the latest ten-year time span. While per million supply rate has been dropped from 195550 m^3/day to 172750 m^3/day (43 MGD - 38 MGD) the reason behind that is the haphazard increment of urban population and increased competition of water resources. And for the total current 2.89 million FWASA jurisdiction population water supply is about 500000 m^3/day (110 MGD). The total water demand of 2.89 million population is 777400 m^3/day (171 MGD) leaving the deficit of 277300 m^3/day (61 MGD). Cumulative trend lines have been drawn on the data and their pattern showed the following results. The water demand trend line is being coincided with the cumulatively added values it means that water demand is according to population. While the water supply cumulative value trend line is lower than the water demand graph which has described that water supply should be more than the current one otherwise the deficit will be increased in upcoming years. Similarly, as the difference between supply and demand has increased deficit value is also increasing with the upcoming year.

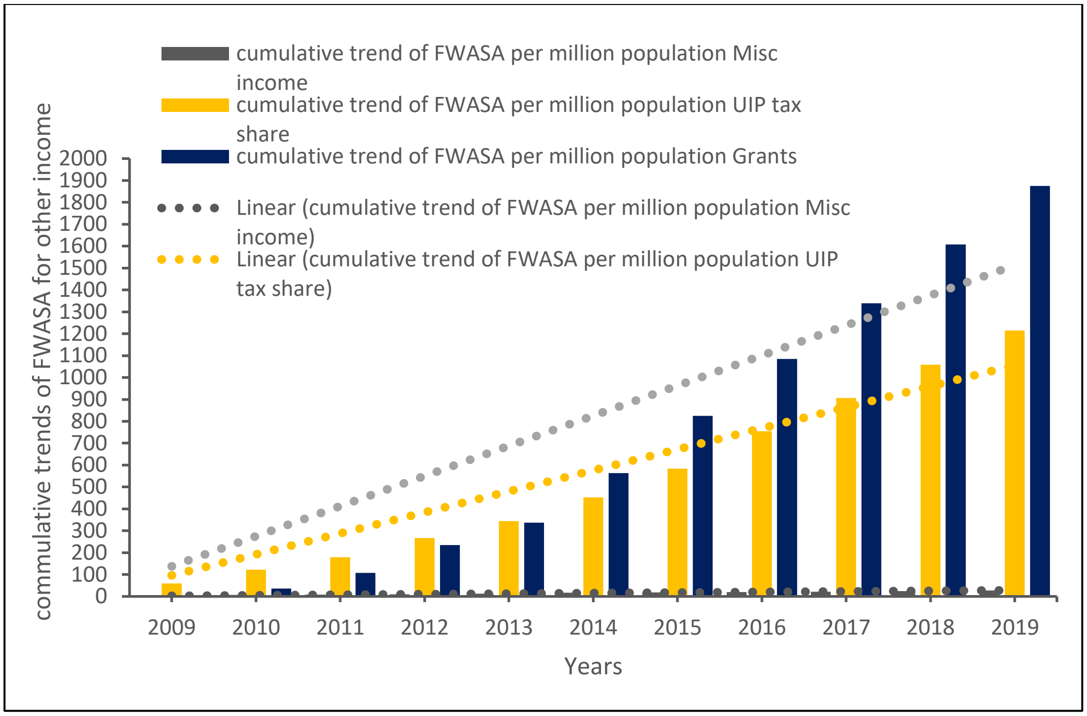

Figure 12: Cumulative trends of FWASA for other income

The trend line of miscellaneous income has a very little share in FWASA revenue generation and showed that cumulative values are coinciding with the average line. Although the cumulative trend in urban immovable property tax share has made a progressive increase in revenues of FWASA in previous years UIP tax share is deviating below the trend line. The cumulative trend of grants has been described that 2009-2010 no or little subsidies or grants are given to FWASA from the government of Punjab or city district government. After that subsidies, loans and grants have been provided in order to cope up with functional expenditures and for developmental projects.

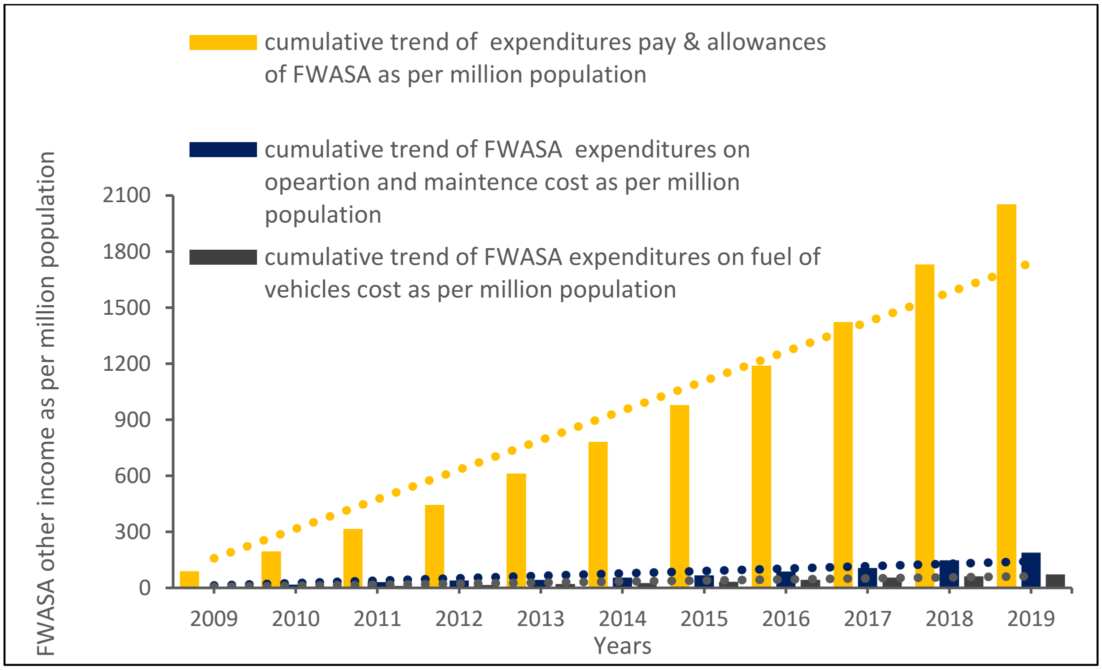

Figure 13: FWASA other income as per million population

The cumulative trend of expenditures on pay and allowances, operation & maintenance, and expenditures on vehicle fuel have been plotted on the graph. They have an increasing trend with each passing year because these factors have a direct relation with increment in the provision of water services. But the comparatively little amount is being used on maintenance and fuel vehicles while major chunk is spent on pay and allowances.

