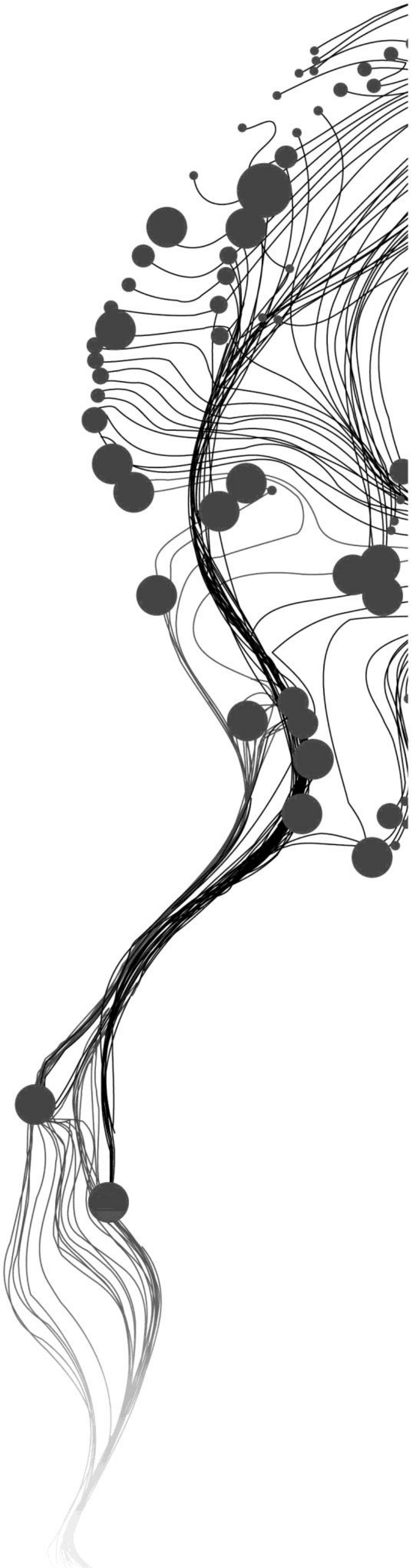
INTEGRAL ASSESSMENT OF THE PERFORMANCE OF WATER SUPPLY SYSTEM IN YOGYAKARTA CITY, INDONESIA

JIWAN KUMARI PUN
February, 2011

SUPERVISORS:
Ir. M.J.G. Brussel
Dr. Sherif Amer



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JIWAN KUMARI PUN
Enschede, The Netherlands, February, 2011

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SUPERVISORS:
Ir. M.J.G. Brussel
Dr. Sherif Amer

THESIS ASSESSMENT BOARD:
Prof. Dr. Ir. M. F. A. M. van Maarseveen (Chairman)
Dr. J. A. Martinez (External Examiner)

ABSTRACT

Problems have been faced by the people of most developing countries to fulfil their daily demands for water in terms of quantity and quality. To overcome this, they have been trying to seek for alternative sources and integrate them so that the adequate requirement is fulfilled or in the absence or low performance of one, the others can be relied on. In Yogyakarta city, the coverage of the piped water supply is quite low so some portion of the population relies on groundwater wells while some households use both the sources as the short comings of one can be fulfilled by the other. Though the perceived quality of groundwater scored better than piped water, laboratory tests have shown groundwater to be contaminated by bacteria. While in the other hand over-abstraction of groundwater has resulted in the decreasing water level. Health and environment being equally important, impacts on both have to be reduced; only that impact on the former is noticed immediately while on the latter it takes time but is irreplaceable. To minimize these impacts, the performance of the piped water supply has to be upgraded and awareness is to be raised among the citizens. The complexity of this problem can be solved by the introduction of a practical measurement strategy - performance assessment. In which a performance measurement framework is developed where the perceptions of the stakeholders are in-corporated considering the causes and effects, and goals are set. Performance criteria and indicators are chosen according to the existing condition and selected parameters. To analyze the performance spatially, performance indices are developed by the chosen criteria and indicators, and Spatial Multicriteria Evaluations (SMCE) was performed at the household level by giving different weights to the criteria and indicators. Criterion maps and Composite Index Maps (CIM) were developed which showed different performance patterns spatially. Some parameters were compared with the standards showing the overall performance. Thus, a base-line can be developed and by informing related stakeholders necessary awareness can be created among them, which help towards improving the performance and leads towards goals achievement.

Key words: Water supply, Performance assessment, Framework, Criteria, Indicators, SMCE, Benchmarking

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LIST OF ACRONYMS

ADB	Asian Development Bank
CIM	Composite Index Map
E.coli	Eschericia coli
GPS	Global Positioning System
GIS	Geographical Information System
ILWIS	Integrated Land and Water Information System
PDAM	Perusahaan Daerah Air Minum
PM	Performance measurement
PMS	Performance measurement system
SMCE	Spatial Multicriteria Evaluation
UGM	University of Gadjah Mada
UNESCO	United Nations Educational Scientific and Cultural Organisation
UN-HABITAT	United Nations Human Settlements Programme
WHO	World Health Organisation

1. INTRODUCTION

This study develops a methodology to measure the performance of the integrated water supply system in Yogyakarta City, Indonesia. It emphasizes on the upgrading of the performance by the introduction of performance assessment such that goals are set which try to improve the human well-being as well as minimize impacts on environment. This chapter gives an overall idea about the research structuring starting from general introduction on water supply in developing countries and integrated water supply, background and justification, research problem, research objectives, research questions, conceptual framework and research design.

1.1. General

In many cities of developing countries, expansion of the population and of the residential areas of urban squatters has been accelerated and accompanied by urbanization (Aiga & Umenai, 2002). The increase in urban settlement has, in general, caused various problems in relation to public health and socio-economic conditions. One of the major difficulties raised due to rapid urbanization and population growth, is the lack of access to water supply. People have to struggle for quality, quantity and accessibility while trying to balance their economic and social conditions, which in the other hand directly impacts the economic development of those areas. Residential water use shows a positive correlation with living standards and is one of the important proxies for economic development (Zhang & Brown, 2005). Due to the sharp increase in the demand of water for residential and industrial use, many urban areas are facing the problem of water scarcity so have to rely on intermittent supply, alternative sources or insufficient quantity. The reasons for prevailing water scarcity in many cities can be attributed not only to source limitation but also to poor efficiency in distribution networks (S. Kumar & Managi, 2010). There are some major challenges facing the water supply sector in the years to come: keeping pace with a net population growth; closing the coverage and service gap; ensuring sustainability of existing and new services; improving the quality of services (Helena *et al.*, 2006).

1.2. Integrated water supply

Utilizing and accessing traditional sources of water will not be sufficient as population grows and water demand increases (Wade Miller, 2006). Communities across the world face water supply challenges due to increasing demand, drought, depletion and contamination of groundwater, and dependence on single source of supply (ibid). Wade Miller (2006) says that one of the current trends of integrated concepts of water reuse in the increase in the use of 'alternative sources'. In most developing countries, as the municipality or the local authorities cannot expand the public/piped water facilities from surface water source to cope with the growth in water demand often consider alternatives such as groundwater, water reuse, desalination, and inter-basin transfer to meet the demands of growth (ibid). While in cities where the public water supply cannot fulfil the demands, people overcome their daily demands of water by integrating sources like digging private wells, relying on communal taps or wells, rainwater harvesting, buying water from vendors, etc.

1.3. Background and justification

Over half of the people living in the large cities of developing countries are poor and live in informal settlements that lack potable water supply (Akbar *et al.*, 2007 as cited in UN-HABITAT, 2007). For most developing countries the supply problem is not an issue of absolute scarcity but of deteriorating resource quality, insufficient connections for a growing population – especially poor households-unreliable services (Kessides, 2004 as cited in ADB, 2000). A significant difference between water supply and most other infrastructure is that water has seen much less technological change over the past few decades, and the change that has occurred has had less effect on the underlying economics of supply (Kessides, 2004). In many systems more than one-third of production is lost, overstaffing is pervasive, revenues do not cover operating costs, piped water flow and pressure are inconsistent, and water is often unsafe to drink (ibid). As Kessides (2004) says that in some areas although piped water can be provided much more cheaply, customers seek unpiped alternatives (such as vendors and wells) if utility water is overpriced or of poor quality. While in most areas it has been found that the piped water supply is generally unreliable and insufficient; an additional source always contributing to requirement is needed.

Regarding the underground water resources, urbanization affects both the quality and quantity. Quantity is affected by the increase in the abstraction process while different sources of recharge affect the quality. In urbanized areas, the source of recharge can be differentiated into two sources; natural recharge from precipitation and urban recharge (Lerner, 2002). In urban areas, the infiltration capacity is too low due to the presence of roads and buildings, which further decreases the capacity of renewal (Van der Bruggen *et al.*, 2010). However the main sources of urban groundwater recharge are on-site sanitation, rain water and main leakage from water supply networks whereas in areas near rivers or flood-prone areas, the underground wells are affected badly after flooding degrading the water quality.

In Asia's cities, common water supply problems are related to the sources and uses of raw water, the large proportion of water loss in distribution networks, intermittent supplies, and the quality of tap water (ADB, 2010a). In many large Asian cities by far the majority of the wells and boreholes sunk are owned by individuals and thus any estimated use of groundwater would need to take private as well as public tube wells into account (Schmoll *et al.*, 2006). In addition, in some cities, the excessive use of groundwater resources has caused serious environmental problems, including rapid depletion of groundwater, deterioration of water quality, and land subsidence (ADB, 2010a). Gessler et al. (2008) say that as 97% of the water supply in Jaipur city, India is dependent on underground supply, the water table is decreasing every year with very limited recharge. Large-scale groundwater use in the City of Bangkok, Thailand, resulted in adverse economic-cum-environmental problems such as the continual depletion of potentiometric levels in pumped aquifers, land subsidence and water quality deterioration by saltwater encroachment (Gupta & Babel, 2005).

1.4. Research Problem

In Yogyakarta city, Indonesia people rely on integrated water supply system, consisting mainly of two improved sources; piped water supply and the groundwater wells. The piped water is supplied by PDAM Tirthamarta, a local water supply company and the service coverage is limited so groundwater from private or communal wells is acting as an alternative source towards fulfilling the daily water demand for many households. While in the other hand the PDAM Tirthamarta is financially unsustainable due to widespread lack of cost recovery tariffs and low revenue collection resulting in the reduction or abandonment of maintenance and investment activities deteriorating the assets (Shen, 2007). It has been found that only 9% of the population in the Yogyakarta City is served by sewage system, it can be assumed that wastewater from on-site sanitation, latrines, soakaways and main leakage from the water supply become the major source of urban recharge to the groundwater.

Salendu (2010) points that in Yogyakarta, though the quality of water from the groundwater wells are not fulfilling the standard of drinking water as the E.coli containments reaches up to or higher than 2400 MPN/ml, the higher percentage of households prefer it than the piped supply due to the taste. It has been noticed that the amount of production and distribution of piped water supply is fluctuating yearly. To upgrade and enhance the performance of water supply system, it has to be accessed and necessary actions have to be undertaken so that the service gained by the end users is efficient to maintain and enhance their quality of life. For that reason the performance of the piped water supply system has to be improved so that people can trust on the quality while discouraging them to rely on bacterial contaminated underground water for drinking, which has adverse effects in the health as well as the environment. So a performance measurement framework has to be developed for integrated water supply system to standardize and improve measurement. This research will look on the performance of integrated water supply system in Yogyakarta, Indonesia.

1.5. Research Objectives & Questions

The main objective of this research is to develop a methodology for measuring the performance of integrated urban water supply in Yogyakarta city, Indonesia.

To achieve the main objective, sub-objectives and research questions are formulated which are as follow:

Table 1-1: Research objectives and questions

Research objectives	Research questions
➢ To develop a performance measurement framework for integrated water supply system.	• How can the performance of integrated water supply be measured? • Who are the stakeholders involved and what are their perceptions? • What are the goals of integrated water supply system?
➢ To develop a set of performance measurement criteria (in the study area).	• Which criteria are important in the study area? • Which performance indicator is related to which criterion?
➢ To analyze and map the performance of existing integrated water supply system.	• How can the existing level of performance be known? • Which criteria and indicators are more important in the existing situation?
➢ To gauge the performance by comparing with appropriate performance benchmarks.	• What is the existing performance level of the integrated water supply system?
➢ To demonstrate how the procedure leads to performance measurement.	• How can the performance be upgraded or improved in future?

1.6. Conceptual Framework

The key components of the integrated water supply system in Yogyakarta City are the piped water supply from local water authority, PDAM Tirthamarta and private or communal groundwater wells. The performances of both the supplies are not satisfactory; the piped water supply being intermittent cannot fulfil the daily demands of the households, the smell and colour quality are the factors affecting the reliability of the people while the quality of groundwater is affected by the urban recharge, mostly the on-site sanitation. These performances have negative impacts on the human well-being and the environment. Since both the supplies are unreliable in terms of quality, they directly affect the health and degrade the living conditions while the excessive construction and abstraction of groundwater wells cause depletion of aquifers followed by land subsidence,. These negative impacts have to be minimized otherwise may cause serious problems in future. The performance assessment of the water supply services seems to be the right tool to help to solve some of the major problems of this sector (Helena*, et al.*, 2006). To get an insight into the performance of water supply and to formulate the best practices to enable them to further improve performance, a performance assessment has to be introduced. It includes developing a performance measurement framework and a set of performance criteria, analyzing the performance level and judging the performance level with appropriate benchmarks. Benchmarking can help to identify and target the main challenges by showing the room for further improvement, identifying the better practices thus improving the performance which in time helps to minimize the negative impacts. Hence this research will look on the performance level of the integrated water supply system in Yogyakarta.