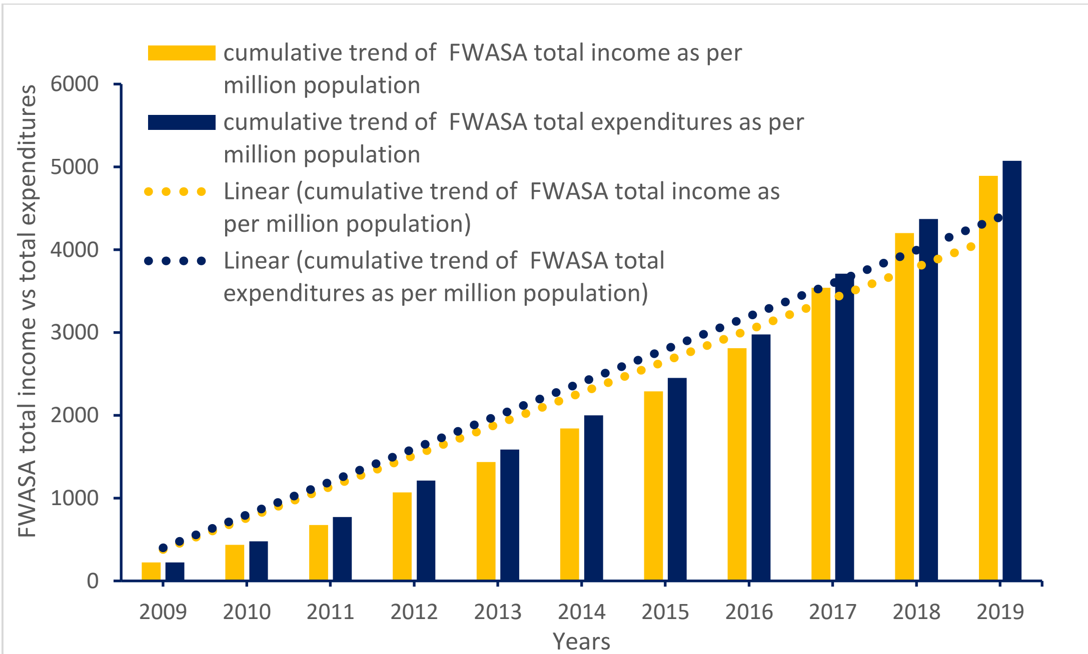

Figure 14: FWASA total income vs total expenditures

Cumulative trend lines of total revenues generated and total expenditures are described in the graph. This shows that the total expenditures trend line has been slightly higher as compared to total revenues of FWASA leaving the deficit of income. But in some years FWASA operates, at no profit no loss situation as well because the total revenues generated have to meet the total expenditures of the year. As the total income of FWASA from per million population was 225 million in 2009 and has increased up to 692 million in 2019, while the expenditures have increased from 225 million to 700 million for providing the services to one million population. Similarly, the slightly higher expenditures trend was found between 200-2019.

4.3 Inferential Analysis

The t-test is used to check the average differences between the two selected cities Rawalpindi and Faisalabad. To perform a t-test there is a requirement of normality assumption for that F test is performed to check either the variance of two data sets is equal or not. If the p-value of the F test is less than 0.05 than it means the variance of the two data sets is equal. But if the p-value exceeds 0.05 than data sets have unequal variation.

The t-test is used to check either mean of the Rawalpindi and Faisalabad is equal or not. Means are checked by p-value. If the p-value of the t-test is less than 0.05 it means the average performance growth of Rawalpindi & Faisalabad for a specific parameter is different because of different mean and vice versa.

The table below abridges the results of eighteen performance indicators for water supply and management systems of Rawalpindi & Faisalabad collectively and have shown the following results.

4.3.1 Results of F & t tests

According to the results jurisdiction population of Rawalpindi WASA & Faisalabad WASA, the total water demand of both cities, deficit of water supply, income from UIP tax shares, expenditures on fuel and their total expenditures have different variances as their p value of F–test exceeds from 0.05.

Table 1: results of F & t tests

Parameters	F test F value	p value	t test t value	p value	Reject/ do not reject
RWASA + FWASA jurisdiction population	2.76	0.125	-15.94	0.000	Reject
(RWASA+ FWASA) service area water demand	0.88	0.837	-24.13	0.000	Reject
(RWASA+FWASA) total water supply	5.48	0.013	-48.61	0.000	Reject
Deficit of supply in (RWASA+FWASA)	0.33	0.098	-10.30	0.000	Reject

RWASA+ FWASA Misc. income	95.99	0.000	3.23	0.009	Reject
RWASA+ FWASA tender fee	0.00	0.000	-3.82	0.003	Reject
(RWASA+ FWASA) UIP tax share	0.34	0.102	-1.11	0.280	Do not reject
(RWASA+ FWASA) Own source revenue	18.599	0.000	18.90	0.005	Reject
(RWASA+ FWASA) water supply charges	0.22	0.027	0.22	0.83	Do not Reject
(RWASA+FWASA) grants	0.73	0.635	-2.17	0.042	Reject
(RWASA+ FWASA) income from water supply	0.33	0.092	1.25	0.224	Do not reject
(RWASA+ FWASA) 0ther income	0.10	0.001	-3.15	0.008	Reject
(RWASA+ FWASA) Pay & Allowances	0.18	0.012	-4.12	0.001	Reject
(RWASA+FWASA)operation & maintenance	16.62	0.000	8.55	0.000	Reject
RWASA+FWASA Energy prices	5219.415	0.000	-0.86	0.401	Do not Reject
RWASA+FWASA Fuel for vehicles	0.44	0.212	1.68	0.109	Do not reject
RWASA +FWASA total income	0.12	0.002	-2.44	0.031	Reject
RWASA+ FWASA expenditures	0.49	0.272	-3.97	0.001	Reject

Independent sample t-test showed a significant difference in average growth over the years on fourteen indicators for instance jurisdiction population, Total water supply, service area water demand, a deficit of supply, tender fee, Misc. Income, Own source revenue, grants, 0ther income, Pay & Allowances, Operation & maintenance, total income, and expenditures having a p-value less than 0.05. While the remaining four indicators showed a statistically insignificant differences.

Through F & t-tests, the average difference between both cities is calculated. But for the future prediction of selected performance indicators, statistical modelling is applied. Linear regression modelling is used in this research work. To apply the regression model it is necessary to check either condition of multicollinearity does exist in the data or not. For that correlation, matrices are developed having a range of -1 to 1. If the value of the correlation matrix of a specific parameter is closer to this range having a strong correlation with the p-value less than 0.05 it means it has a significant and strong correlation.

Table 2: RWASA Correlation Matrix

		RWASA jurisdiction population	RDA service area water demand	total water supply of RDA	Deficit of supply in RDA	RWASA Misc income	RWASA tender fee	RWASA UIP tax share	RWASA Own source revenue	RWASA water supply charges	RWASA grants	RWASA income from water supply	RWASA 0ther income	RWASA Pay & Allowances	RWASA operation & maintenance	RWASA Energy prices	RWASA Fuel for vehicles	RWASA total income
RDA service area water demand	Pearson Correlation coefficient	**0.953**																
	P- value	**0.000**																
total water supply of RDA	Pearson Correlation	**0.972**	**0.962**															
	P- value	**0.000**	**0.000**															
Deficit of supply in RDA	Pearson Correlation	**0.893**	**0.980**	**0.888**														
	P- value	**0.000**	**0.000**	**0.000**														
RWASA Misc income	Pearson Correlation	**-0.904**	**-0.964**	**-0.942**	**-0.933**													
	P- value	**0.000**	**0.000**	**0.000**	**0.000**													
RWASA tender fee	Pearson Correlation	**0.654**	**0.831**	**0.746**	**0.853**	**-0.827**												

	P- value	**0.029**	**0.002**	**0.008**	**0.001**	**0.002**												
RWASA UIP tax share	Pearson Correlation	**0.655**	**0.770**	**0.679**	**0.800**	**-0.809**	**0.852**											
	P- value	**0.029**	**0.006**	**0.022**	**0.003**	**0.003**	**0.001**											
RWASA Own source revenue	Pearson Correlation	**0.891**	**0.892**	**0.903**	**0.842**	**-0.826**	**0.735**	**0.677**										
	P- value	**0.000**	**0.000**	**0.000**	**0.001**	**0.002**	**0.010**	**0.022**										
RWASA water supply charges	Pearson Correlation	0.428	0.548	0.499	0.557	-0.489	0.761	**0.706**	**0.670**									
	P- value	0.189	0.081	0.118	0.075	0.127	0.007	**0.015**	**0.024**									
RWASA grants	Pearson Correlation	0.214	0.386	0.318	0.417	-0.275	**0.685**	0.342	0.315	0.599								
	P- value	0.527	0.241	0.340	0.202	0.414	**0.020**	0.303	0.345	0.051								
RWASA income from water supply	Pearson Correlation	0.165	0.282	0.234	0.304	-0.206	0.571	0.514	0.463	**0.954**	0.580							
	P- value	0.629	0.401	0.488	0.364	0.543	0.067	0.106	0.151	**0.000**	0.062							
RWASA 0ther income	Pearson Correlation	0.412	**0.603**	0.531	**0.626**	-0.591	**0.827**	**0.617**	0.600	0.759	**0.646**	**0.652**						