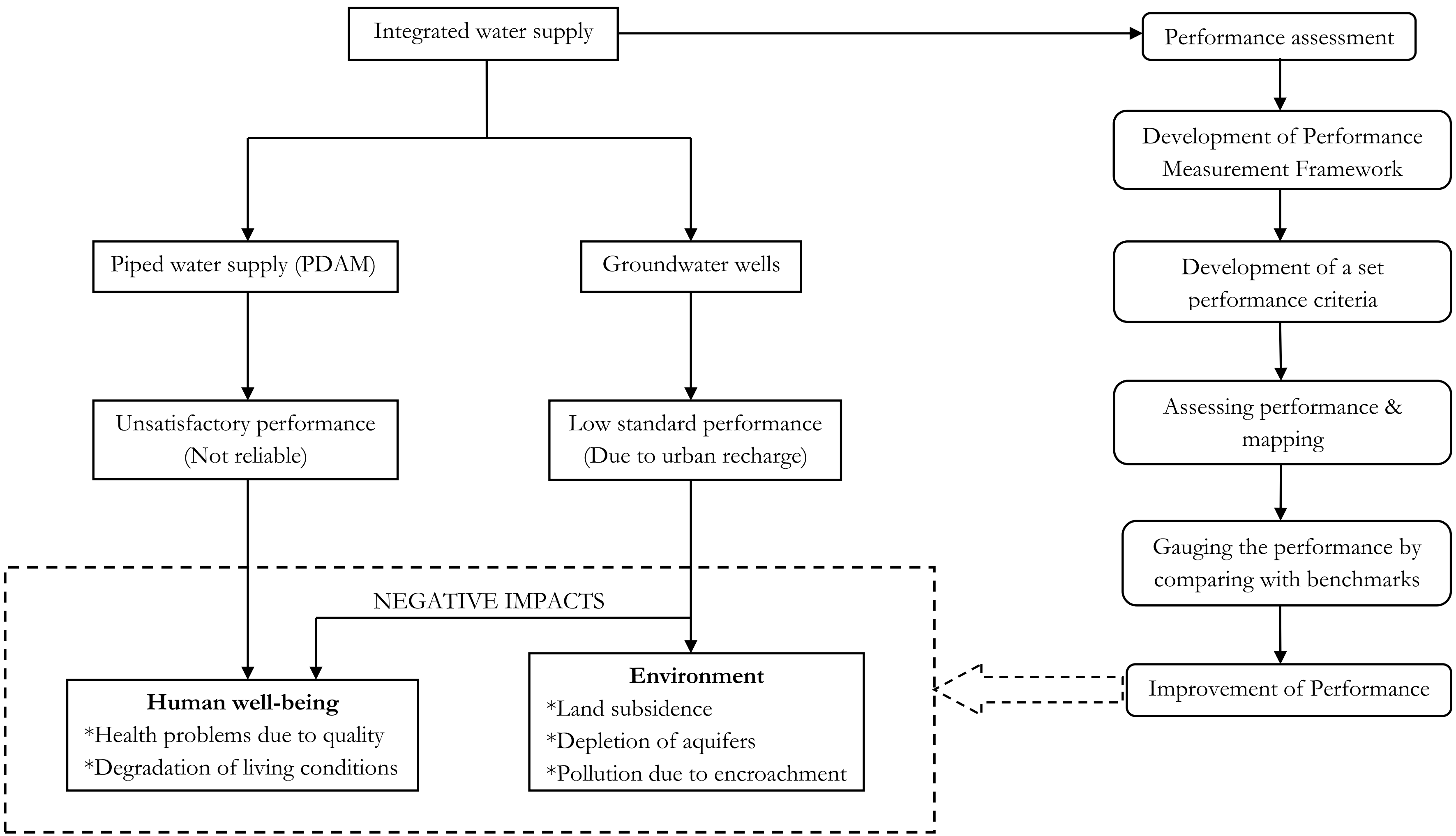

Figure 1.1: Conceptual Framework

1.7. Research Design

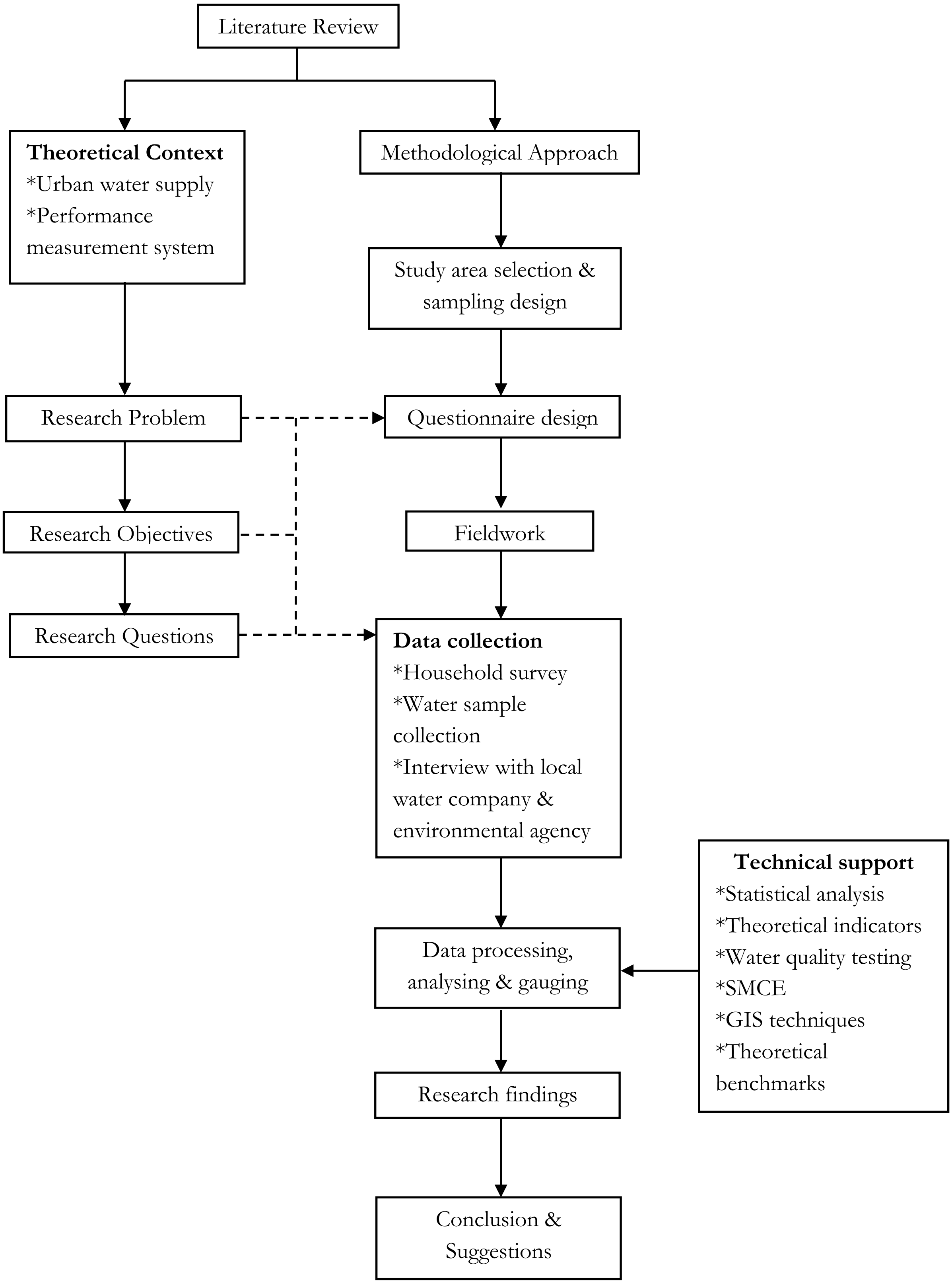

Figure 1.2: Research Design

The research flow started from literature review. In the theoretical context, the literature review was done to get the insight of performance measurement system (PMS), urban water supply and the related parameters of performance. Then the research problem was identified along with objectives and questions. In the methodological approach, study area was selected, sample and questionnaire designed, data was collected during the fieldwork which included household survey, interviews with the local water company and Environmental Agency of Yogyakarta city, collection of water samples and secondary data. Data processing and analysis were done based on theoretical indicators and benchmarking, laboratory tests of water samples, statistics and GIS techniques leading towards research findings. The research concluded on conclusion and suggestions.

2. PERFORMANCE MEASUREMENT, URBAN WATER SUPPLY, URBAN RECHARGE AND PERFORMANCE MEASURES

This chapter looks on the performance measurement system of urban water supply which consists of goals and objectives, performance measurement framework, performance indicators and benchmarking performance. It also looks on urban water supply highlighting on the improved and unimproved sources, urban recharge and its effect on groundwater source and the various parameters of integrated water supply.

2.1. Performance measurement of water supply

The provision of safe water is a service and requires a service-orientated attitude on the part of the water undertakings involved (Helena*, et al.*, 2006). A Performance Measurement System (PMS) has to be introduced to get an insight into the performance of water supply and to formulate the best practices to enable them to further improve performance. In the context of urban local bodies, performance measurement (PM) can be defined as the process of determining how efficiently and effectively the concerned agencies are delivering the services (TERI, 2004). It also serves as a tool for strategic decision-making and long-range planning (ibd).

According to TERI (2004) designing a PMS involves the following:

- Deciding what to measure
- Selecting appropriate performance indicators
- Establishing procedures for recording and reporting performance
- Interpreting performance measures to decide what needs to be done for improving performance, especially in those areas where it is not satisfactory at present.

The key elements of a PMS are a performance measurement framework, a set of performance indicators, a supporting management information system and a strategy for performance benchmarking (TERI, 2004).

2.1.1. Goals and objectives

An urban body should define its goals and objectives to start the performance measurement process. As TERI (2004) says that each agency must determine what is important at a particular time, set priorities and define its areas of focus. Objectives are more specific statements of what the agency wishes to accomplish (TERI, 2004).

2.1.2. Performance Measurement Framework

A performance measurement framework focuses on the objectives of an urban body. TERI (2004) says that one of the PM frameworks used by some developed countries is the I-O-E-O (input-output-efficiency-outcome) framework and it has four types of measures.

A. Input measures indicate the amount of resources used.

B. Output measures indicate the level of services provided.

C. Efficiency measures relate the outputs to inputs.

D. Outcome measures measure the level of service provide from the end-users perspective and the degree to which the objectives are fulfilled.

Different stakeholders have different perspectives and importance on the above four measures. The end-users focus more towards the outcome measures as the level of service value them most, the water companies are interested towards input and output measures while the health agencies' job is to minimize the incidence of water borne disease so they are also interested in the outcome measures.

2.1.3. Performance Indicators

The use of a sound performance indicator system accepted internationally can play a key role in this process of inducing a continuous incentive to the water undertaking to increase effectiveness and efficiency and improve quality of service (Helena, et al., 2006). The performance indicators provide effective tools for gauging performance (ADB, 2010b).

According to TERI (2004) there are four types of performance indicators:

A. **Input indicators** are primarily useful for keeping track of resources deployed in each activity.
B. **Output indicators** are a basic measure of the agency's performance and are useful for determining the extent to which the agency has succeeded in meeting its quantitative goals for service provision.
C. **Efficiency indicators** by examining these, the performance level can be judged whether it is satisfactory and whether there is room for further improvement.
D. **Outcome indicators** tell the impacts of a service on its end-users.

According to ADB (2010b) Project Performance Management System (PPMS) indicators are classified into following categories:

A. Classification by the level of gauged target

B. Classification by the contents of performance evaluation

C. Classification by the method of gauging targets

D. Classification based on whether the indicator can be quantified

Whichever indicators are adopted for measuring the performance of an urban water supply should be clear, relevant, economical, adequate and monitorable. The set of indicators chosen for gauging the performance depends upon the objectives and goals to be fulfilled and is area-specific.

2.1.4. Benchmarking Performance

Benchmarking is a method of documenting the performance of an urban infrastructure to promote and improve the service delivery. PM must necessarily be accompanied with performance benchmarking, otherwise it becomes difficult to judge how well or how poorly the agency is performing and what types of corrective actions are required (TERI, 2004). Each performance indicator has to be examined separately to identify the suitable benchmarking strategy (ibid). S. Kumar & Managi (2010) say that the conventional measures of benchmarking concentrate only on the water produced or water delivered and ignore the service quality, as a result the 'low-cost and low-quality' utilities are rated as efficient units.

According to TERI (2004) there are four alternative benchmarking approaches:

A. **Standards**: Some performance indicators for urban services can be benchmarked against established standards, which the performance level should meet to be considered satisfactory.
B. **Trends**: Another approach for benchmarking of performance indicators is to observe the trend in the values of the indicator over a period of time, and assess whether the agency's performance is on the path of improvement or decline.

C. **Comparison**: By comparing the performance of an agency with other agencies or cities benchmarking can be done. It is a practical approach with the benefit of being compared with peer organizations.

D. **Targets**: In this approach benchmarking is done by comparing the actual performance with a pre-established target.

According to S. Kumar & Managi (2010) usually two different categories of performance benchmarking techniques are employed to measure the efficiency of water utilities.

A. **Single-measure gap analysis approach**: It generally refers to the activity of studying the differences between standards and the delivery of those standards for assessing the performance of public utilities.

B. **Total factor productivity approach**: This technique takes into account all of the multiple inputs used and outputs produced by the utilities.

Some developed countries have developed their own benchmark methodology. Like the Netherlands has developed its own benchmarking methodology in co-operation with drinking water industry experts. The benchmark methodology is based on the four accepted perspectives; Water Quality, Service, Environment, Finance and Efficiency so as to provide a complete picture of the social functions of water supply companies.

Large parts of the population in many countries, especially the poor, bear substantial economic and human costs because of serious shortages in infrastructure services, both in quantity and quality terms (Bank, 1994). To overcome these shortages and improve the standard of living, performance measurement is necessary. Performance measurement establishes how effectively and efficiently a public utility delivers the required service, it accounts for both the quantitative and qualitative aspects of an agency's functioning, and relates policy options and their outcomes (S. Kumar & Managi, 2010). Benchmarking is an essential tool for improving the performance of water utilities (ibid). The estimates of benchmarking are important for evaluating the performance of reforms, comparing the relative performance of different utilities, informing citizens who might exert pressure in order to improve performance, and helping regulatory bodies to provide incentive frameworks for improving the performance of the utilities (Lin, 2005).

2.2. Urban water supply

An improved drinking water source is more likely to provide safe drinking water than a not-improved drinking water source, by nature of its construction, which protects the water source from external contamination particularly with faecal matter (UNESCO, 2006). Van der Bruggen *et al.* (2010) say that the three factors that influence the availability of clean water in urbanised regions in developing countries are the rate of population growth, the lack of infrastructure and the upper limits to naturally available sources.

Having water piped to your houses saves time and energy that would otherwise have to be spent collecting water for drinking, cooking and washing. New water connections are one measure of improvement in basic living conditions. In general households without access to piped water connection are considered as poor, but even if the middle and high income consumers are not satisfied with the performance of piped water, mainly quality or if it is costly then they seek for alternative sources.

Table 2-1: Classification of improved and unimproved drinking water sources

Improved sources of drinking water	Unimproved sources of drinking water
Piped water (into dwelling, yard or plot)	Unprotected dug well
Public tap/standpipe	Unprotected spring
Tubwell/borehole	Vendor-provided water
Protected dug well	Tanker truck water
Protected spring	Surface water (river, stream, dam, lake, pond, canal, irrigation channel)
Rainwater collection	
Bottled water*	

Source: UNESCO, 2006

*Bottled water is considered an 'improved' source of drinking water only where there is a secondary source that is 'improved'.

Most renewable groundwater is of high quality, is adequate for domestic use, irrigation and other uses, and does not require treatment (UNESCO, 2006). But groundwater sources are increasingly depleted and not renewed. In urban areas, the infiltration capacity is too low due to the presence of roads and buildings, which further decreases the capacity of renewal (Van der Bruggen*, et al.*, 2010). In addition, the quality of sources may degrade due to uncontrolled discharge of waste water mainly, septic tanks and soaks pits in high density urban areas. While on the other hand, the over exploitation of groundwater for agricultural and industrial purposes renders the availability of shallow groundwater for drinking and domestic purposes increasingly problematic (UNESCO, 2006).

Many aspects of the environment, economy and society are dependent upon water resources, and changes in the hydrological resource base have the potential to severely impact upon environmental quality, economic development and social well-being (Arnell, 1999). In many urban areas the performance of water supply is not effective due to lack of autonomy, lack of staff motivation, lack of public awareness about water use, lack of sufficient revenues from tariffs to maintain the existing system and become financially viable (ADB, 2007).

2.3. Urban recharge

Land use affects groundwater resources through changes in recharge and by changing demands for water. In urban areas where the surface is mostly impervious the groundwater is mostly affected by rainfall and urban recharge (Lerner & Harris, 2009). Urban recharge is variable in time, responding to changes in land use and subsurface infrastructure as well as to climatic changes (Lerner, 2002). Urban recharge can be a combination of leakages from water pipes, sewerages, on-site sanitations like soaks pits and septic tanks, underground water and fuel tanks, etc. The lack of specific criteria and guidelines governing the artificial recharge of groundwater with the on-site sanitation is hampering the quality of the underground water. Most disease-causing bacteria and viruses are short-lived relative to typical groundwater travel times, except in Karstic aquifers or where the source is very close to the point of water abstraction (Lerner & Harris, 2009). As a result, the near-surface groundwater beneath many urban areas is grossly polluted and can no longer be used for drinking purposes.

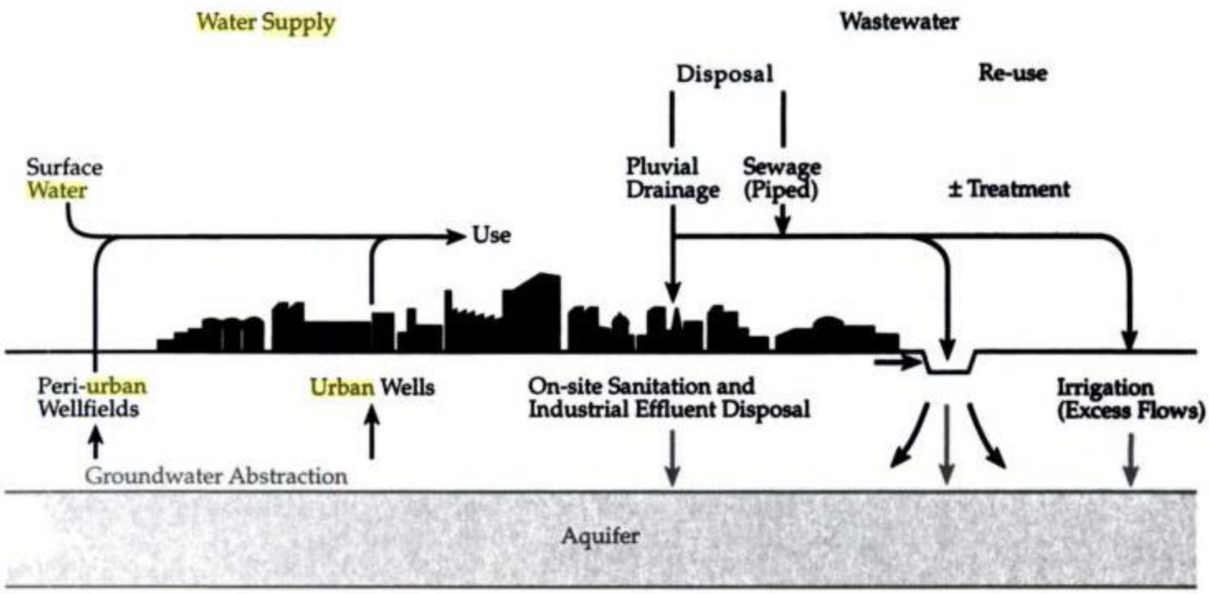

Figure 2.1: Interaction of Groundwater Supply and Wastewater Disposal in a City Overlying a Shallow Aquifer (*Source*: Groundwater in Urban Development)

2.4. Performance measures

A range of water conditions and parameters essentially determine the health status of communities (UNESCO, 2006). To increase the performance of integrated water supply system the following measures have to be taken into considerations:

Production: Drinking water can be produced from any natural sources like groundwater, lakes, springs, rivers or seawater. As population increases demand for water increases so the production of water has to be increased at the production plant.