	P- value	0.209	**0.049**	0.093	**0.039**	0.055	**0.002**	**0.043**	0.051	0.007	**0.032**	**0.030**						
RWASA Pay & Allowances	Pearson Correlation	**0.982**	**0.914**	**0.962**	**0.836**	**-0.882**	0.583	0.561	**0.854**	0.305	0.146	0.034	0.305					
	P- value	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	0.060	0.073	**0.001**	0.363	0.669	0.920	0.33					
RWASA operation & maintenan ce c	Pearson Correlation	-0.205	0.009	-0.055	0.055	-0.056	0.514	0.393	0.135	**0.707**	0.517	**0.779**	**0.609**	-0.282				
	P- value	0.545	0.979	0.873	0.873	0.870	0.106	0.232	0.692	**0.015**	0.104	**0.005**	**0.05**	0.401				
RWASA Energy prices	Pearson Correlation	**0.964**	**0.965**	**0.983**	**0.906**	-0.929	**0.784**	**0.736**	**0.920**	**0.602**	0.369	0.354	0.530	**0.938**	0.030			
	P- value	**0.000**	**0.000**	**0.000**	**0.000**	0.000	**0.004**	**0.010**	**0.000**	**0.050**	0.263	0.285	0.55	**0.000**	0.929			
RWASA Fuel for vehicles	Pearson Correlation	0.544	0.479	0.585	0.380	-0.508	0.374	0.368	0.713	0.301	-0.014	0.157	0.160	**0.613**	0.134	0.581		
	P- value	0.083	0.136	0.059	0.249	0.111	0.257	0.266	0.014	0.369	0.967	0.645	0.639	**0.045**	0.695	0.061		
RWASA total income	Pearson Correlation	**0.872**	**0.845**	**0.925**	0.748	**-0.815**	**0.717**	**0.630**	**0.938**	**0.649**	0.339	0.444	0.525	**0.864**	0.149	**0.937**	0.738	
	P- value	**0.000**	**0.001**	**0.000**	0.008	**0.002**	**0.013**	**0.038**	**0.000**	**0.031**	0.308	0.171	0.097	**0.001**	0.662	**0.000**	0.009	
RWASA expenditure	Pearson Correlation	**0.803**	**0.841**	**0.897**	0.762	**-0.856**	**0.806**	**0.650**	**0.891**	**0.638**	0.390	0.420	**0.631**	**0.805**	0.292	**0.899**	**0.734**	**0.952**
	P- value	**0.003**	**0.001**	**0.000**	0.006	**0.001**	**0.003**	**0.030**	**0.000**	**0.035**	0.236	0.199	**0.037**	**0.003**	0384	**0.000**	**0.010**	**0.000**

Table 3: FWASA Correlation Matrix

		FWASA jurisdiction population	FDA service area water demand	total water supply of FDA	Deficit of supply in FDA	FWASA Misc. income	FWASA tender fee	FWASA UIP tax share	FWASA Own source revenue	FWASA water supply charges	FWASA grants	FWASA income from water supply	FWASA 0ther income	FWASA Pay & Allowances	FWASA operation & maintenance	FWASA Energy prices	FWASA Fuel for vehicles	FWASA total income
FDA service area water demand	Pearson Correlation coefficient	**0.988**																
	P- value	**0.000**																
total water supply of FDA	Pearson Correlation coefficient	**0.723**	**0.708**															
	P- value	**0.012**	**0.015**															
Deficit of supply in FDA	Pearson Correlation coefficient	**0.986**	**0.999**	**0.687**														
	P- value	**0.000**	**0.000**	**0.019**														
FWASA Misc income	Pearson Correlation coefficient	0.020	0.089	-0.248	0.097													
	P- value	0.955	0.795	0.462	0.776													
FWASA tender fee	Pearson Correlation coefficient	-0.196	-0.168	0.160	-0.180	-0.166												
	P- value	0.563	0.000	0.638	0.595	0.626												
FWASA UIP tax share	Pearson Correlation coefficient	**0.951**	0.919	**0.673**	**0.917**	-0.093	-0.269											
	P- value	**0.000**	0.621	**0.023**	**0.000**	0.786	0.423											

FWASA Own source revenue	Pearson Correlation coefficient	-0.271	-0.291	-0.209	-0.294	-0.480	-0.299	-0.072										
	P- value	0.421	0.000	0.538	0.379	0.135	0.372	0.834										
FWASA water supply charges	Pearson Correlation coefficient	**0.886**	0.882	0.577	**0.884**	0.221	-0.288	**0.781**	-0.378									
	P- value	**0.000**	0.384	0.063	**0.000**	0.513	0.391	**0.005**	0.252									
FWASA grants	Pearson Correlation coefficient	**0.946**	**0.916**	**0.798**	**0.909**	-0.114	-0.153	**0.952**	-0.213	**0.758**								
	P- value	**0.000**	**0.000**	**0.003**	**0.000**	0.739	0.654	**0.000**	0.529	**0.007**								
FWASA income from water supply	Pearson Correlation coefficient	**0.881**	**0.881**	0.518	**0.884**	0.322	-0.406	**0.777**	-0.315	**0.964**	**0.746**							
	P- value	**0.000**	**0.000**	0.102	**0.000**	0.334	0.215	**0.005**	0.346	**0.000**	**0.008**							
FWASA 0ther income	Pearson Correlation coefficient	**0.942**	**0.949**	**0.676**	**0.948**	0.031	-0.249	**0.907**	-0.218	**0.878**	**0.912**	**0.834**						
	P- value	**0.000**	**0.000**	**0.022**	**0.000**	0.928	0.460	**0.000**	0.520	**0.000**	**0.000**	**0.001**						
FWASA Pay & Allowances	Pearson Correlation coefficient	**0.973**	**0.979**	**0.633**	**0.981**	0.143	-0.225	**0.885**	-0.328	**0.877**	**0.872**	**0.911**	**0.883**					
	P- value	**0.000**	**0.000**	**0.036**	**0.000**	0.674	0.506	**0.000**	0.324	**0.000**	**0.000**	**0.000**	**0.000**					
FWASA operation & maintenan ce c	Pearson Correlation coefficient	**0.829**	**0.852**	0.375	**0.863**	0.185	-0.175	**0.735**	-0.319	**0.757**	**0.686**	**0.817**	**0.713**	**0.914**				

	P- value	**0.002**	**0.000**	0.255	**0.001**	0.585	0.607	**0.010**	0.339	**0.007**	**0.020**	**0.002**	**0.014**	**0.000**				
FWASA Energy prices	Pearson Correlation coefficient	**0.969**	**0.963**	0.597	**0.965**	0.019	-0.223	**0.925**	-0.165	**0.845**	**0.870**	**0.873**	**0.876**	**0.976**	**0.905**			
	P- value	**0.000**	**0.001**	0.052	**0.000**	0.955	0.511	**0.000**	0.627	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**			
FWASA Fuel for vehicles	Pearson Correlation coefficient	**0.890**	**0.862**	**0.668**	**0.859**	-0.213	-0.088	**0.914**	-0.061	**0.789**	**0.845**	**0.699**	**0.883**	**0.792**	**0.616**	**0.858**		
	P- value	**0.000**	**0.000**	**0.025**	**0.001**	0.529	0.797	**0.000**	0.858	**0.004**	**0.001**	**0.017**	**0.000**	**0.004**	**0.044**	**0.001**		
FWASA total income	Pearson Correlation coefficient	**0.969**	**0.951**	**0.677**	**0.949**	0.096	-0.274	**0.924**	-0.246	**0.955**	**0.894**	**0.940**	**0.932**	**0.934**	**0.788**	**0.934**	**0.886**	
	P- value	**0.000**	**0.000**	**0.022**	**0.000**	0.778	0.415	**0.000**	0.465	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.004**	**0.000**	**0.000**	
FWASA expenditure	Pearson Correlation coefficient	**0.964**	**0.948**	**0.690**	**0.947**	0.058	-0.236	**0.913**	-0.239	**0.957**	**0.886**	**0.933**	**0.928**	**0.929**	**0.796**	**0.933**	**0.890**	**0.997**
	P- value	**0.000**	**0.000**	**0.019**	**0.000**	0.865	0.485	**0.000**	0.479	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.003**	**0.000**	**0.000**	**0.000**

The individual correlation matrix table has shown that the parameters of Rawalpindi city i-e RWASA service area water demand, total supply, a deficit of supply, miscellaneous income, tender fee UIP tax share, and own-source revenues, total income and total expenditures have almost all correlated values so multiple regression modelling is not applicable to the results. All the highlighted values in the table of the RWASA correlation matrix have shown a strong linear relationship. And almost a similar trend has been shown from the FWASA correlation matrix, mostly parameters have a high linear relationship. Due to the problem of multicollinearity, it is appropriate to use a simple regression model for the future projection of the water supply management system.