Supply: In most cities of developing countries, unlike the developed countries the water supply is intermittent. Intermittent water supply often results from elected officials insisting on extending the distribution pipework beyond its hydraulic capabilities (Mclntosh, 2003). Vairavamoorthy *et. al* (2008) say that intermittent supply is usually adopted through necessity rather than by design and this results in serious problems with the supply including insufficient pressure, inequitable distribution of the available water, water quality deterioration, consumers' coping costs, etc. Less-than-24-hour water supply exposes consumers to high health risk from contamination entering distribution pipes during vacuum conditions created when water is absent (ADB, 2007). Due to this reason people tend fulfil their daily demands by adopting alternative sources which can be an improved or an unimproved source. The best measure of good water supply service in a city is 24-hour piped supply to the home because it is linked to water quality and quantity, as well as to price, reliability, and convenience (Mclntosh, 2003).

Coverage: Coverage of piped water supply shows the level of infrastructure development of the city. In most cities of developing countries the coverage of piped water supply is low as the rate of infrastructure development cannot cope with settlement growth. In most cases though the households are connected with piped water supply, the service provided is unsatisfactory due to limited supply with increased demand.

Pressure: Pressure of water supply at the end-user's tap is an important measure of performance as low pressure is related to insufficient quantity, more time for collection, more cost as electricity is needed to pump, etc.

Leakage: One of the reasons of Unaccounted for water (UFW) is the leakage from the pipe connections due to poor maintenance or workmanship. It also degrades the quality of water due to the contamination from the broken pipes. Ageing pipe infrastructure can also lead towards leakage.

Quality: Quality water supply is the most important measure of performance as it directly impacts the health of the consumers and if the quality of drinking water does not meet the standard due bacterial contamination, more percentage of chemicals then various problems are raised like water related diseases, child mortality which impacts the economic development. Bacterial contamination is due to raw water supplied from the production plant or contamination entering distribution pipes during vacuum conditions in case of piped water supply and pollution of groundwater due to encroachment of on-site sanitation due to violation of bye-laws.

Dupont (2005) highlights that a research conducted in United States showed that 60% of the respondents believed that the quality of their drinking water affects their health. Consumer satisfaction depends to very large extent on the taste and odour of the water and whether we like it or not, subjective judgement is the only way to measure the sensory quality (Koster *et al.*, 1981).

Physical characteristics of water

As Doria (2010) says that though the interaction between taste, odour and colour of drinking water are due to psychological factors, the relative importance attributed to each of the senses varies according to time and culture.

Taste: As Zuane (1997) says that taste is used to determine the acceptability of drinking water from a judgement based on sensory evaluation (nerve endings in papillae located on the tongue and stimulated by chemicals).

Odor: It is assumed that odor in water is created by chemicals – particularly organic chemicals – or natural processes of decomposition of vegetable matter or microorganism activity (Zuane, 1997). As Koster *et. al* (1981) points out that our sense may provide good warning systems for the presence of undesirable compounds in drinking water.

Colour: Colour, when noticed in drinking water by the consumer, is an objectionable characteristic that would make the water supply psychologically unacceptable (Zuane, 1997). Unusually high intensity of colour at the source is caused by the presence of iron and manganese, humus and peat materials, plankton and weeds (ibid). It is usually an aesthetic parameter evaluated at the consumer's tap (ibid).

Turgeon *et al.* (2004) highlight that though drinking water that does not have a noticeable taste, odor or visible colour may be considered by the consumer to be safe, it may contain contaminants with potentially adverse health effects like pathogenic micro-organisms or trace organic compounds such as pesticides.

Quantity: Water is required for healthy living and to maintain hygiene and sanitation (UNESCO, 2006). Though the quantity of water required depends upon climate, season and life style, the average daily consumption of 123 litres per capita per day is sufficient for health requirement and low enough so not to be wasteful. For Asia, it has been found that the average domestic consumption is 100-150 litres per capita per day (Mclntosh, 2003). Rietveld *et al.* (2000) say that the average water use by households with piped connections is 130 litres per capita per day in Salatiga City, which lies to the north of Yogyakarta City. However, water demand at the household level is the function of climate, family characteristics, availability and culture, ranges, etc. Also modernisation or urbanisation directly affects the amount of water used.

Metered connections: Metering is important to fully account for water production and consumption in reducing UFW. Consumption metering is also important for consumers to pay for what they are using, which could help in promoting prudent use of water (ADB, 2007).

Affordability: Since water is a basic necessity, it should be provided to the citizens at an affordable price i.e. it should be less than 10% of the total household income (UNHABITAT, 2004). If water supply is expensive then consumers seek for alternative sources.

Tariff: The main source of funding for urban water supplies should be tariffs (Mclntosh, 2003). The average tariff is a good measure of the financial discipline of a utility and its ability to cover operational costs with revenues from tariffs (UNESCO, 2006). Higher tariffs will reduce excessive consumption and waste while in the other hand encourage the consumers to seek for alternative sources. Well-designed tariff schedules serve multiple purposes. They can allow the water supplier to be self-financing, thereby encouraging the extension of water service to new users.

Operation and maintenance: Timely and proper operation and maintenance increases the life time of the pipe networks. But in most developing countries once the infrastructure is built, repair and rehabilitation are neglected which after sometime degrades the quality of the service and the infrastructure dies before its useful lifetime.

Reliability: To make the citizens reliable on the water supply system the service provided should fulfil their needs and demands, more focus are to be given to quality and quantity. Dupont (2005) points out that in a survey conducted as a part of UK Periodic Review of the water system, respondents ranked a reliable and continuous water supply as the most highly rated service aspect.

Willingness to pay for improved services: Willingness to pay for improved piped water supply depends on the tariff, the household income, and alternative water supplies (Mclntosh, 2003). Dupont (2005) highlights that in an internet-based survey conducted on Canada's water quality, it was found that the respondents were willing to face higher water bills in order to reduce health risks associated with water.

Depth of the well: Depth of the well affects the quality and quantity of water; deeper the more quality and quantity. If there is excessive abstraction of groundwater then the level of the water decreases so depth has to be increased which in turn depletes the natural aquifer followed by land subsidence. Since it degrades the environment by depletion of aquifers, it has to be taken into consideration.

Distance between well and house: The distance between well and house should be considered before digging a well, as time passes the effect can be seen like, damages on the building structure due to land subsidence. At least a distance of 3 meters is required between a house and a well for operational purposes like cleaning the well. Land subsidence occurs when large amounts of groundwater have been excessively withdrawn from an aquifer. The clay layers within the aquifer compact and settle, resulting in lowering the ground surface in the area from which the ground water is being pumped. Overtime, as more water is removed from the area, the ground drops and creates a cone. Once the water has been removed from the sediment, it cannot be replaced. Land subsidence can lead to many problems, including changes in elevation; damage to structures such as storm drains, sanitary sewers, roads, railroads, canals, levees and bridges; structural damage to public and private buildings; and damage to wells. Most commonly, though, subsidence is known for causing an increase in the frequency of flooding.

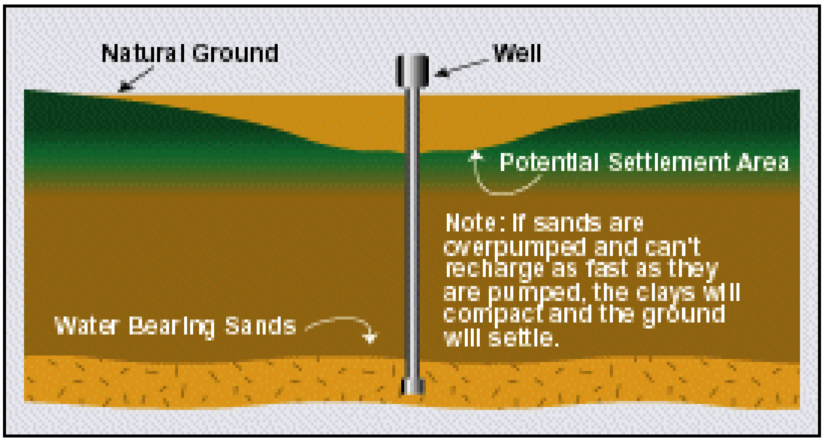

Figure 2.2: Land subsidence
(*Source*: http://www.sanjacintoriverauthority.com/facts/land-subsidence.html)

Distance between well and on-site sanitation: The health risks associated with faecal groundwater contamination from on-site sanitation is critical in residential areas where households are using water from shallow wells for drinking and domestic purposes. The distance between the well and on-site sanitation affects the quality of water, shorter the distance more pollution due to encroachment from septic tanks and soak pits. The best available indicator of faecal pollution of individual drinking sources is Escherichia coli or thermo-tolerant coliform bacteria (UNESCO, 2006). Pathogenic bacteria, viruses and parasites often present in faecal matter can cause illness, some having flu-like symptoms such as nausea, vomiting, fever and diarrhoea. In some cases, symptoms can be more severe. The presence of E.coli bacteria in water represents a serious problem. So in order stop or protect the groundwater being polluted the distance between well and on-site sanitation has to be taken in consideration otherwise the water will be unfit for drinking purpose.

3. STUDY AREA DESCRIPTION AND WATER SUPPLY SYSTEM

This chapter consists of the brief introduction of study area; its physical condition, urbanisation trend, demographic characteristics and the existing integrated water supply conditions.

3.1. Physical condition

Yogyakarta is one of the 32 provinces of Indonesia which is situated between 110°24'19" - 110°28'53" East Longitude and 07°49'26" - 07°15'24" South Latitude. It has total area with 32.5 km² and consists of 14 districts. Topographically, Yogyakarta region is a plain with elevation of about 8 m to 136 m above mean sea level. Geologically, Yogyakarta formation consists of sand, gravel, silt and clay from the Sleman Formation. Hydroclimate condition makes rain water as a source of groundwater recharge in Yogyakarta. Builder material of Yogyakarta Formation which is 20-40 m layer thick is very permeable and become the builder of Merapi aquifer that is highly potential for water supply in the region. Since it lies between the southern plains of Merapi mountain and Indian Ocean with its elevation slowly declining towards the south, the groundwater flows from the north towards the south so the recharge of Yogyakarta city have source from both local area and from the northern plains.

Figure 3.1: Map of Yogyakarta, Indonesia

(*Source*: http://www.google.nl/indonesia map)

3.2. Urbanisation

In 1970s more than a half of Yogyakarta city was covered by non built-up areas with total built-up area of 15.7 km² and by 1980s the built-up areas increased to 19.9 km² indicating physical growth, even then the city was classified as over-bounded city. Entering 1990s there were significant changes converting the city into over-bounded class, the most important determinant of urban development being transportation networks. In the last two decades, urbanisation has transformed the structures of Yogyakarta City and grew boundary. Urbanisation has transformed rural dwellings to become urban settlements and generated urban agglomeration. Recently population growth and business activities have increased rapidly in Yogyakarta. Being an education centre with about 137 higher education institutes, many students and other people from the surrounding areas come for temporary stay or make living there. Being one of the most attractive and ancient historical cities in Java, and its proximity to many touristic places, it is a major stop on the touristic route.

3.3. Demographic Characteristics

In Yogyakarta the population has found to be increased from 2002 to 2006 in all the districts but from 2006 to 2008, it has found that in some district the population decreased slightly. Even though the population density is high with Ngampilan having the highest density of 29,077 inhabitants/km² while the lowest density is 9,168 inhabitants/km² in Umbulharjo.

Table 3-1: Districts with land area, population and population density

No.	District	Land area (km²)	Population				Population Density (2008)
			2002	2004	2006	2008	
1	Tegalrejo	2.91	39433	40981	41860	43225	14854
2	Jetis	1.7	37497	37700	38213	38047	22381
3	Gondokusuman	3.66	73730	74919	75803	76761	20973
4	Danurejan	1.103	30840	31284	31707		
5	Gedongtengen	0.96	26448	23956	26791	25006	26048
6	Ngampilan	0.82	23189	23425	23841	23843	29077
7	Gondomanan	1.12	16693	17215	17958	17483	15610
8	Pakualaman	0.63	14762	14902	15118	15040	23873
9	Kotagede	3.07	30662	31222	32269	33060	10769
10	Umbulharjo	8.12	71344	71904	74347	74448	9168
11	Mergangsan	2.31	42208	42768	42811	43261	18728
12	Kraton	1.4	28533	29043	29952	29545	21104
13	Wirobrajan	1.76	30533	31162	31397	31484	17889
14	Mantrijeron	2.61	39693	40582	41124	36835	14113
	Total	**32.173**	**505565**	**511063**	**523191**	**503268**	

Source: PUSTRAL, UGM

3.4. Water supply conditions

In Yogyakarta City the piped water supply system was initiated by the Dutch during their colonisation in 1918, controlled by the Japanese after they defeated the Dutch and went under the government's management in 1955 after independence. Now the piped water supply within the city is supplied by a private company, PDAM Tirthamarta serving 40% of the total population. Figure 3.2 shows the pipe network and coverage of PDAM Tirthamarta. The water production plant is located at the sub-urban area of Seleman Regency, transferred to three reservoirs near the city and distributed to the households. The main sources of raw water are direct water abstraction, groundwater, springs and short wells. The quantity produced at the production plant depends upon the amount of water abstracted from the deep wells but due to the limited number of deep wells i.e. 15, PDAM is not able to increase its production.

Due to the pace of development, Yogyakarta city is becoming an urban agglomeration area with settlement pattern extending towards many directions defined by road networks and service centres but without proper development of infrastructure facilities. For the increased population and urban activities, there is need for supporting infrastructures mainly water supply and sewerage. Ministry of Public Works (MPW) has the responsibility for determining policies and standards in the water sector and sanitation, but urban sanitation is the least well- addressed of major policy issues in Indonesia.

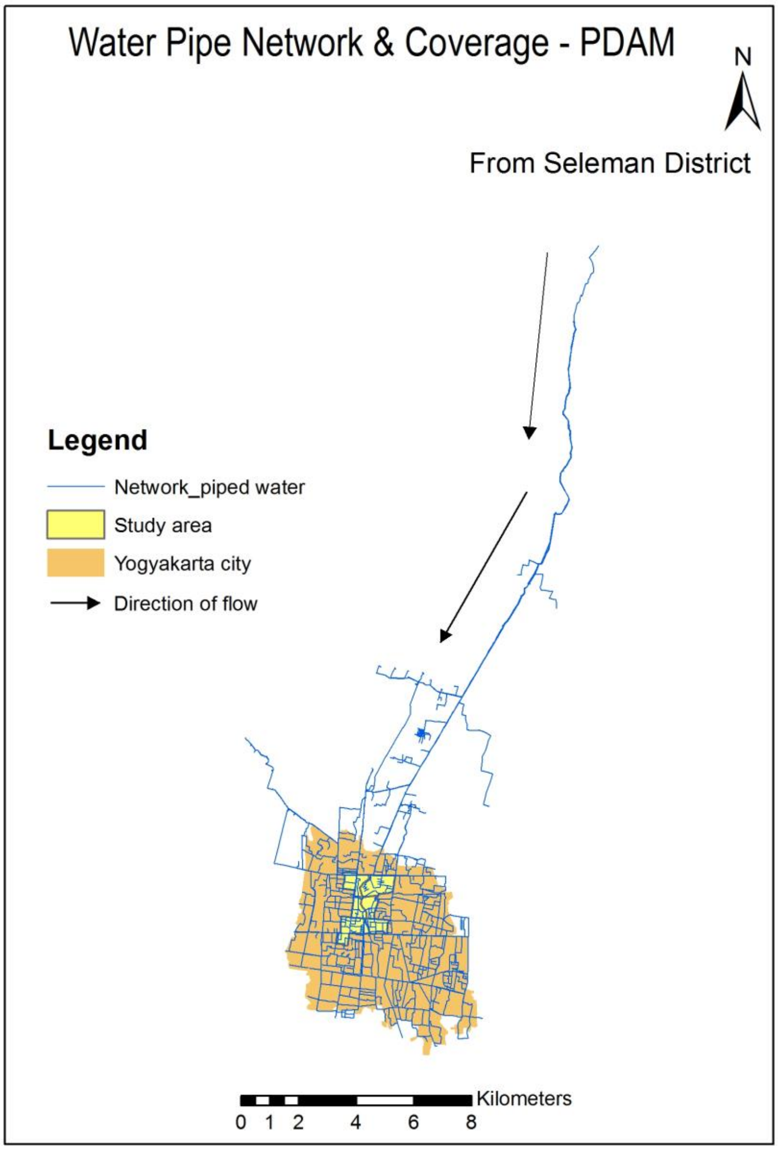

Figure 3.2: Pipe network and coverage of PDAM Tirthamarta

According to the Indonesian Drinking Water Companies Association (Ministry of Public Works, 2005), about 90% of piped water supply companies, PDAMs (Perusahaan Daerah Air Minum) are in unhealthy financial condition, with many of them described as technically poor – reporting low levels of service. Non-availability of raw water has been another common problem facing by the operators, especially during the dry season (April–October). It was reported that Java Island, Indonesia's most populated island, experiences around 13 billion m^3 of water deficit every year. This has led the government to alleviate millions of people and farmers impacted by the drought via a variety of supporting schemes including: free rice support, re-forestation projects, and designing less water-dependent agriculture systems.

In case of PDAM Tirthamarta due to the financial constraints, new development and expansion of piped water supply are halted. Limitation of the service coverage of piped water supply as well as the unwillingness of the people to use it resulted in the wide-use of groundwater for domestic purposes. The wide-use of shallow infiltration wells for water supply and on-site sanitations like septic tanks to dispose domestic waste into ground directly, and their proximity has polluted the groundwater source making it unfit for drinking. The majority of people are using residential septic tanks for their daily domestic waste while informal settlements near the river banks dispose their wastes directly into the rivers; in both the cases the environment is being degraded. Table 3-2 shows the tariff design of the piped water supply for different socio-economic groups fixed by the supplier.

Table 3-2: Tafiff design of PDAM Tirthamarta for residential use

S. No.	Income group	Tariff (in Rp)			
		0-15	16-30	31-50	>50
1.	Low	1,750	3,150	4,175	7,550
2.	Middle	2,350	3,500	4,700	7,550
3.	High	2,800	3,750	5,400	7,550

(*Source*: PDAM Tirthamarta)

4. DATA COLLECTION METHODOLOGY

This chapter includes the methodology for data collection; fieldwork preparation, questionnaire design based on the parameters chosen after literature review and situation in study area, study area selection, sampling design, sample size, procedure for household survey, GPS points and other measurements, water quality sampling procedure, secondary data collection, post fieldwork and limitations of the fieldwork.

4.1. Fieldwork Preparation

Based on the literature review and the existing conditions of the water supply system in Yogyakarta, various parameters of piped and groundwater supply were selected like supply, coverage, pressure, leakage, quality, quantity, affordability, tariff, revenue, operation and maintenance, reliability, depletion of aquifers, land subsidence, pollution due to encroachment and willingness to pay for improved service. For each parameter one or more indicators were chosen, questions were formulated accordingly and grouped according to the stakeholders from whom the answers would be collected like household questionnaire for the consumers, interview questionnaires for piped water supply company (PDAM Tirthamarta) and Environmental Agency. Most of the questions in the household questionnaire were qualitative so that it would be easy for the respondents to answer. Before conducting the household survey official letters were sent to the head of each village for permission which took more a week for approval. For secondary data collection official letter along with questions translated into the local language 'Bahasa' had to be sent a week prior to interview so that it would be easy for them to gather the required information before the interviews were conducted.

4.2. Questionnaire Design

The household questionnaire was designed to find out the consumers' perception on the performance of the integrated water supply; piped water supply and groundwater wells. Other sources of water supply like river water, buying from vendors, mineral water were not considered as they are not included in the improved sources of supply. First different parameters of piped water supply and groundwater wells were chosen and related indicators were selected and questions were formulated accordingly. The first part of the household questionnaire was short and was mainly designed to identify the position of the respondent in the family, numbers of family members and the source of water supply. The second part was focused on the parameters of piped water supply so those questions were answered by respondents using piped water supply, the third part was on the parameters of groundwater wells so the related respondents had to answers those questions while the respondents using both the sources had to answer all the questions. A pilot survey was conducted on 30th Sep 2010 and some questions were further simplified (changed from quantitative to qualitative) so that the respondents could easily understand the questions.

Table 4-1: Performance Indicators

S.No	**Parameter**	**Type of source**	**Indicators**
1	Supply	Pipe	Hours of daily supply
			No. of times a day water is supplied
2	Coverage	Pipe	Household's meter connection
3	Pressure	Pipe	Discharge from the end user's tap
4	Leakage	Pipe	Unaccounted for water (UFW)
5	Quality	Well	Quantity of total Coliform & E-coli in the water
		Well	Number of family members suffering from water borne diseases
		Pipe	Perceived chlorine content
6	Quantity	Pipe	Average litres per capita per day
		Well	Depth of the well from the ground level
7	Affordability	Pipe/well	Total household income spent to buy piped water
8	Operation & maintenance	Pipe	Number of complaints received per month
			Time taken to repair major leakages
9	Reliability	Pipe	Satisfaction on complaints attended
			Overall satisfaction of citizens with service
10	Depletion of aquifers	Well	Level of water decreasing
11	Land subsidence	Well	Distance between well and house
			Cracks seen in the portion of building near to the well
12	Pollution due to encroachment	Well	Distance between well and on-site sanitation
13	Willingness to pay for improved service	Pipe	Household's willing to pay for improved piped water supply

4.3. Selection of study area

The intention of the household survey was to identify the consumers' perception of the performance of integrated water supply. Six urban villages within the Yogyakarta City were chosen as none of the households outside the city are connected with piped water supply and totally rely on groundwater source. The study area chosen are the six urban villages along the river Code; the same villages which were chosen by a student from last year as the dataset was easily available. Table 4-2 shows the population and area of each village. Figure 4.1 shows the study area. Figures 4.2 to 4.7 show the existing condition of the integrated water supply system within the study area.

Table 4-2: Study Area; Population and Area

District	Village	Population (2008)	Area (km²)
Jetis	Gowongan	10889	0.459
Gondokusuman	Kotabaru	5870	0.71
Danurejan	Suryamatajan	3429	0.279
Danurejan	Tegalpanggun	6746	0.351
Gondomanan	Ngupasan	6912	0.67
Parualaman	Purwokinanti	9019	0.33

(Source: PUSTRAL)

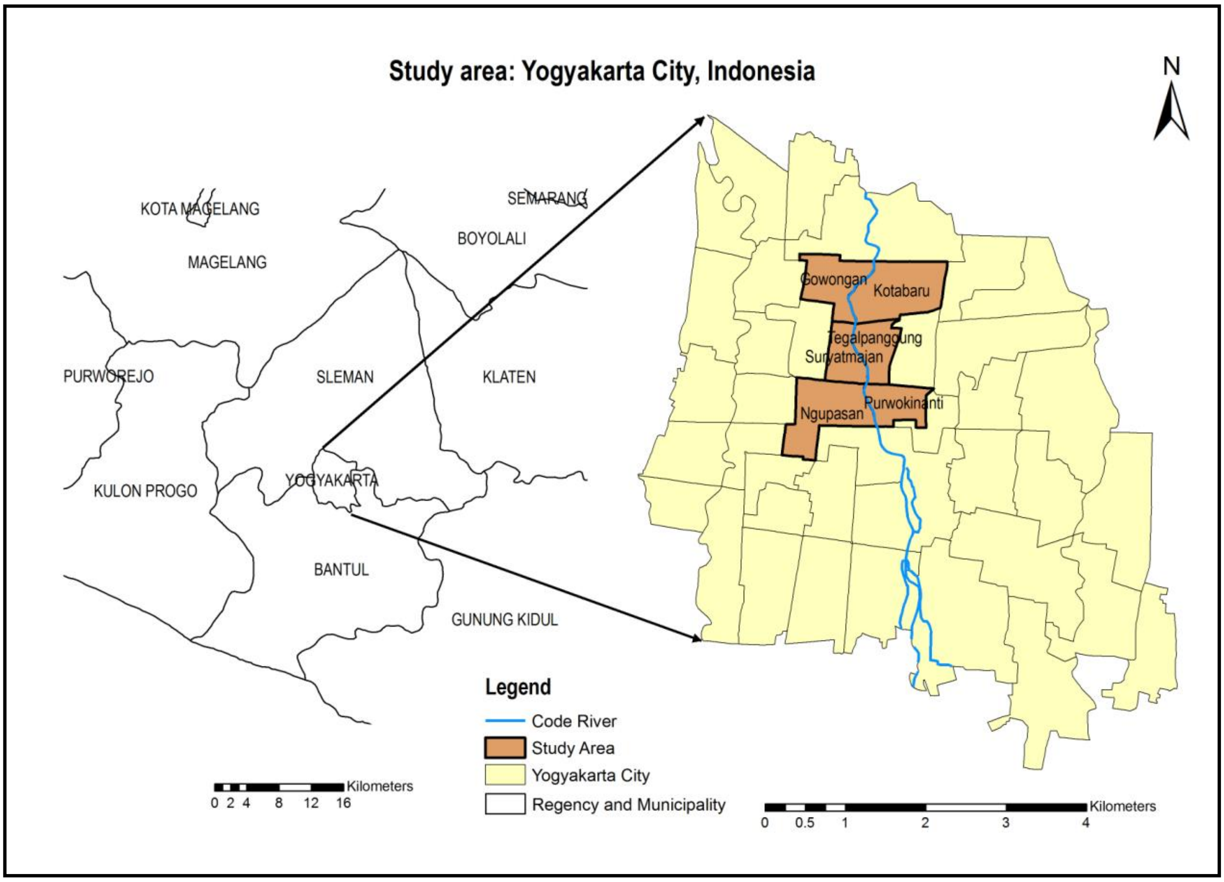

Figure 4.1: Study Area, Yogyakarta City

Figure 4.2: Communal well surrounded by impervious surface at Gowongan Village

Figure 4.3: Communal well and piped water supply at Kotabaru Village

Figure 4.4: Communal well and meter connection for piped water supply in Suryamajan Village

Figure 4.5: Overhead water tank and communal well at Tegalpanggung Village

Figure 4.6: Private well attached to a building at Ngupasan Village

Figure 4.7: Private well and water outlet at Purwokinanti Village

4.4. Sampling Design

Random Sampling:
The sampling design chosen for this research was Random sampling so that every household in these urban villages has an equal and independent chance of selection in the sample.

Sampling frame:
From the built-up shapefile of Yogyakarta city and Google earth image, buildings were identified within the study area though it was not easy to identify the use of those buildings.

Sampling unit:
Since the purpose of the survey was to identify the consumers' perception on the performance of the water supply system, households were chosen as sampling units.

4.5. Sample size

The targeted sample size was around 300 households so the study area of total area 2.799 km^2 was divided by 90 x 90 m^2 grids which gave around 346 individual grids over the study area. To code every grid, the grids were extended beyond the study area to form a rectangular mesh where the columns were numbered alphabetically and rows numerically so that every grid was coded like C12, N24, etc. The strategy was to survey a household from each grid performing random sampling so that every household whether it used only piped water supply, groundwater well or both had the chance of selection. But in the ground, most of the buildings in the villages Kotabaru, Suryatmajan and Ngupasan were used or built for commercial purpose so it was not easy for the surveyors to find a single household in the stated grids which affected the sample size hugely, reducing it to 122. Since the sample size was reduced by 60%, only the perceptions of the consumers from the 122 households are used for this research. As sampling is a process of selecting a few elements from a sampling population and from the collected data as the perceptions of the consumers using the same source/sources were found similar it showed that the extent of variation is low. As Kumar(2005) says that in qualitative research the main aim is either to explore or describe the diversity in a situation or phenomenon, the issue of sampling has little significance. He also adds that if a population is homogeneous with respect to the characteristics under study, a small sample can provide a reasonably good estimate.

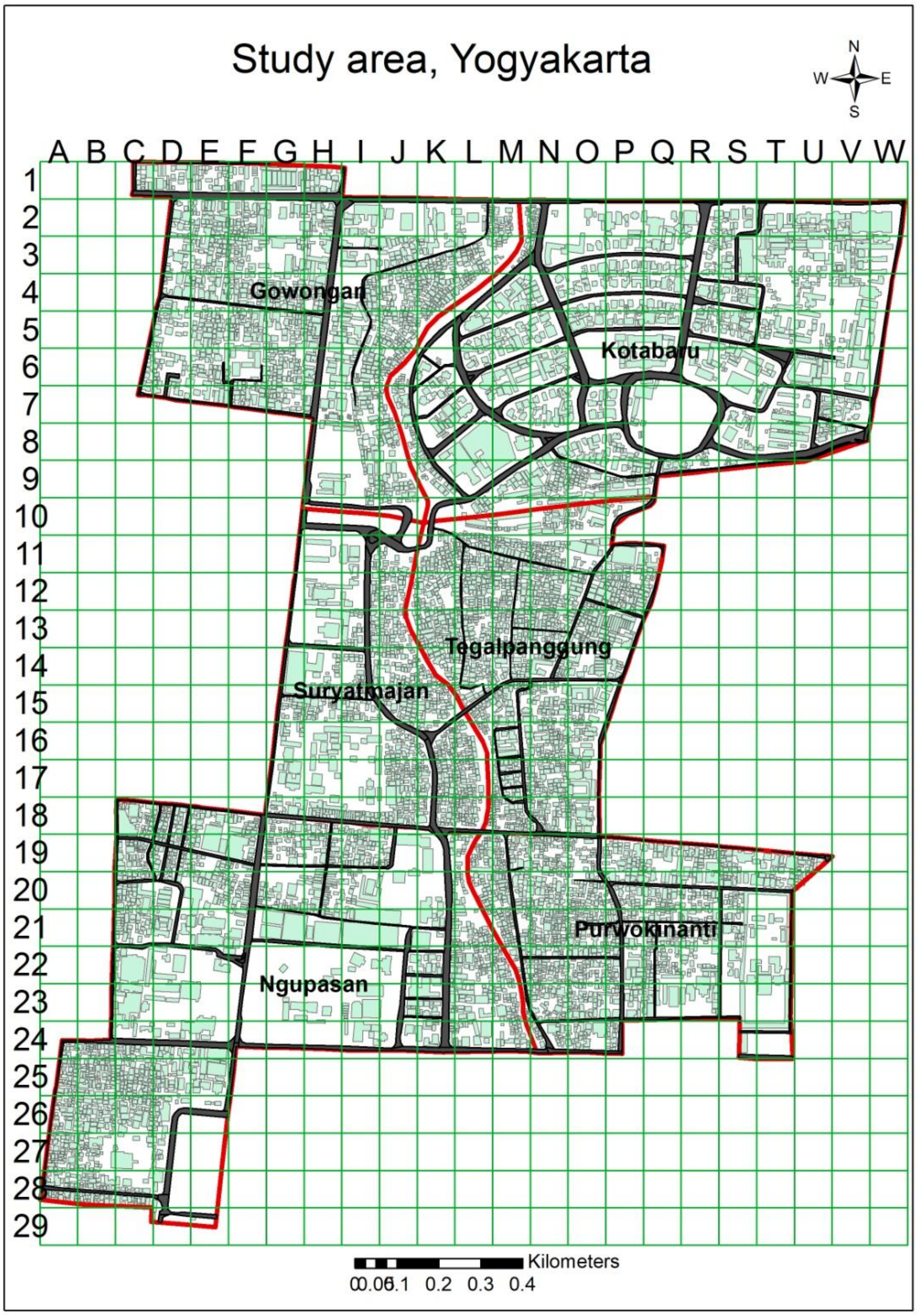

Figure 4.8: Sampling Design

4.6. Procedure for Household survey

To conduct the household survey six students of Gadjah Mada University were hired as the study area was quite large and the interviews had to be done in the local language 'Bahasa'. Before starting the survey, the questionnaire and the sampling procedure were explained to them. They were also taught to use the GPSs. A pilot survey was conducted on 30th Sep '10 in two villages; Gowongan and Tegalpanggung. After which some modifications was done in the questionnaire as some questions were not easy for them to answer. The proper survey started from 6th Oct '10 till 24th Oct '10. To remove overlapping and conduct the survey more easily, the surveyors gathered every morning and decided the area to visit that day. As the study area was quite large and it was not possible to conduct survey by walking as each grid was 90 m^2, the surveyors divided themselves in a group of three each with two people so that each group conducted the survey using a motorbike which is a common means of transport for students as well as other people in Yogyakarta City. For the water samples collection as the time was limited the same procedure was followed after which each group took the collected samples to the laboratory within 3 hrs.