4.4 Simple Linear Regression Analysis

In simple linear regression modelling, each performance indicator is compared with respect to time. Because time is only the independent variable and remaining all eighteen parameters for the individual city are dependent variables. All parameters are related to the time that is used as a predictor. As the time span for collecting data is 10 years, but each year has one average value for a specific performance indicator. That is a limitation of research as well. So the equation for each parameter of the two stations would be developed individually and from developed equations, some showed a linear relationship with respect to time. These equations can be interpreted for the next 10 years.

The table below illustrates the regression equation for future estimation, coefficient of standard error along with calculated t and p values for the estimation of significant regression coefficients of both cities individually.

Table 4: RWASA Linear Regression Analysis

Response (Y)	Predictors (X)	Regression Equation	Coef	t-Value	p-Value	R-sq	R-sq(adj)
RWASA jurisdiction population	Years	$RWASA\ population = -158.04 + 0.07905\ years$	-158.04 0.07905	-17.49 17.62	0.000 0.000	97.18%	96.87%
RWASA service area water demand	Years	$RWASA\ service\ area\ water\ demand = -5344 + 2.680\ years$	-5344 2.680	-10.42 10.52	0.000 0.000	92.48%	91.65%
total water supply of RWASA	Years	$RWASA\ total\ water\ supply\ = -2353 + 1.1909\ years$	-2353 1.1909	-23.08 23.53	0.000 0.000	98.40%	98.22%
Deficit of supply in RWASA	Years	$RWASA\ Deficit\ of\ supply = -2993 + 1.490\ years$	-2993 1.490	-5.98 6.00	0.000 0.000	79.98%	77.75%
RWASA Misc income	Years	$RWASA\ Misc\ income = 1122 - 5.558\ years$	11220 -5.558	7.21 -7.19	0.000 0.000	85.17%	83.52%
RWASA tender fee	Years	$RWASA\ income\ from\ tender\ fee = -101.6 + 0.0507\ years$	-101.6 0.0507	-3.18 3.20	0.011 0.011	53.24%	48.05%
RWASA UIP tax share	Years	$RWASA\ income\ from\ UIP\ Tax\ share = -31585 + 15.81\ years$	-31585 15.81	-2.78 2.80	0.022 1.00	46.51%	40.57%
RWASA Own source revenue	Years	$RWASA\ \ own\ source\ revenues = -35992 + 18.08\ years$	-35992 18.08	-7.39 7.48	0.000 0.000	86.13%	84.59%
RWASA water supply charges	Years	$RWASA\ \ water\ supply\ charges\ = -20757 + 10.48\ years$	-20757 10.48	-1.79 1.82	0.108 0.102	26.85%	18.73%
RWASA grants	Years	$RWASA\ \ grants = -46415 + 23.1\ years$	-46415 23.1	-0.95 0.95	0.369 0.367	9.10%	0.00%
RWASA income from water supply	Years	$RWASA\ \ income\ from\ water\ supply = -9189 + 4.75\ years$	-9189 4.75	-0.78 0.81	0.457 0.439	6.78%	0.00%
RWASA 0ther income	Years	$RWASA\ other\ \ income\ \ = -50940 + 25.5\ years$	-50940 25.5	-1.70 1.71	0.123 0.121	24.53%	16.14%
RWASA Pay & Allowances	Years	$RWASA\ EXP\ on\ pay\ \&\ allowances\ \ = -79432 + 39.59\ years$	-79432 39.59	-11.92 11.97	0.000 0.000	94.09%	93.43%

RWASA operation & maintenance	Years	$RWASA\ EXP\ on\ opeartion\ \&\ maintenance\ = 6824 - 3.2\ years$	6824 -3.2	0.22 -0.20	0.834 0.845	0.45%	0.00%
RWASA Energy prices	Years	$RWASA\ EXP\ on\ Energy\ prices\ = -55855 + 27.88 years$	-55855 27.88	-20.27 20.37	0.000 0.000	97.88%	97.64%
RWASA Fuel for vehicles	Years	$RWASA\ EXP\ on\ vehicles\ fuel\ = -2184 + 1.096\ years$	-2184 1.096	-2.30 2.32	0.047 0.045	37.49%	30.55%
RWASA total income	Years	$RWASA\ total\ income\ = -60129 + 30.2 years$	-60129 30.2	-1.56 1.58	0.153 0.148	21.74%	13.05%
RWASA expenditures	Years	$RWASA\ total\ expenditures\ = -228687 + 114.1 years$	-228687 114.1	-2.92 2.93	0.017 0.017	48.85%	43.17%