4.7. GPS points and other measurements

For each household GPS was used to find the coordinates. Other physical measurements were also carried out like the distance of the well from the house and septic tank, measuring tapes were used for this purpose. Since it was not easy to measure the depth of the wells, the owners' knowledge on the depth of the well was taken. As mentioned earlier as the survey had to be conducted beyond the fieldwork period of the author and the fieldwork materials were not possible to leave there , the households which were surveyed later were without GPS measurements so for those households the coordinates of the centroid of the respective grid was given to it.

4.8. Water Quality Sampling Procedure

The water quality sampling was done to find out the quantity of total Coliform and Faecal Coli in the groundwater wells, hence to find out the water from each sampled groundwater well was qualified for drinking or not. Since the budget was limited and the surveyed household were spread out, the laboratory for water sample tests had to be search in such a way that it would be within or near the study area and the budget allocated would be enough to pay. Help from a staff from PUSTRAL was required to search a laboratory, Laboratorium Pengawasan Kualitas Air which was within the study area and relatively cheaper. After which it was visited by the author to book the number of samples for a week, the number of samples handled by the laboratory was only 20 per day. The staff in the laboratories demonstrated the different procedures for water sample collection; 1) if the well water was drawn from bucket, a special bottle wounded with a string had to be used to withdraw the sample water, 2) if the water from the groundwater well was withdrawn with pipe then the sample water was collected first sterilising the bottle's rim and the tap's rim by burning cotton dipped in spirit and 3) if the tap was of plastic then the rim of the tap was sterilised by cotton dipped in 70% alcohol. After labelling the bottle the sample had to be sent to the laboratory within 3 hrs before 11:00 am and the maximum number of bottles to be taken per day was 20. The survey started from 9th Oct '10 but due to the spread sample points and limited time for collection and submission of the samples the number of samples collected was around 8 per day. Since it was not feasible to conduct the sampling tests in only one laboratory another laboratory had to be searched. Balai Laboratorium Kesehatan Kota Yogyakarta was another laboratory which could handle 15 samples a day but the price was a little bit higher. Due to limited budget and time, only around 45% of the well water from the surveyed households was taken for the laboratory test.

4.9. Secondary Data Collection

The secondary data collection consisted of interviews with the piped water company (PDAM Tirthamarta) and the Environmental Agency. The interview with the director of Engineering department from PDAM Tirtamarta was conducted on 8th Oct 2010. This secondary data acquired included the different parameters of the performance of piped water supply like coverage, production, purification process at the plant, unaccounted for water (UFW), revenue collected per unit of water sold, number of staff trained, number of complaints received per week and the time taken for repair, etc. Likewise, the interview with the head of the Environmental Agency of Yogyakarta was conducted on 11th Oct 2010. He gave some information about the decreasing water table as they are inspecting 10 shallow groundwater wells in different locations within the city, policies to control the depletion of aquifers and the bye-laws to control the pollution of aquifers. Since the interviews were conducted in the local language 'Bahasa', translation had been done by the help of a staff from PUSTRAL, Centre for Transportation and Logistics, Gadjah Mada University. The population data of Yogyakarta City, 2008 was provided by PUSTRAL.

Table 4-3: Secondary data

Type of Data	Description	Data Condition	Sources
Spatial data	Administrative boundary of Yogyakarta City	GIS data (vector)	PUSTRAL, UGM
	Piped water network	GIS data (vector)	PUSTRAL, UGM
	Household points for Water quality tests (done by last year's student)	GIS data (vector)	PUSTRAL, UGM
Demographic data	Population data	Excel	PUSTRAL, UGM
Interview	Parameters of piped water supply	Oral	PDAM Tirthmarta
Interview	Groundwater conditions and policies	Oral	Environmental Agency of Yogyakarta City

4.10. Post Fieldwork

After the completion of household survey the questionnaires were collected from the surveyors and entered in the digital format in Microsoft Excel by the author everyday and cross checks were done at the end. If there was any confusion then the surveyor who conducted that household survey was contacted and asked the following day for clarity as every questionnaire had the name of the surveyor, household code and the date of survey. For the water sampling tests, the result took a week time for every batch of samples and they were in hard copies in the local language. So as soon as the results were received the remarks were translated by the use of Google translator for every household and entered in digital format along with the questionnaires. Since the household survey had to be extended beyond fieldwork period a meeting was held between the staff of PUSTRAL and the author so that the surveyors continue conducting the survey in the absence of the author and hand the filled questionnaires and laboratory reports to a staff in PUSTRAL which she could scan and mail to the author. So as discussed the author received the scanned questionnaires and laboratory reports which were printed and entered in the digital format. For the secondary data, after conducting the interviews in the local language the interpreter translated the answers in English and the author copied which was entered in digital format later.

4.11. Limitations of the fieldwork

Following are the limitations faced by the author during the field visit:

Time taking bureaucracy: As permissions had to be taken prior to conduct household surveys in each village, the survey started a week later than was estimated. For the interviews official permission letters had to be sent beforehand along with the translated questions so that it would be easy for the interviewees to collect the required information. As the head of the Environmental Agency had a busy schedule that time it was not easy to meet him so the interview was conducted quite late than as scheduled.

Lack of high resolution satellite image: Due to the lack of high resolution satellite image and as the Google earth image was of low resolution it took time for sampling design. Later a dataset of Yogyakarta City with built-up area and road network were used for sampling design which made the surveyors conduct the survey more easily.

Sample size reduced: The reason for choosing the six villages as study area was that the coverage of the piped water supply is only within the city of Yogyakarta and dataset was available. But since the area was vast and unknown to the author the sample size reduced than estimated by 60%, the reason was that in the villages Kotabaru, Suryatmajan and Ngupasan most of the buildings were commercial.

Water quality testing: As the water quality testing was expensive the budget provided for fieldwork was not enough to conduct laboratory test for all the groundwater wells which were surveyed. Different procedures had to be followed for different facilities which were time consuming, the collected samples had to be labelled and taken to the laboratories within 3 hrs before 11:00 am and as the study area was quite spread-out the number of samples collected per day was around 8.

Time consuming survey: In some grids, the number of households was limited with most of the households without people at the time the surveyors went there so they had to go there again another day to conduct the survey.

Ignorance of respondents: After the pilot survey some quantitative questions had been changed into qualitative as it was not easy for the respondents to answer. Even then some questions remained unanswered as the respondents were not much concerned about the water supply system or they were not willing to answer or they were unknown about the issues.

Language problem: As the medium of conversation was in the local language 'Bahasa', surveyors had to be hired who also had some knowledge in this field and for the interviews interpreters were needed.

Strict rules: A library in the department of Architecture and Urban Planning, University of Gadja Mada was visited during the fieldwork in search for relevant literatures in the study area but most of the documents were in the local language and only a few were in English, but unfortunately the copies could not be made as it was against the rule of the university.

5. DEVELOPMENT OF A METHODOLOGY TO MEASURE THE PERFORMANCE OF INTEGRATED WATER SUPPLY SYSTEM

This chapter presents the development of a methodology for measuring the performance of the integrated water supply system. The first section includes the development of a performance measurement framework for the integrated water supply system in Yogyakarta City. The second section consists of a set of performance measurement criteria and indicators for Yogyakarta itself. The third section includes the performance indices for different types of households and mapping of the performance of the integrated water supply system. The fourth section includes the comparison of different parameters of performance with appropriate benchmarks. The fifth section describes briefly the procedure of performance assessment.

5.1. Development of performance measurement framework

In Yogyakarta City at the macro level i.e. the city itself mainly three stakeholders are involved – PDAM Tirthamarta, the Environmental Agency and the Health Agency while at the micro level are the residences within the city with the consumers as stakeholders. Although the performance of water supply systems varies differently in different locations, integration on two aspects of performance is required; the different parameters of performance and the perceptions of different stakeholders on performance.

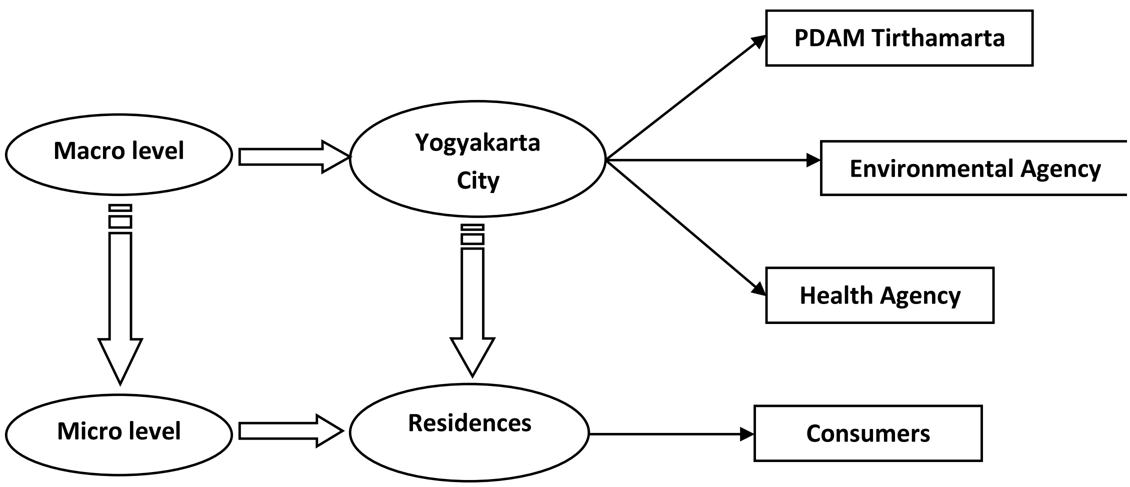

Figure 5.1: Related stakeholders at the macro and micro level in Yogyakarta City

The figure 5.1 shows that in Yogyakarta city different stakeholders are involved in the performance of the integrated water supply at the macro and micro level. The general perception of each stakeholder is explained as;

Perception of supplier (PDAM): The supplier has a responsibility to supply water to the community, but at the same time they are running a business that must balance increasing demands for water due to population growth while considering the cost of supply and the willingness of the community to pay for that water. So the main objective of the supplier should be to provide water supply service that is responsive to the consumers' needs and desires, it should be more service-oriented than business-oriented so that the consumers can rely on it. But in case of Yogyakarta, the PDAM Tirthamarta is financially weak so it is very difficult to increase the coverage, replace the old pipes and increase the production to cope with the population growth.

Perception of Environmental Agency: In most developing countries the impact on environment due to human behaviour is not considered. But without considering the negative impacts on environment due to human activities sustainability can never be achieved. So in order to minimize negative environmental impacts, the perception of the environmentalists should be taken into consideration and excessive abstraction of groundwater has to be minimized. One of the jobs of the Environmental Agency of Yogyakarta city is to monitor the level of groundwater, they have been observing 10 wells in different locations within the city and noticed that the water level is being decreasing, which is a major concern and necessary steps required to minimize this impact.

Perception of Health Agency: The Health Agency of Yogyakarta city determines the quality of groundwater in terms of bacterial contaminations by conducting water quality tests in the laboratory and provides health education. If the laboratory test for a sample of water taken from a well shows bacterial contamination, it is important to treat the water properly before drinking and cooking, and search for reliable source.

Perception of consumers: Since the water supply service is provided for the benefit and well-being of the consumers, their perceptions regarding service quality are central to evaluate water utility performance. By judging the different parameters of performance from the perspective of the consumers the level of performance can be known, which helps to improve the service.

According to the type of source/s and their preferences, stratification of households on the basis of collected samples was done as follows:

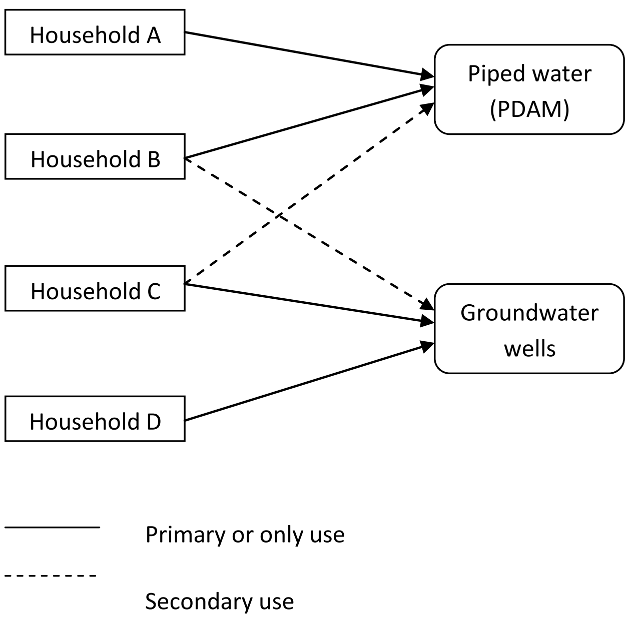

Figure 5.2: Division of households on the basis of source/sources used

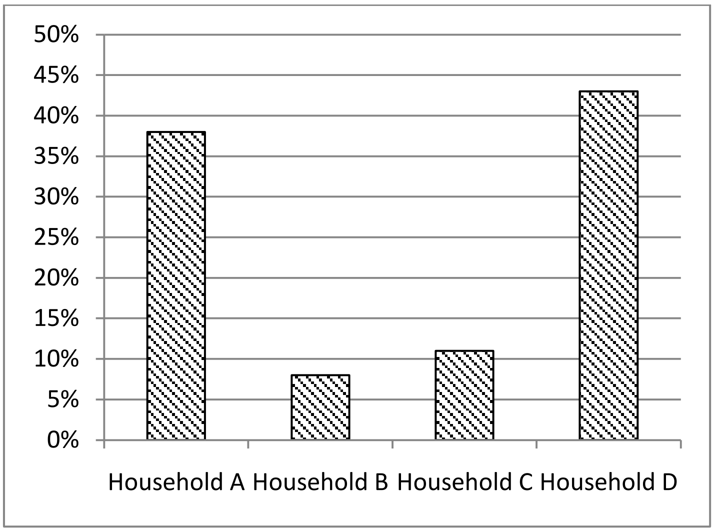

Figure 5.3: Percentage of households using different sources of water supply

From the figures 5.2 and 5.3, it is found that the Household type A who use only piped water supply is 38% of the total household surveyed. The Household type B who use piped water as a primary source and groundwater as secondary source is 8% and Household type C is 11% who use groundwater as primary source and piped water as secondary source. Household type D who use only groundwater whether from private or communal well is 43% out of the total households surveyed.

5.1.1. Descriptive Analysis: Consumers' perception on Odor, Taste and Colour on piped water (PDAM) and groundwater

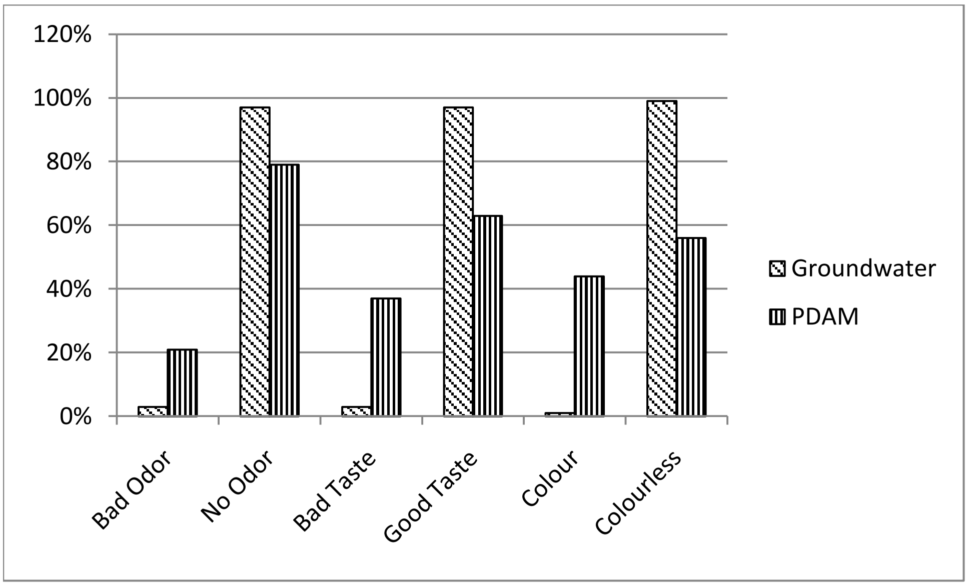

Figure 5.4: Consumers' Perception on three sensory attributes of PDAM and Groundwater source

Figure 5.4 shows the consumers' perceptions on the three sensory attributes colour, odor and taste of the piped water (PDAM) and groundwater. It is found that the consumers' perception on the quality of groundwater ranked higher than the piped water supply. The consumers of piped water are not fully satisfied in terms of quality. The three attributes odor, taste and colour of their water supply were asked to the respondents to identify their perceptions on it. Almost all households using groundwater source perceived the quality of water as good without odour, taste and colour whereas most of the consumers of piped water (PDAM) were not satisfied with the quality.

Since majority of consumers using groundwater seemed to be satisfied with the quality of water, analyses on the three sensory attributes of piped water supply were done, as Koster *et al.* (1981) say that the sensory assessment of water remains very important because it is the ultimate measure of water quality for the consumer.

5.1.2. Descriptive Analysis: Perception on Colour, Odor & Taste quality of PDAM water by different household types

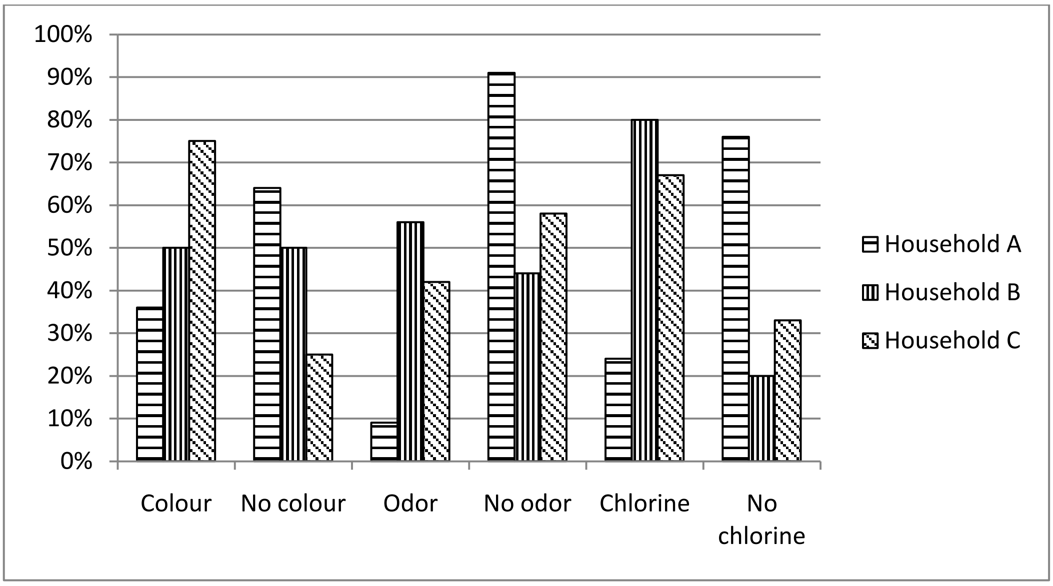

Figure 5.5: Households' perception on Colour, Odor and Taste of piped water

Figure 5.5 shows the perception on colour, odor and taste quality of piped water supply (PDAM) by the Households A, B and C. Different household types perceived the colour quality of PDAM supply differently. About 65% percentage of respondents from Household A perceived the water as colourless, 50% percentage of respondents from Household B perceived as coloured and 76% of respondents from Household C perceived it as coloured. So it is easy to predict that those consumers who found the source as colourless relied more on it while those who found the water to be coloured seek for alternative source. Among the respondents who found the source to be coloured replied it to be red, brown, dark occasionally, grey, black after rainfall, sometimes black or black in the morning.

As taste cannot be measured objectively, consumers' perception on the taste quality of PDAM water was asked. According to Zuane (1997) some of the chemicals most frequently alluded to are chlorine, lime scale/hardness and lead. Figure 5.5 also shows the perceived values of piped water by different household types in terms of taste. The respondents were asked about the taste of the PDAM supply, more than 75% of the respondents from Household type A replied it as good taste (without Chlorine) while 80% and 68% of the respondents from Household type B and C respectively replied as the taste to be Chlorine. From this we can conclude that those households that use both piped water and groundwater experience the taste differently. Sometimes consumers seek for alternative source of drinking water due to the presence of offensive tastes in the public water supply but it may or may not be subjected to the same degree of protection afforded by the rejected supply.

In figure 5.5 shows the perception on the odor quality of piped water by the three household groups. More than 90% of the respondents from Household type A considered the odor quality to be good while about 56% and 42% of the respondents from Household type B and C perceived it as smelly. From this graph it is noticed that majority of Household A perceived the water to be odorless while more consumers relying on both the sources perceived it with odor.

So among the three attributes of water quality, colour is perceived as an important factor to determine the quality of their water supply by the consumers, as in Figure. 5.5 it has been found that as the colour quality is degrading consumers tend to move towards groundwater source.

5.1.3. Descriptive Analysis: Distance between Private well and Septic tank

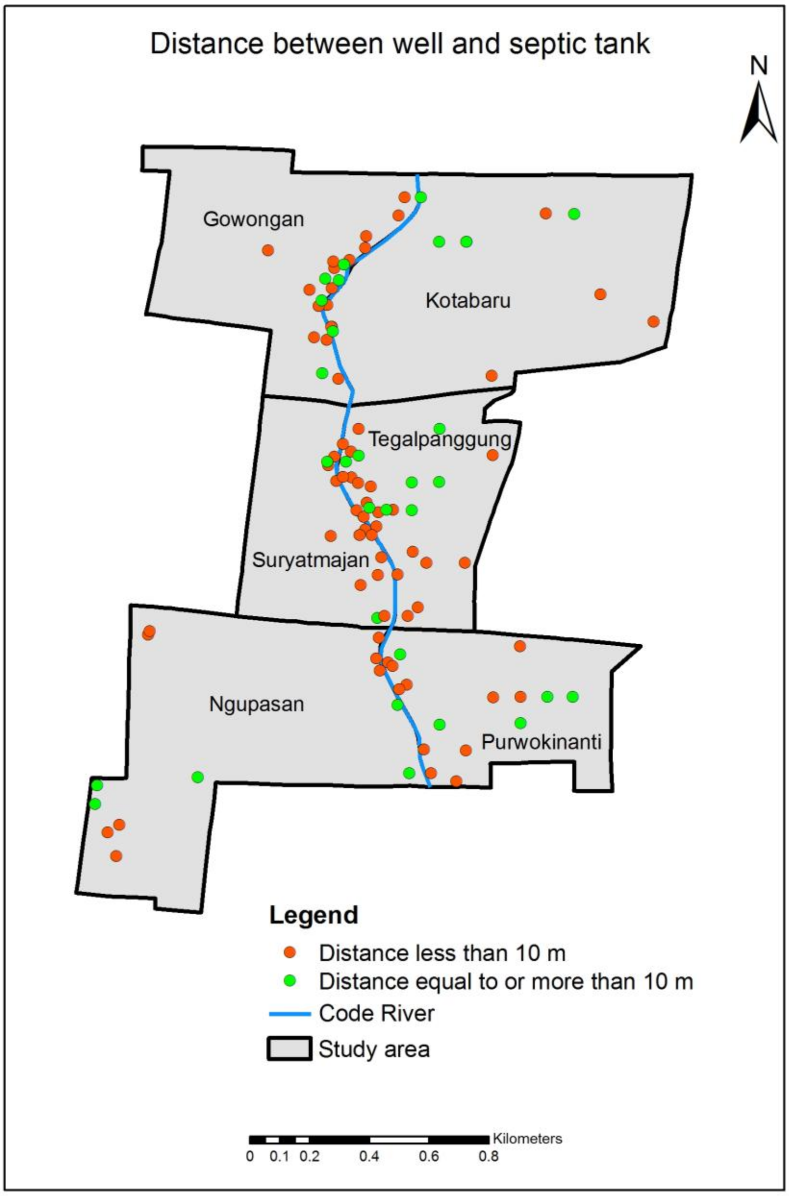

Figure 5.6: Households showing the distance between well and septic tank

Figure 5.6 shows the household points with distance within 10 meters and equal to or more than 10 meters between the groundwater well and septic tank. In Yogyakarta city, most of the households use on-site sanitation as the sewerage system is inefficient. Actually in the bye-laws there should be at least 10 meters of distance between a well and septic tank but according to the head of environmental agency in average a distance of 2 to 3 meters is found within the Yogyakarta City. Since the data collected consisted of 52 households using groundwater wells, the data from a last year's student, who took the same study area, was used consisting of additional 59 households. Based on the spatial analysis in the study area, most of the wells were found within 10 meters of distance from the septic tank. In some cases those households who do not have private toilets rely on communal toilets while some households near the Code River disposed their wastes into the river. In addition, the surrounding surface around most of the wells are made highly impervious by laying water-proof ceramic tiles, this increases the chance of recharge from the septic tanks feed the wells as the precipitation has less chance of infiltration.

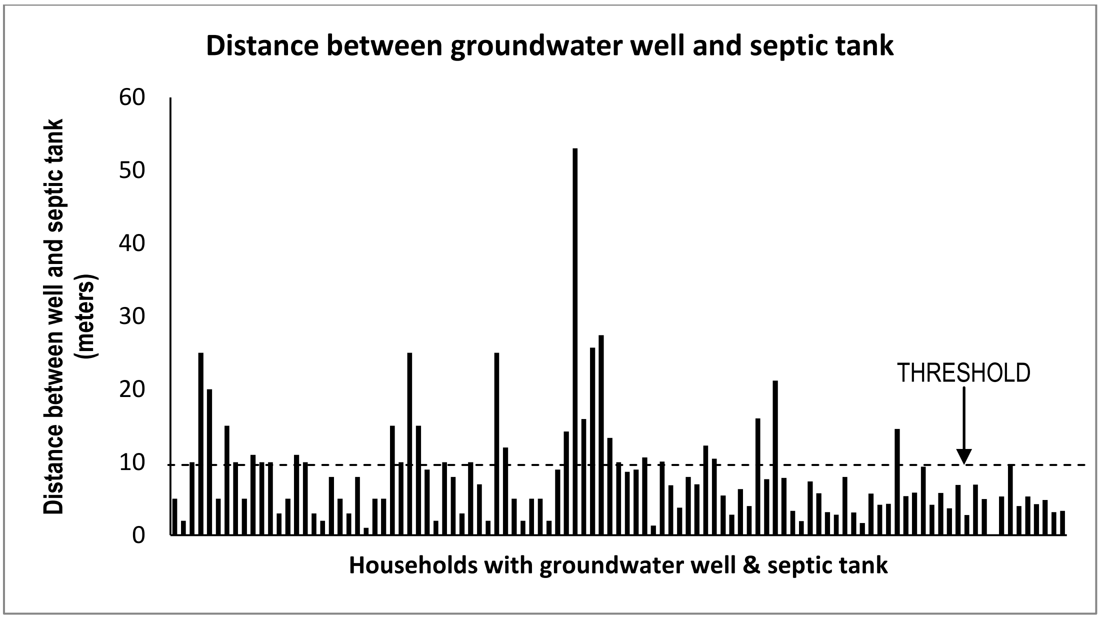

Figure 5.7: Distance between groundwater well and septic tank with 10 m as threshold

5.1.4. Descriptive Analysis: Perception on level of water decreasing by consumers using groundwater wells

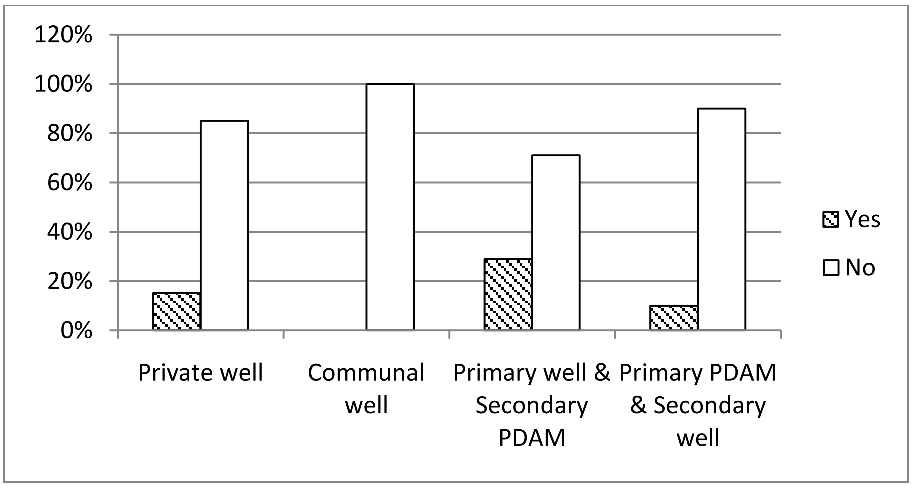

Figure 5.8: Consumers' perception on level of water decreasing in the groundwater wells

Figure 5.8 shows the perception on the level of water decreasing in the wells by different consumer groups, it shows the level of environment awareness. The consumers using groundwater seemed less aware about the level of water decreasing in their wells though the Environmental Agency has detected a decrease in level of groundwater. Among the consumers using groundwater, none of them using communal wells were aware of the level of water decreasing in the wells. About 10% of respondents using it as a secondary source found the level decreasing and the level of detection increased with the importance of the source, with 30% of respondents having private wells as the only source found the water level to be decreasing.

5.1.5. Descriptive Analysis: Laboratory results of groundwater wells

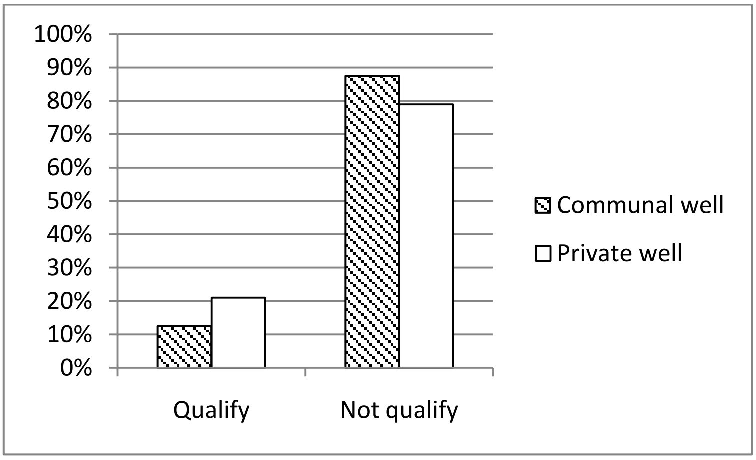

Figure 5.9: Laboratory results of groundwater wells

Among the households surveyed, 45% of the groundwater was sampled for water quality tests. The two parameters 'Total Coliforms' and 'E.coli' were chosen to measure the bacterial contamination. Figure 5.9 shows that only 21% of the sampled water from private wells was qualified whereas for the communal wells only 12.5% was qualified while the rest were found to be contaminated.

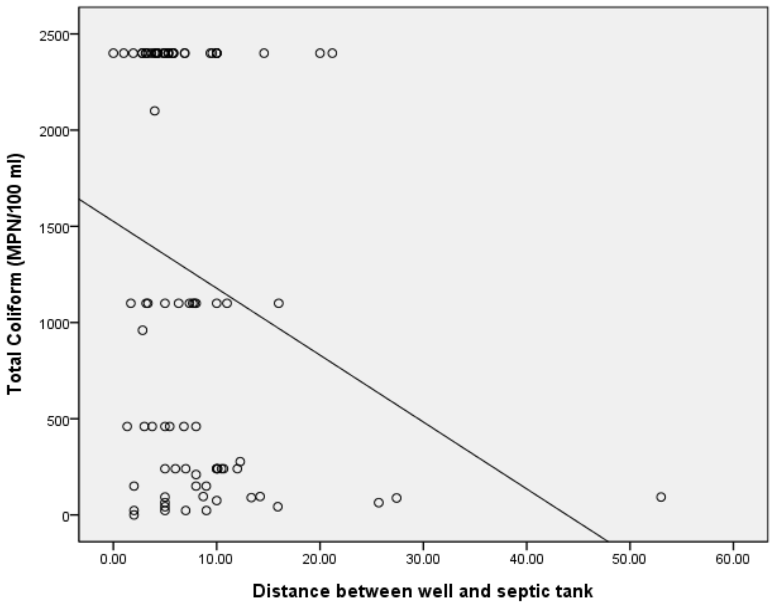

Figure 5.10: Scatter diagram showing relation between Total Coliform and proximity of septic tank for groundwater wells

Due to the limitation of laboratory results, the dataset of the research conducted within the same study area in 2009 was used to find the relation between Total Coliforms and proximity of septic tanks in case of groundwater wells. Figure 5.10 shows that proximity of the septic tank is one of the factors for the high amount of Total Coliforms in case of groundwater as the amount of Total Coliforms decreased with the distance.