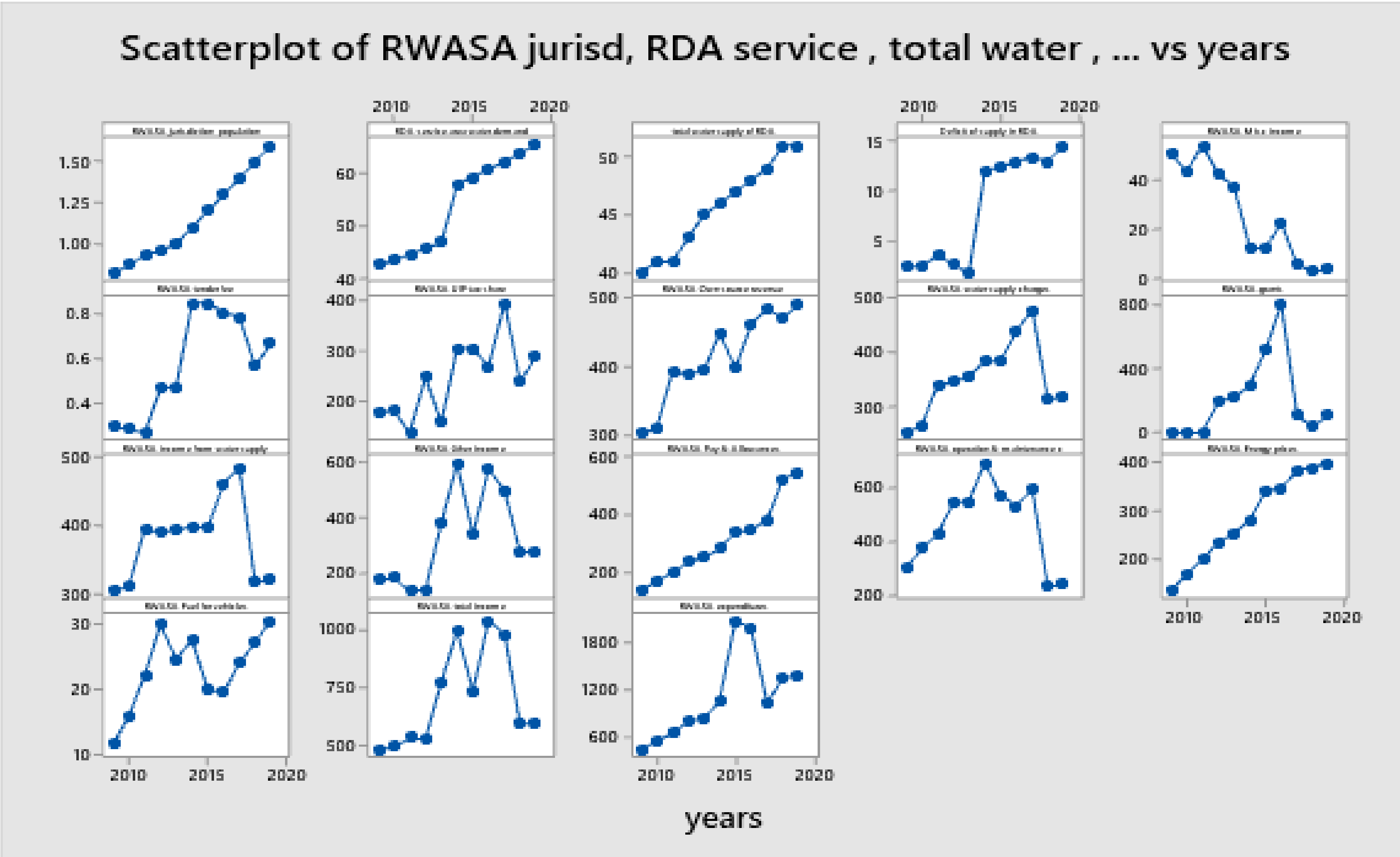

Figure 15: Scatterplot of RWASA parameters showing Regression Analysis

Regression coefficients w.r.t time series reference and Scatter plot were made to check the growth manner of specific variables in upcoming years. The parameters having high R^2 value with respect to the time series reference have a good linear relationship. For Rawalpindi Water & Sanitation Agency 7 parameters have a linear relationship. RWASA regression modelling results are described as

$$RWASA\ population = -158.04 + 0.07905\ years \quad \text{(i)}$$

This is a RWASA jurisdiction population equation which shares a good linear relationship with predictor that are years, having the value of R^2 of 97.18%, with a regression coefficient of 0.07905. Because the regression coefficient of year depicts the slope here and in this equation regression coefficient has positive growth. Which means, of increasing one unit of the year in the equation, there will be increment of 0.07905 units in the RWASA jurisdiction population.

$$RWASA\ service\ area\ water\ demand = -5344 + 2.680\ years \quad \text{(ii)}$$

This is a RWASA water demand in a service area equation which shares a good linear relationship with predictor that are years, having the value of R^2 of 92.48%, with a regression coefficient of 2.680. Because the regression coefficient of year depicts the slope here and in this equation regression coefficient has positive growth. Which means, of increasing one unit of the year in the equation, there will be increment of 2.680 units in RWASA service area water demand.

$$RWASA\ total\ water\ supply\ = -2353 + 1.1909\ years \quad \text{(iii)}$$

This is a RWASA water supply in a service area equation which shares a good linear relationship with predictor that are years, having the value of R^2 of 98.40%, with a regression coefficient of 1.1909. Because the regression coefficient of year depicts the slope here and in this equation regression coefficient has positive growth. Which means, of increasing one unit of the year in the equation, there will be increment of 1.1909 units in RWASA total water supply in the service area. Although water supply is increasing linearly with years, but not in that much of a demand. Other parameters equation which share linear relation includes deficit of supply, miscellaneous income, own source revenues, pay & allowances expenditures and fuel price

$$RWASA\ Deficit\ of\ supply = -2993 + 1.490\ years \quad \text{(iv)}$$

$$RWASA\ Misc\ income = 1122 - 5.558\ years \quad \text{(v)}$$

$$RWASA\ \ own\ source\ revenues = -35992 + 18.08\ years \quad \text{(vi)}$$

$$RWASA\ expenditures\ on\ pay\ \&\ allowances\ = -79432 + 39.59\ years \quad \text{(vii)}$$

$$RWASA\ EXP\ on\ Energy\ prices = -55855 + 27.88 years \quad \text{(viii)}$$

While remaining parameters have a non-linear relationship with respect to the time series reference which includes tender fee, UIP tax share, water supply charges, RWASA grants, RWASA other income, expenditures on operation and maintenance, expenditures on fuel, RWASA total income and RWASA total expenditures.

Table 5: FWASA Linear Regression Analysis

Response (Y)	Predictors (X)	Regression Equation	Coef	t-Value	P-Value	R-sq	R-sq(adj)
FWASA jurisdiction population	Years	$FWASA\ population = -94.25 + 0.04811\ years$	-94.25 0.04811	-37.96 39.02	0.000 0.000	99.41%	99.35%
FDA service area water demand	Years	$FWASA\ service\ area\ water\ demand = -5777 + 2.944\ years$	-5777 2.944	-18.95 19.45	0.000 0.000	97.68%	97.42%
total water supply of FDA	Years	$FWASA\ total\ water\ supply = -678 + 0.391\ years$	-678 0.39	-3.05 3.54	0.014 0.006	58.14%	53.49%
Deficit of supply in FDA	Years	$FWASA\ Deficit\ of\ supply = -5683 + 2.843\ years$	-5683 2.843	-16.99 17.11	0.000 0.000	97.02%	96.69%
FWASA Miscellaneous income	Years	$FWASA\ Misc\ income = 1122 - 5.558\ years$	-33 0.020	-0.08 0.10	0.938 0.925	0.10%	0.00%
FWASA tender fee	Years	$FWASA\ income\ from\ tender\ fee = 389 - 0.191\ years$	389 -0.191	0.48 -0.48	0.640 0.640	2.47%	0.00%
FWASA UIP tax share	Years	$FWASA\ income\ from\ UIP\ Tax\ share = -75506 + 37.64\ years$	-75506 37.64	-8.60 8.63	0.000 0.000	89.22%	88.02%
FWASA Own source revenue	Years	$FWASA\ own\ source\ revenues = 2721 - 1.33\ years$	2721 -1.33	0.94 -0.93	0.372 0.378	8.71%	0.00%
FWASA water supply charges	Years	$FWASA\ water\ supply\ charges = -75220 + 37.52\ years$	-75220 37.52	-5.44 5.46	0.000 0.000	76.82%	74.24%
FWASA grants	Years	$FWASA\ grants = -171338 + 85.30\ years$	-171338 85.30	-9.39 9.41	0.000 0.000	90.78%	89.75%
FWASA income from water supply	Years	$FWASA\ income\ from\ water\ supply = -55686 + 27.82\ years$	-55686 27.82	-5.28 5.31	0.001 0.000	75.81%	73.13%
FWASA 0ther income	Years	$FWASA\ other\ income = -303672 + 151.2\ years$	-303672 151.2	-7.94 7.96	0.000 0.000	87.57%	86.19%

FWASA Pay & Allowances	Years	$FWASA\ EXP\ on\ pay\ \&\ allowances = -185360 + 92.40\ years$	-185360 92.40	-10.58 10.62	0.000 0.000	92.62%	91.79%
FWASA operation & maintenance	Years	$FWASA\ EXP\ on\ opeartion\ \&\ maintenance = -18908 + 9.41\ years$	-18908 9.41	-4.20 4.21	0.002 0.002	66.37%	62.64%
FWASA Energy prices	Years	$FWASA\ EXP\ on\ Energy\ prices = -748.4 + 0.3729\ ears$	-748.4 0.3729	-9.75 9.78	0.000 0.000	91.41%	90.45%
FWASA Fuel for vehicles	Years	$FWASA\ EXP\ on\ vehicles\ fuel = -4753 + 2.369\ years$	-4753 2.369	-5.51 5.53	0.000 0.000	77.24%	74.71%
FWASA total income	Years	$FWASA\ total\ income = -359359 + 179.0\ years$	-359359 179.0	-8.81 8.84	0.000 0.000	89.67%	88.52%
FWASA expenditures	Years	$FWASA\ total\ expenditures = -351931 + 175.9\ years$	-351931 175.9	-3.40 3.42	0.008 0.000	56.54%	51.71%