5.1.6. Development of performance measurement framework for Yogyakarta City

In Yogyakarta city the majority of people are using groundwater therefore a better approach is needed to improve piped water supply system for which cooperation and joint-effort between different stakeholders is required. Public awareness is necessary to minimize environmental impacts while the level of service provided by the PDAM has to be upgraded so that consumers can rely on piped water. So to upgrade the performance of the integrated water supply system three fundamental goals are formulated in figure 5.11.

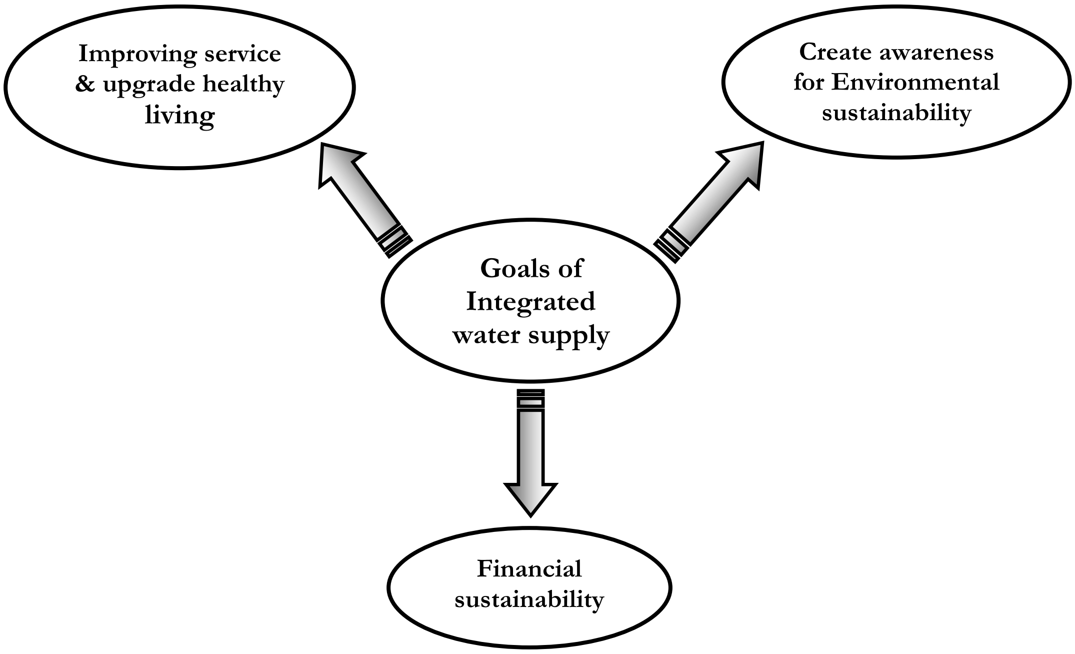

Figure 5.11: Goals of Integrated water supply

Improving services and upgrading healthy living by providing every citizen with quality water supply which is not below the average daily need for healthy living (130 litres per capita per day for Indonesia) and affordable i.e. within 10% of the average household income (refer Chapter 2.4). Informing the citizens to stop using untreated groundwater for drinking and cooking as most of the groundwater wells in Yogyakarta are contaminated by bacteria (E. Coli) due to encroachment of on-site sanitation and make the local government to act strongly so that byelaws are implemented strictly in the ground.

Create awareness among citizens for environmental sustainability by informing them about the degrading environmental conditions; excessive withdrawal of groundwater with limited recharge will soon deplete the valuable resources, deteriorate the water quality and cause land subsidence which is a serious problem, so awareness is necessary for environmental sustainability.

Financial sustainability is achieved when the quantity of water sold is billed and revenue is collected such that the present and future needs are fulfilled like operating costs, repair, rehabilitations, expansion and the useful life of the infrastructure is complete. As the PDAM Tirthamarta is financially weak, the replacement of old pipes as well as the timely operation and maintenance are lacking, which degrade the quality of water.

A performance measurement framework is developed for the integrated water supply in figure 5.12, which shows the two sources of water supply; piped water and groundwater wells, the related stakeholders, their perceptions, causes, effects and the goals to achieve a satisfied level of performance.

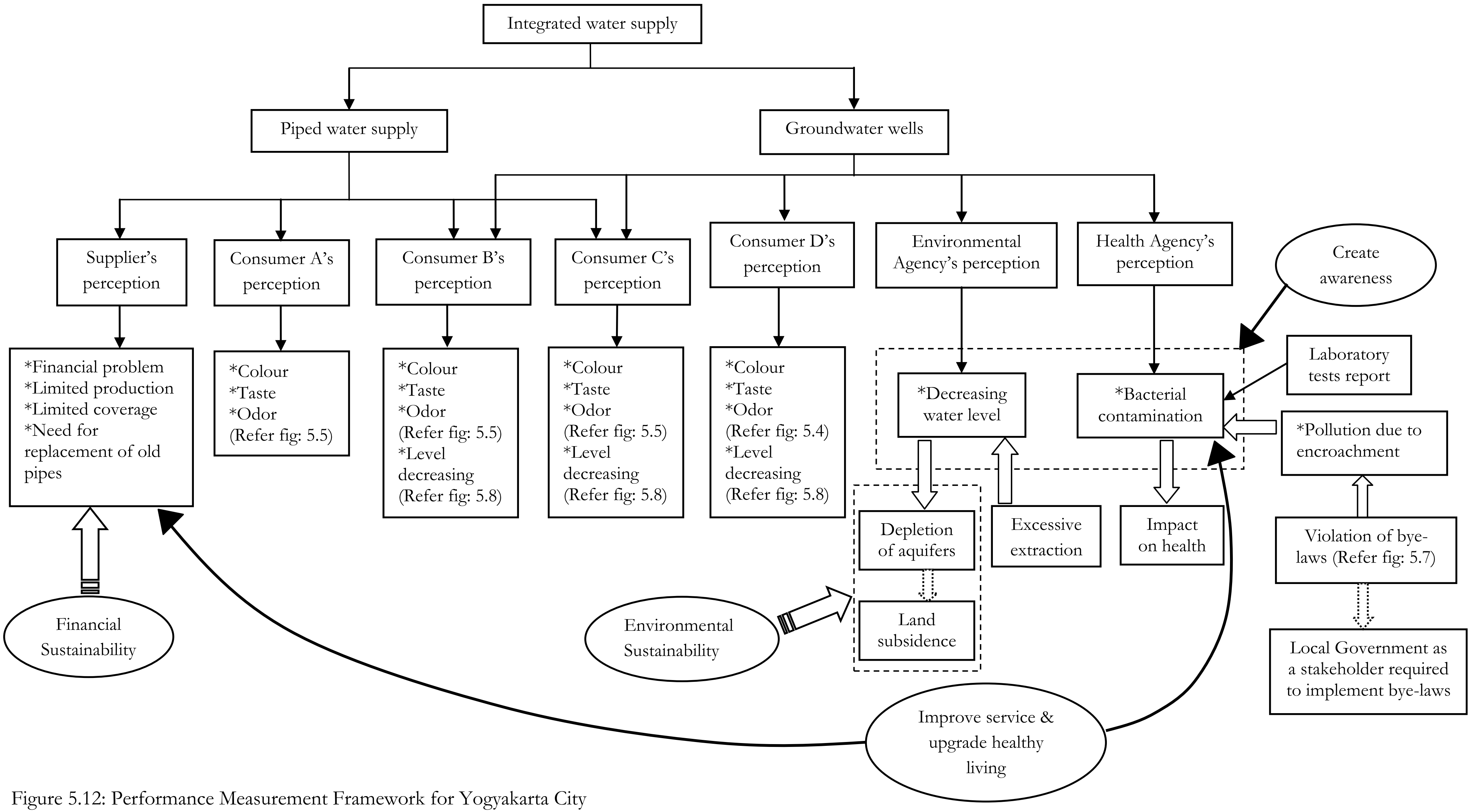

Figure 5.12: Performance Measurement Framework for Yogyakarta City

5.2. Development of a set of Performance Measurement Criteria

In order to know the level of performance of the integrated water supply system, a set of performance measurement criteria were developed. One way of understanding and quantifying the causes and interacting effects within the performance measurement framework is through the use of performance criteria and indicators, by assessing them the level of performance can be known.

In case of Yogyakarta city the groundwater has been extensively used for residential as well as commercial purposes. In the interview with the head of Environmental Agency of Yogyakarta city held on 11th Oct 2010 it has been known that 15,000 private groundwater wells are being used within the city. From the data collected about 37% of the households used communal wells while for commercial and business purposes the policy is to use deep wells, which means that if this process of abstraction is continued in the same manner it may create a huge environmental impact in near future by the depletion of aquifers. In order to reduce the environmental impact, over-abstraction and construction of new wells have to be stopped otherwise it may lead to depletion of aquifers followed by land subsidence like in the capital of Indonesia, Jakarta where problems have been faced. As Abidin *et al.* (2001) inform that the impact of land subsidence in Jakarta have been seen in several forms like the cracking of permanent constructions, wider expansion of flooding areas, lowering of the ground water level and increased inland sea water intrusion.

The performance of urban water supply is considered good if the provided service satisfies the consumers in terms of quantity, quality and affordability without degrading the environment while in the other hand the suppliers have to be financially stable to repair and rehabilitate the infrastructure such that its useful service life is achieved. For Yogyakarta City to achieve this level of performance, the coverage of piped water should be increased satisfying the consumers in terms of quantity and quality with cost within 10% of the total household income, for which the supplier has to be financial healthy.

Based on the data collected, a set of performance criteria is developed for Yogyakarta city in figure 5.13. A desired level of performance of the integrated water supply system will be achieved by creating a balance between these criteria.

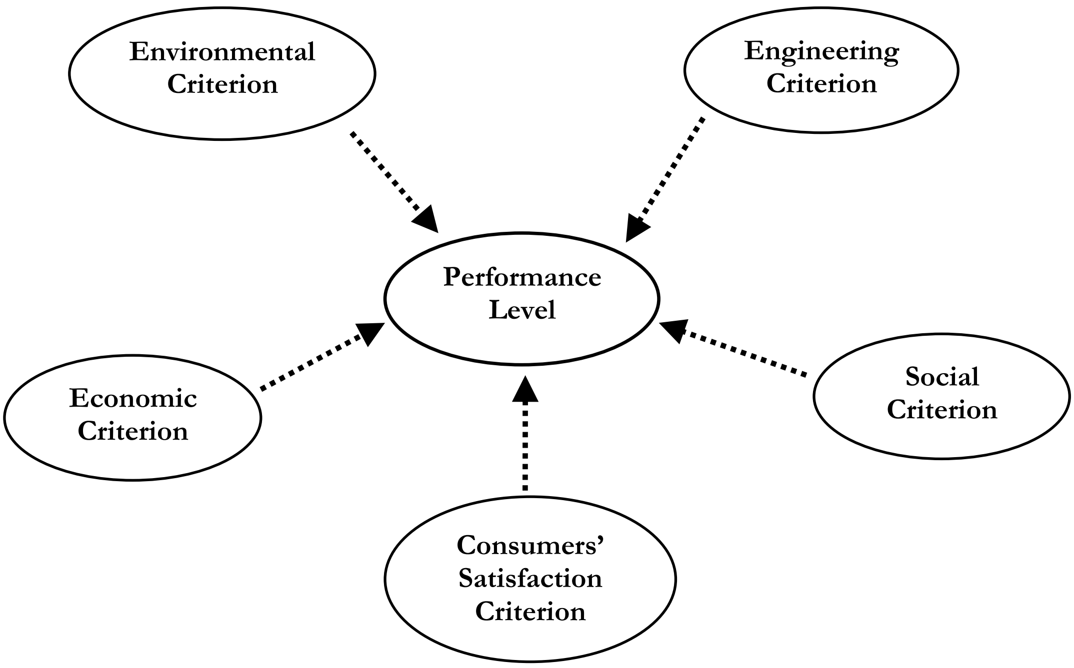

Figure 5.13: Set of Performance Criteria

Environmental criterion is achieved when the over extraction of groundwater and the pollution due to encroachment of human waste is minimized, for which public awareness has to be developed and the performance of the piped water supply has to be increased.

Social criterion is met when the consumers are provided with safe water supply which is enough to maintain their health, hygiene and sanitation and the time required for collection should not hamper their time for other domestic activities.

Economic criterion is met when the cost of water supply is within 10% of the total household income and they do not require extra charges for the use of electricity to pump water, purification process, etc.

Engineering criterion is met when the PDAM is financial healthy to repair, rehabilitate, replace and expand the infrastructure with the revenues collected such that the useful service life is achieved as well as the consumers are satisfied with the outcome.

Consumers' satisfaction criterion is achieved when the consumers are satisfied with quality, quantity and costs so that they do not have to seek for alternative sources to fulfil their daily domestic demand for water.

The household data collected consisted of different parameters of the integrated water supply and the related performance indicators so they were grouped under the developed criteria, as Sahely *et al.* (2005) inform that indicators are not useful when considered in isolation. Table 5-1 consists of the parameters of the integrated water supply, related indicators and the developed criteria.

Table 5-1: Performance criteria and related indicators

S.No	Parameter	Indicators	Criterion
1	Supply	Hours of daily supply	Engineering criteria
		No. of times a day water is supplied	
2	Coverage	Household with meter connection	Engineering criteria
3	Pressure	Discharge from the consumer's tap	Engineering criteria
5	Quality	Quantity of total Coliform & E-coli in the water	Social criteria
		Number of family members suffering from water borne diseases	
6	Quantity	Average litres per capita per day	Social criteria
7	Affordability	Household's income spent to buy piped water	Economic criteria
8	Reliability	Satisfaction on complaints attended	Consumers' satisfaction criteria
		Overall satisfaction of consumers with the service	
9	Depletion of aquifers	Level of water decreasing	Environmental criteria
10	Land subsidence	Distance between well and house	Environmental criteria
		Cracks seen in the portion of building near to the well	
11	Pollution due to encroachment	Distance between well and on-site sanitation	Environmental criteria
12	Willingness to pay for improved service	Household's willingness to pay for improved piped water supply	Consumers' satisfaction criteria

Performance indicators are to be monitored timely to know the level of performance so that those performing poorly will be given more focus, hence the overall performance will be upgraded. Environmental, social, economic and consumers' satisfaction indicators give insight into the efficiency of the system, whereas engineering indicators determine the effectiveness of the system. By assessing the performance framework and the set of performance criteria along with the indicators the current level of performance can be known, which offers a base for future performance assessment.

5.3. Analysing and mapping the existing performance of water supply at household level

Performance measurement indices were developed for the integrated water supply based on the performance criteria and indicators developed in chapter 5.2. The overall performance of the integrated water supply system based on different criteria were analysed on ILWIS 3.6 using Spatial Multi-Criteria Evaluation (SMCE) tool. Performance maps based on each criterion were produced and finally, Composite Index Maps (CIM), which is the aggregation of the performance scores of each household for the developed set of criteria, was produced. Figure 5.14 shows the development of CIM, where the values from each criterion are aggregated.

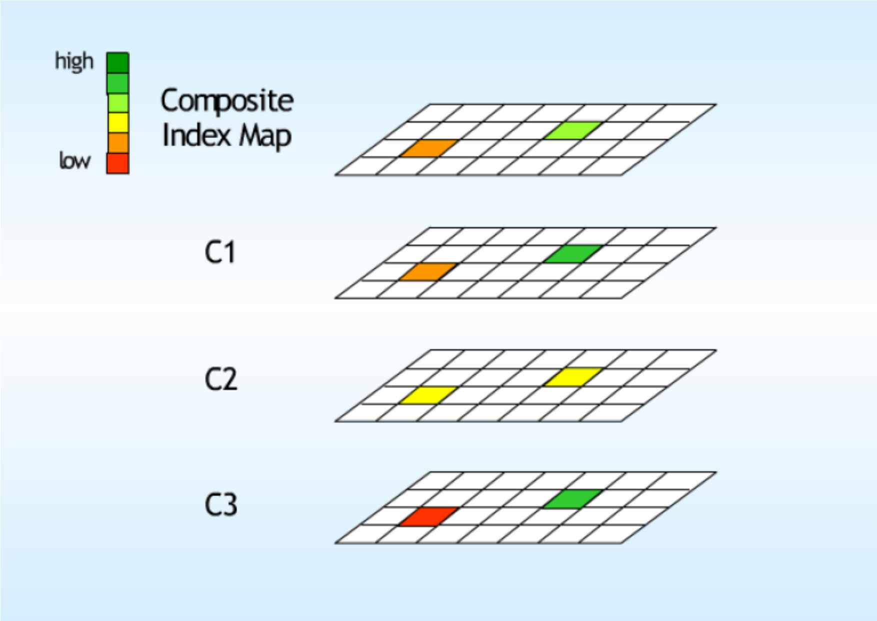

Figure 5.14: Composite Index Map

Maps were developed based on the following;

1. Consumers' Satisfaction Criteria
2. Social Criteria
3. Engineering Criteria
4. Economic Criteria
5. Environmental Criteria
6. Composite Index Map (CIM)

To perform SMCE, based on the consumers' reliance on the water source/s the households were grouped into 3 groups; (i) households using only piped water, (ii) households using only groundwater and (iii) households using both groundwater and piped water. The reason for doing this was to simplify and perform the evaluation precisely, as not all the criteria are applied to all the households. For example, environmental criterion does not apply to a household using only piped supply, similarly engineering criterion does not apply to a household relying on groundwater whereas both the criteria apply to a household using both the sources. Since most of the primary data collected were qualitative, before performing SMCE they were converted to numerical values from 0 to 1, '0' for low performance and '1' for high performance and intermediate performance was given value of '0.5'.