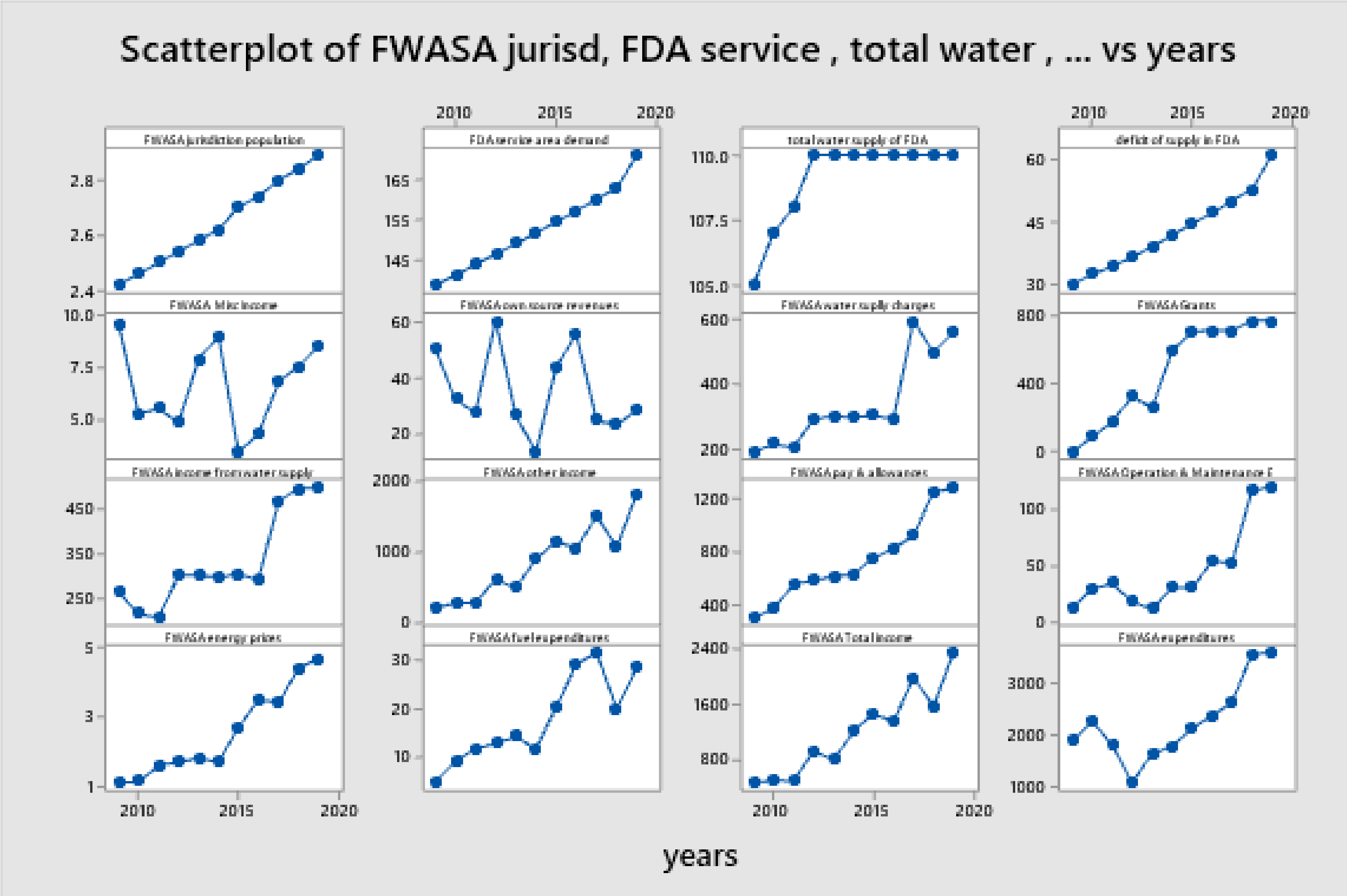

Figure 16: Scatterplot of FWASA parameters showing Regression Analysis

Regression coefficients w.r.t time series reference and Scatter plot were made to check the growth manner of specific variables in upcoming years. The parameters having high R^2 value with respect to the time series reference have a good linear relationship. 8 equations have a good linear relationship with respect to time. FWASA regression modelling results are described as

$$FWASA\ population = -94.25 + 0.04811\ years \qquad \text{(i)}$$

This is a FWASA jurisdiction population equation which shares a good linear relationship with predictor that are years, having the value of R^2 of 99.41%, with a regression coefficient of 0.04811. Because the regression coefficient of year depicts the slope here and in this equation regression coefficient has positive growth. Which means, by increasing one unit of the year in the equation, there will be increment of 0.04811 units in the FWASA jurisdiction population.

$$FWASA\ service\ area\ water\ demand = -5777 + 2.944\ years \qquad \text{(ii)}$$

This is FWASA service area water demand equation which shares a good linear relationship with predictor that are years, having the value of R^2 of 97.68%, with a regression coefficient of 2.944. Because the regression coefficient of year depicts the slope here and in this equation regression coefficient has positive growth. Which means, by increasing one unit of the year in the equation, there will be increment of 2.944 units in FWASA service area water demand.

As the water supply of FWASA to the coverage area population does not share a linear relationship w.r.t time series reference which is a key reason of linearly increasing deficit of water supply.

$$FWASA\ Deficit\ of\ supply = -5683 + 2.843\ years \qquad \text{(iii)}$$

This is a FWASA service deficit of supply equation which shares a good linear relationship with predictor that are years, having the value of R^2 of 97.02%, with a regression coefficient of 2.843. Because the regression coefficient of year depicts the slope here and in this equation regression coefficient has positive growth. Which means, by increasing one unit of the year in the equation, there will be increment of 2.843 units in FWASA water deficit. If the supply amount will not increase according to the population expansion. Other parameters which share a good relationship with time series reference are written in equation form as follows.

$$FWASA\ income\ from\ UIP\ Tax\ share = -75506 + 37.64\ years \qquad \text{(iv)}$$

$$FWASA\ water\ supply\ charges = -75220 + 37.52\ years \qquad \text{(v)}$$

$$FWASA\ grants = -171338 + 85.30\ years \qquad \text{(vi)}$$

$$FWASA\ income\ from\ water\ supply = -55686 + 27.82\ years \qquad \text{(vii)}$$

$$FWASA\ other\ income = -303672 + 151.2\ years \qquad \text{(viii)}$$

$$FWASA\ EXP\ on\ pay\ \&\ allowances = -185360 + 92.40\ years \qquad \text{(ix)}$$

$$FWASA\ EXP\ on\ Energy\ prices = -748.4 + 0.3729\ years \qquad \text{(x)}$$

$$FWASA\ EXP\ on\ vehicles\ fuel = -4753 + 2.369\ years \qquad \text{(xi)}$$

$$FWASA\ total\ income = -359359 + 179.0\ years \qquad \text{(xii)}$$

While remaining parameters have a non-linear relationship with respect to the time series reference which includes FWASA total water supply, FWASA tender fee, miscellaneous income, expenditures on operation and maintenance, expenditures on fuel, FWASA own source revenues and FWASA total expenditures.

Thirty-six regression equations are developed for both stations. To avoid the complexity of performance indicators they can be reduced to a few significant indicators. That is the process of dimension reduction, which is done by principal component analysis (PCA). Performance indicators of each station are separately reduced because they are independent of one another

4.5 Principal Component Analysis

The PCA was done on eighteen independent variables of both cities to predict the future scenario of the water supply management system of Faisalabad and Rawalpindi Table below abridges the results of the PCA on the major ten independent variables and each principal component explain the variance. Up to 10 values of PCs explain the variance of 100% for Rawalpindi as well as Faisalabad individually and Table that shows the initial three PCs have eigenvalues higher than 1. Besides, these initial three PCs of Rawalpindi clarified around 91% of the variance in PCA variables. And initial three PCs of Faisalabad have also shown a cumulative variance of 91%. The commitment of a specific variable inside a PC is typically judged by the value of its variable loadings. The higher the variable loading, the more commitment is reflected by that variable inside a specific PC.

Table 6: Variance explained by the PCs for RWASA

Value	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Eigenvalue	11.942	3.275	1.136	0.608	0.499	0.293	0.157	0.067	0.017	0.006
Var.%	66.3	18.2	0.63	0.34	0.28	0.16	0.09	0.04	0.01	0.00
Cum.%	66.3	84.5	90.9	94.2	97.0	98.6	99.5	99.9	100	100

Table 7: Variance explained by the PCs for FWASA

Value	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Eigenvalue	13.197	1.793	1.419	0.546	0.318	0.296	0.247	0.101	0.061	0.022
Var.%	73.3	10.0	7.9	3.0	1.8	1.6	1.4	0.6	0.3	0.1
Cum.%	73.3	83.3	91.2	94.2	96.0	97.6	99.0	99.5	99.9	100

Table 8: Component loadings of RWASA

Variables	PC1	PC2	PC3
RWASA jurisdiction population	**0.260**	0.222	0.074
RWASA service area water demand	**0.277**	0.107	0.188
total water supply of RWASA	**0.274**	0.159	0.039
Deficit of supply in RWASA	**0.266**	0.065	**0.287**
RWASA Misc. income	-0.269	-0.118	-0.151
RWASA tender fee	0.258	-0.178	0.184
RWASA UIP tax share	0.235	-0.105	0.126
RWASA Own source revenue	**0.273**	0.056	-0.186
RWASA water supply charges	0.209	-0.341	-0.123
RWASA grants	0.136	-0.322	**0.296**
RWASA income from water supply	0.141	-0.426	-0.184
RWASA 0ther income	0.202	-0.293	0.186
RWASA Pay & Allowances	0.246	**0.285**	0.009
RWASA operation & maintenance c	0.069	-0.498	-0.220
RWASA Energy prices	**0.280**	0.109	0.016
RWASA Fuel for vehicles	0.172	0.132	-0.656
RWASA total income	**0.269**	0.064	-0.261
RWASA expenditures	**0.270**	0.014	-0.222

All eighteen water supply management variables of Rawalpindi WASA are included in the three selected PCs. but, only certain variables have shown high loading rate within each PC, such as the first PC was heavily loaded on RWASA jurisdiction population, RDA service area water demand, the total water supply of RDA, Deficit of supply in RDA, RWASA Own source revenue, RWASA Energy prices, RWASA total income and RWASA expenditures, and the second and third PC was heavily loaded with RWASA Pay & Allowances, Deficit of supply in RDA and RWASA grants respectively.

Table 9: Component loadings of FWASA

Variables	PC1	PC2	PC3
FWASA jurisdiction population	**0.274**	0.036	0.028
FWASA service area demand	**0.272**	-0.008	0.046
total water supply of FWASA	0.193	0.270	0.333
deficit of supply of FWASA	**0.272**	-0.019	0.035
FWASA Misc. Income	0.018	-0.687	-0.042
FWASA Tender Fee	-0.063	0.116	**0.751**
FWASA UIP Tax Share	0.259	0.161	-0.081
FWASA own source revenues	-0.076	**0.471**	-0.527
FWASA water supply charges	0.254	-0.155	-0.034
FWASA Grants	0.255	0.159	0.075
FWASA income from water supply	0.252	-0.217	-0.143
FWASA other income	0.262	0.049	-0.023
FWASA pay & allowances	**0.268**	-0.082	0.005
FWASA Operation & Maintenance	0.231	-0.172	-0.025
FWASA energy prices	0.266	0.025	-0.058
FWASA fuel expenditures	0.243	0.237	0.024
FWASA Total income	**0.271**	-0.015	-0.046
FWASA expenditures	**0.270**	0.005	-0.024

All eighteen water supply management variables of Faisalabad WASA are included in the three selected PCs. but, only certain variables have shown high loading rate within each PC, such as the first PC was heavily loaded on FWASA jurisdiction population, FDA service area water demand, Deficit of supply in FDA, FWASA pay & allowances, FWASA total income, and FWASA expenditures and the second and third PC was heavily loaded with FWASA own source revenues and FWASA tender fee respectively.

The original variable values of the individual city and individual eigenvectors which are the coefficients of component scores were multiplied to acquire PC score values. These score values are utilized as principal components (PCs) as RWASA and FWASA's future prediction

Table 10: RWASA principal component scores

PC1	PC2	PC3
-5.58268	0.50158	1.44492
-4.77266	0.49989	0.79568
-3.45819	-0.09183	-1.06926
-1.71324	-0.51337	-1.71782
-1.06488	-0.80803	-1.31170
1.99967	-1.68401	-0.15706
1.81837	-1.00936	1.08642
2.78924	-2.13434	1.23431
4.02022	-1.28277	-0.28586
2.52566	3.27030	0.06689
3.43849	3.25194	-0.08651

Table 11: FWASA principal component scores

PC1	PC2	PC3
-4.84135	-1.62614	-2.26249
-4.03410	-0.15749	-0.35559
-3.53480	0.18857	2.17114
-1.92248	1.47380	-0.73859
-1.66538	-0.56626	0.96483
-0.58985	-1.16122	1.52151
0.65031	1.86226	-0.49410
1.69263	2.35014	-0.18458
3.99190	-0.19436	-0.07884
4.36561	-1.13184	-0.34035
5.88750	-1.03745	-0.20293

Chapter 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Descriptive analysis has shown that water supply & demand gap is increasing every year because of increasing population in both cities but water infrastructure has not developed with that pace. Inferential statistics showed that the difference between the average growth of RWASA & FWASA is statistically significant for fourteen characteristics namely jurisdiction population, water demand, total supply, deficit of supply, total income and total expenditures. As a result, it was found that a similar growth trend for four characteristics, namely water supply charges and income from the water supply. Linear regression modelling was applied to check the growth manner of specific variables in upcoming years. The parameters having high R^2 value with respect to time series reference have good linear relations, means by increasing one unit of year in the equation there will be increment of specific unit value in that specific parameter. From total eighteen developed equations for Rawalpindi WASA 7 equations have linear relation with respect to time. This proposed simple linear regression model can be used to predict the growth of these 7 parameters of Rawalpindi including RWASA jurisdiction population, service area water demand, total water supply, misc. Income, own-source revenues, pay & allowances and energy prices. And these parameters can be predicted for next 10 years. Similarly, eighteen developed equations of Faisalabad, eight equations have linear relation with respect to time. These parameters include FWASA jurisdiction population, total water demand, UIP tax share, grants, other income, pay & allowances, energy, prices and total income. Only these linearly developed equations can predict for next 10 years. On this basis it has been concluded that these models show statistical as well as practical significance in organization's evaluation process by predicting future scenarios.

Parameters of both cities were 36 in total and in order to avoid complexity in performance parameters only eighteen performance indicators of each station have been reduced to three principal components by using principal component analysis. PCA favours for three principal components (PCs) for each station having Eigen values greater than 1 and cumulative variations of 90%. It was established that PC1, PC2 and PC3 were most independent variables having Eigen value greater than 1. These PCs could be considered as key variables for demand forecasting which had significant component loading rate within these three PCs. Those PCs could be considered as key variables for demand forecasting which have a significant component loading rate. The results of the study would be useful for the planning and management of WASAs.

5.2 Recommendations

5.2.1 Revision of tariff and induction of metered supply system

Impact of tariffs should be studied in line with the water demand management of different WASAs. Water tariffs should be charged according to the utilization rate of water rather than applying flat rates. Because just expanding flat rate couldn't reasonably influence the utilization of water. Furthermore, it should combine with metering of water. Moreover, replacing the worn-out pipelines and adding new pipelines, to increase storage capacity should be done timely to prevent from severe revenue or water loss.

5.2.2 Application of developed equations to other WASAs

Derived equations should be considered for application on the data of other WASAs of different cities. But data collection on a monthly or at least quarterly basis is recommended for more validated results.

5.2.3 Application of modelling for future prediction

Impact of water supply loses and illegal connections should be predicted through statistical modelling on WASAs of different other cities. Developed principal components for RWASA & FWASA could be used further for prediction modelling.

5.2.4 Efficient Organizational design of FWASA & RWASA

The should be no external interference, for exercising autonomy by water utility managers in making important decisions. But there should be Internal accountability and external accountability for achieving performance targets of the organization and to account for performance of final results to the government respectively. The system should be Customer-oriented, that is a business technique that empowers a utility to listen to their clients and work to all the more likely address their issues and they need to improve their Market direction and market-style motivating forces moreover. And finally there is a need of proper vision, mission as well as moral, social and behavioural norms that inspire staff and managers to excel.

CHAPTER 6

REFERENCES

Abdul-wahab, s. a., Bakheit, c. s. & Al-alawi, s. m. 2005. Principal Component and multiple regression analysis in modelling of ground-level ozone and factors affecting its concentrations. *environmental modelling & software,* 20**,** 1263-1271.

Ahmed, u., Mumtaz, r., Anwar, h., Shah, a. a., Irfan, r. & García-nieto, j. 2019. Efficient water quality prediction using supervised machine learning. *water,* 11**,** 2210.

Alegre, h., Baptista, J. m., Cabrera jr, e., Cubillo, f., Duarte, p., Hirner, w., Merkel, w. & Parena, r. 2016. *Performance indicators for water supply services*, iwa publishing.

Alfano, m., Brockley, s., Muir, m. a., Areikat, s. & Gracy, m. 2015. Water scarcity and drought management plans as enabling elements for achieving the sdgs in west Asia and north Africa.

Archer, d. r., Forsythe, n., Fowler, h. j. & Shah, s. m. 2010. Sustainability of water resources management in the indus basin under changing climatic and socio economic conditions. *hydrology and earth system sciences*.

Authority, s. c. 2009. Blue mountains water supply system: Strategic review. *Sydney catchment authority, penrith, Australia*.

Bach, p. m., Rauch, w., Mikkelsen, p. s., Mccarthy, d. t. & Deletic, a. 2014. A critical review of integrated urban water modelling–urban drainage and beyond. *environmental modelling & software,* 54**,** 88-107.

Barlow, m., & Clarke, t. 2017. Blue gold: the battle against corporate theft of the world's water: routledge.

Berg, s. 2010. *water utility benchmarking*, iwa publishing.

Black, m. 2016. The atlas of water: mapping the world's most critical resource: univ of California press.

Clarke, r. 2013. *water: the international crisis*, routledge.

Connor, g., Mcfadden, m. & Mclean, i. 2012. Organisation design. *developing people and organisations***,** 1-35.

Connor, r. 2015. *The united nations world water development report 2015: water for a sustainable world*, unesco publishing.

Connor, r. 2016. the united nations world water development report 2016: water and jobs, chapter 2: the global perspective on water. paris: unesco.

De witte, k. & Marques, r. c. 2010. Designing performance incentives, an international benchmark study in the water sector. *central european journal of operations research,* 18**,** 189-220.

Desa, u. 2016. International migration report 2015 highlights. *new york, un department of economic and social affairs*.

Eliasson, j. 2015. The rising pressure of global water shortages. *nature,* 517**,** 6-6.

Falkenmark, m. 2004. Towards integrated catchment management: opening the paradigm locks between hydrology, ecology and policy-making. *international journal of water resources development,* 20**,** 275-281.

Franczyk, j. & Chang, h. 2009. Spatial analysis of water use in oregon, usa, 1985–2005. *water resources management,* 23**,** 755-774.

García-rubio, m. a., Ruiz-villaverde, a. & González-gómez, f. 2015. Urban water tariffs in Spain: what needs to be done? *water,* 7**,** 1456-1479.

Gleick, p. h. 2014. Water, drought, climate change, and conflict in Syria. *weather, climate, and society,* 6**,** 331-340.

González-gómez, f., García-rubio, m. a. & González-martínez, j. 2014. Beyond the public–private controversy in urban water management in spain. *utilities policy,* 31**,** 1-9.

Haque, m., Rahman, a., Hagare, d. & Kibria, g. 2013a. Principal component regression analysis in water demand forecasting: an application to the blue mountains, nsw, Australia. *j. hydrol. environ. res,* 1**,** 49-59.

Haque, p. m. p. p. m., Rahman, a., Hagare, d. & Kibria, g. 2013b. Principal component regression analysis in water demand forecasting: an application to the blue mountains, nsw, Australia. *journal of hydrology and environment research,* 1.

Hoekstra, a. y. & Mekonnen, m. m. 2016. Imported water risk: the case of the uk. *environmental research letters,* 11**,** 055002.

Jaladhi, v., Dhruv, b., Utkarsha, k. & Mahroof, m. 2016. Online performance assessment system for urban water supply and sanitation services in India. *aquatic procedia,* 6**,** 51-63.

Kayaga, s., Kingdom, w. & Jalakam, a. 2018. Organisational design for improved performance of urban water utilities in developing countries. *utilities policy,* 50**,** 49-59.

Khan, f. 2009. water, governance, and corruption in Pakistan. *running on empty,* 2003**,** 2025.

Khattak, m. s., Babel, m. & Sharif, m. 2011. Hydro-meteorological trends in the upper indus river basin in pakistan. *climate research,* 46**,** 103-119.

Matteson, d. s. & Tsay, r. s. 2017. Independent component analysis via distance covariance. *journal of the american statistical association,* 112**,** 623-637.

Mcdonnell, r. a. 2008. Challenges for integrated water resources management: How do we provide the knowledge to support truly integrated thinking? *international journal of water resources development,* 24**,** 131-143.

Melgarejo-moreno, J., López-ortiz, m.-i. & Fernández-aracil, p. 2019. Water distribution management in south-east spain: a guaranteed system in a context of scarce resources. *science of the total environment,* 648**,** 1384-1393.

Pedro-monzonís, m., Solera, a., Ferrer, j., Estrela, t. & Paredes-Arquiola, j. 2015. A review of water scarcity and drought indexes in water resources planning and management. *journal of hydrology,* 527**,** 482-493.

Postel, s. 2014. The last oasis: facing water scarcity: routledge.

Rajab, j. m., Jafri, m. z. m., Lim, h.-s. & Abdullah, k. 2012. Regression analysis in modeling of air surface temperature and factors affecting its value in peninsular malaysia. *optical engineering,* 51**,** 101702.

Sanli, s. g., Kizilkanat, e. d., Boyan, n., Ozsahin, e. t., Bozkir, m. g., Soames, r., Erol, h. & Oguz, o. 2005. Stature estimation based on hand length and foot length. *clinical anatomy: The official journal of the american association of clinical anatomists and the british association of clinical anatomists,* 18**,** 589-596.

Tortajada, c., González-gómez, f., Biswas, a. k. & Buurman, j. 2019. Water demand management strategies for water-scarce cities: the case of spain. *sustainable cities and society,* 45**,** 649-656.

UN-water, u. & unicef 2012. the post 2015 water thematic consultation report.

Van den berg, c. & Danilenko, a. 2010. *The ibnet water supply and sanitation performance blue book: the international benchmarking network for water and sanitation utilities databook*, the world bank.

Vidal, j. 2010. UN report: World's biggest cities merging into 'mega-regions'. *The guardian,* 22.

Water, u. 2016. Monitoring water and sanitation in the 2030 agenda for sustainable development. *an introduction. Geneva, Switzerland*.

Watkins, k. 2006. Human development report 2006-beyond scarcity: power, poverty and the global water crisis. *UNDP human development reports (2006)*.

Wescoat jr, j. l. 2009. Comparative international water research. *journal of contemporary water research & education,* 142**,** 61-66.

Zhou, s. l., Mcmahon, T. a., Walton, a. & Lewis, j. 2000. Forecasting daily urban water demand: a case study of Melbourne. *journal of hydrology*, 236**,** 153-164.