Table 5-2: Performance indicators with perceived & converted values

S.No	Performance Indicators	Standardize Value Input	Perceived/Measured Values	Converted Values
1.	Level of groundwater decreasing	Cost	Yes	0
			No	1
2.	Distance between well and septic tank	Benefit	From 0 to<5m	0
			From 5 to <10m	0.5
			More than 10m	1
3.	Distance between well and building	Benefit	Less than 3 metres	0
			More than 3 metres	1
4.	Cracks seen in the portion of the building near to the well	Cost	Yes	0
			No	1
5.	Discharge as measured from the consumers' tap	Benefit	Insufficient/electricity needed	0
			Sufficient	1
6.	Meter connection	Benefit	No	0
			Yes	1
7.	Hours of daily supply	Benefit	Less than 3 hrs	0
			Around 3hrs (2 times a day)	0.5
			Regular	1
8.	Bacterial contamination test	Cost	Not qualify	0
			Qualify	1
9.	Family members suffered from water borne disease	Cost	Yes	0
			No	1
10.	Average litres per capita per day	Benefit	Insufficient	0
			Sufficient	1
11.	Total household income spent for piped water	Cost	More than 10%	0
			Less than 10%	1
12.	Perception on piped water quality	Benefit	Odorless , Chlorine, Colour	0
			Odorless, Chlorine, Colourless	0.5
			Odorless, Good taste, Colourless	1
13.	Perception on groundwater quality	Benefit	smell, taste, colour	0
			No smell, good taste, colourless	1
14.	Households' satisfaction with complaints	Benefit	Not satisfied	0
			Moderately satisfied	0.5
			Satisfied	1
15.	Level of satisfaction of household with piped water supply	Benefit	Not satisfied	0
			Moderately satisfied	0.5
			Satisfied	1
16.	Household's willing to pay for improved service	Benefit	No	0
			Not sure	0.5
			Yes	1

5.3.1. Steps followed to perform Spatial Multicriteria Evaluation (SMCE):

The following steps were adopted to perform SMCE:

- During primary data collection the coordinates of each surveyed household was determined using GPS. Since SMCE was to be performed separately for the three types of households, separate dataset was created for each of them.
- The datasets were imported to ILWIS 3.6, a new coordinate system file was prepared and the vector datasets were rasterised using the coordinate system file as SMCE is a raster operation.
- A criteria tree was built and different criteria (refer Chapter 5.2) added as 'Groups' with indicators as 'Spatial Factors' for each type of household.
- Related values were added to each indicator.
- Each intermediate/criterion map and the final Composite Index Map (CIM) were named.
- In the Multicriteria Analysis mode, each criterion had to be given weight. For weighing three methods are available; 'Direct', 'Rank Order' and 'Pairwise Comparision'. 'Direct' method was chosen when equal weights were given to each criterion as ILWIS automatically normalises the values. 'Rank Order' method was used when the criteria were prioritised due to the lack of information, as in this method as the ranking is done the normalised values are given automatically.
- Each indicator was also given weight by 'Direct' or 'Rank Order' method based on the conditions. 'Direct' method used when all indicators under a criterion were given equal weight and 'Rank Order' used when indicators under a criterion were prioritised. Standardization of all indicators\ spatial factors was done using 'Maximum' method.
- After analysis, maps were generated for each criterion including the Composite Index Map.
- The raster maps were converted to vector maps, exported to ArcGIS. The reason is that ArcGIS has better visualisation application than ILWIS.

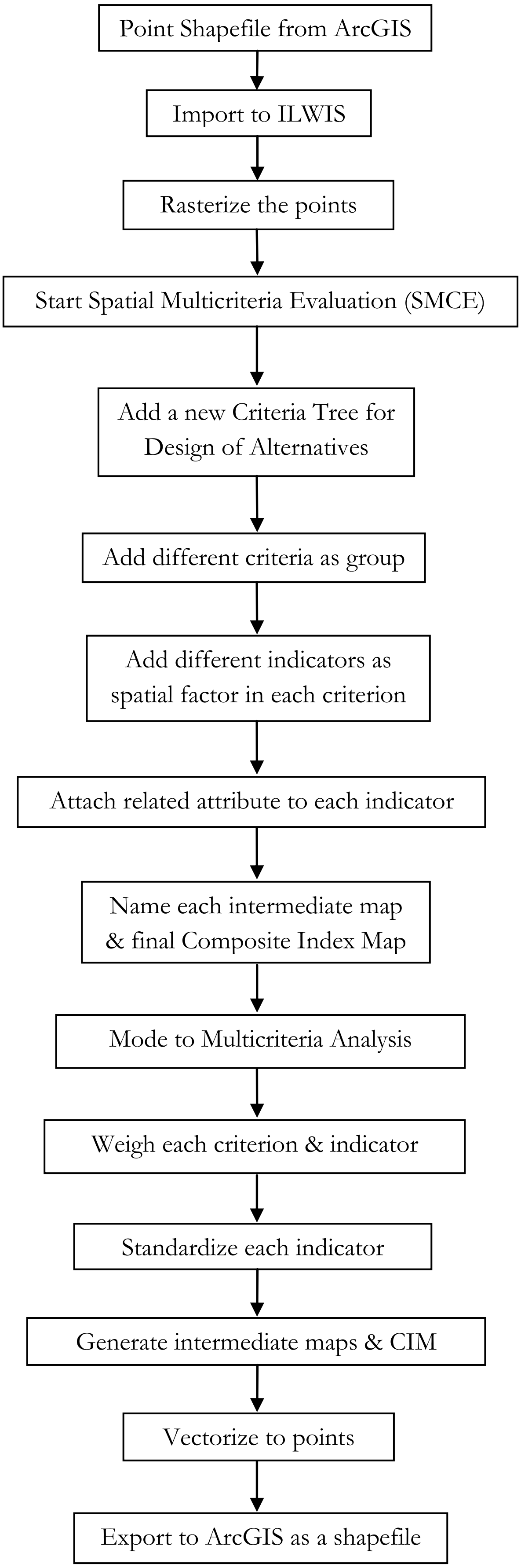

Figure 5.15: Flowchart for mapping performance

5.3.2. Criteria Tree for each household type with equal weight to each criterion

In this case every criterion was given same weight as each criterion is equally important. As the consumers were of three groups based on the reliance of source/s, criteria trees were developed accordingly. Criteria were added as 'Groups' and indicators as 'Spatial Factors'. All indicators under a criterion were also given equal weight by direct method, defined as 'Benefit' or 'Cost'. The factors/indicators were defined as 'Benefit' whose higher pixel value showed higher performance and as 'Cost' whose lower pixel value showed higher performance. 'Maximum standardisation' value function was used due to the lack of other knowledge. Figures 5.16, 5.17 and 5.18 show the criteria tree for the three types of households.

The criteria tree for the households using only piped water consisted of four criteria as groups:

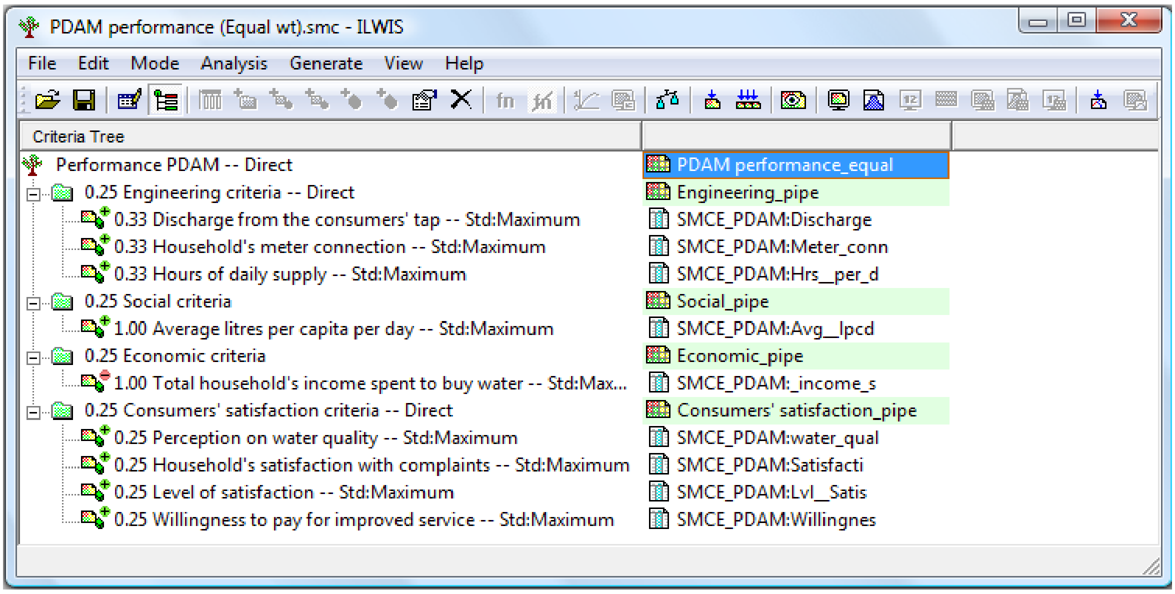

Figure 5.16: Criteria Tree for households using only piped water (Equal weights)

The criteria tree for the households using only groundwater consisted of three criteria as groups:

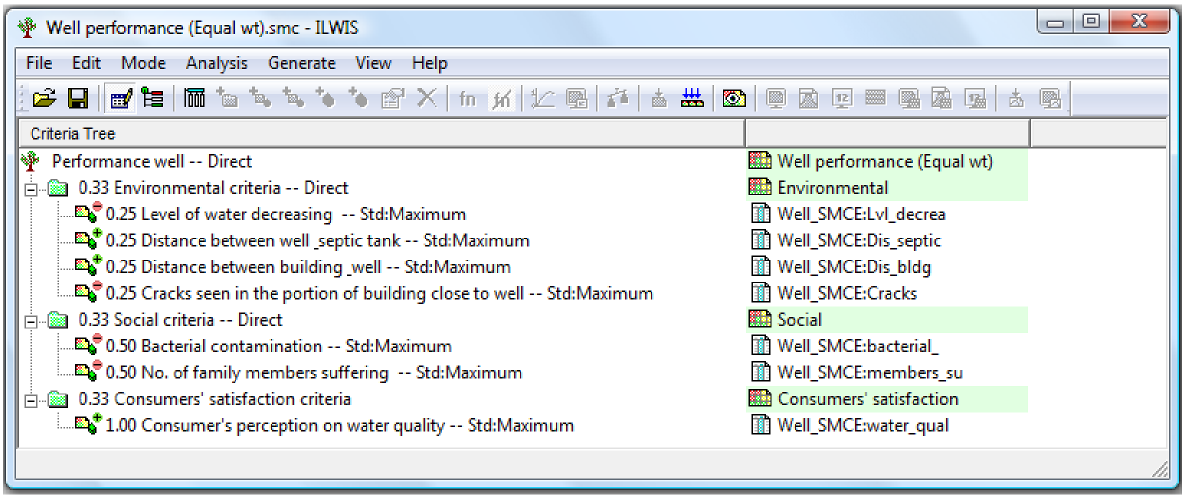

Figure 5.17: Criteria Tree for Households using groundwater only (Equal weights)

The criteria tree for the households using both piped water and groundwater consisted of five criteria as groups:

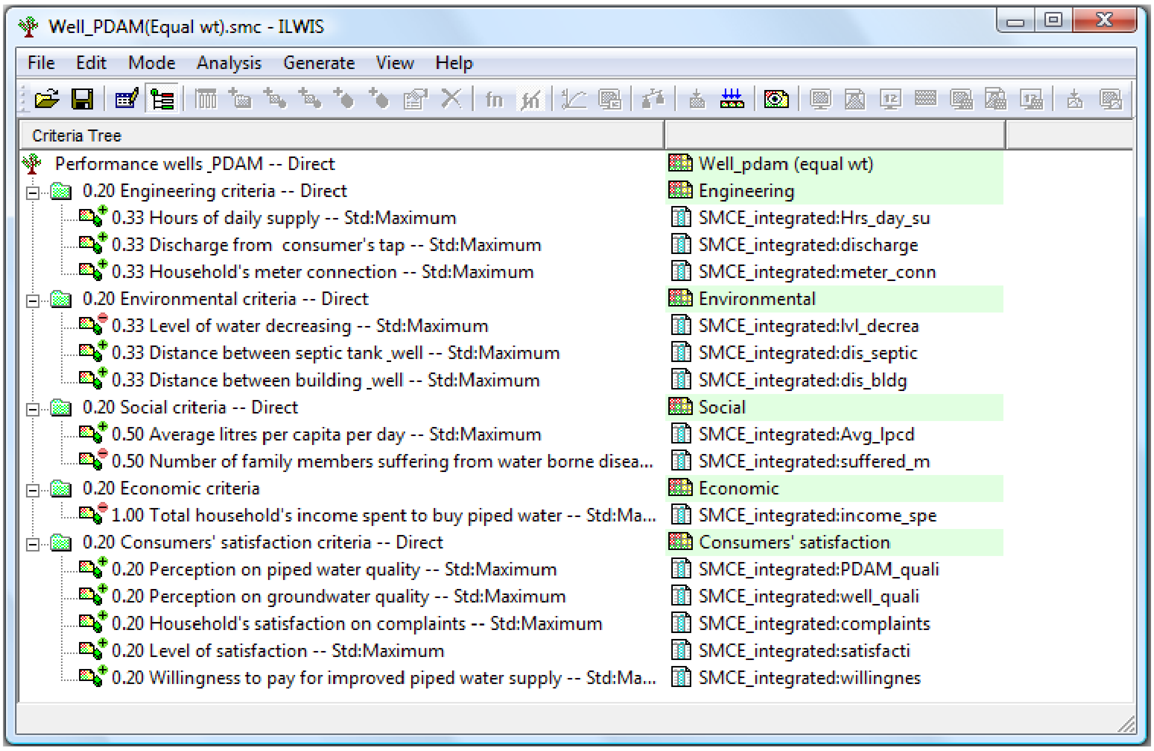

Figure 5.18: Criteria Tree for households using both piped water and groundwater (Equal weights)

The performance of the integrated water supply system for every household was determined after performing Spatial Multicriteria Evaluation (SMCE). Intermediate/criterion maps and final Composite Index Map (CIM) were produced for each household type. Each criterion map showed the performance of the integrated water supply system at the household level for that criterion while the Composite Index Map showed the overall performance of the system as all the values of the criterion maps are aggregated. These maps were vectorized and exported to ArcGIS for better visualisation.

Figure 5.19 shows the performance of the integrated water supply system in terms of each criterion and the Composite Index Map. The three types of households were visualised with different shapes and the performance scores ranged from 0 to 1, '0' showing worst performance and '1' the best. They were ranked into three groups with values 0 to 0.32 as 'Bad', 0.33 to 0.66 as 'Satisfactory' and 0.67 to 1 as 'Good' representing them with colours 'Red', 'Yellow' and 'Green' respectively.

- Based on the consumers' satisfaction criterion, the performance of the groundwater wells showed a spatial homogeneous pattern across the study area, this means that the households using only wells are fully satisfied with the performance of the source. While in case of piped water supply, a spatial variation was found in all the six urban villages as the households using only piped water or both sources performed 'Good', 'Satisfactory' as well as 'Bad'.

- Based on the social criterion, the performance of piped water supply showed a variation in space with either 'Good' or 'Bad' performance in all villages except Suryatmajan where a homogenous pattern of 'Good' performance was found. In case of groundwater, the performance was either

Satisfactory' or 'Bad'. In Tegalpanggung, the pattern of satisfaction was dominant whereas in villages Kotabaru, Ngupasan and Purwokinanti the pattern of 'Bad' performance was dominant spatially. For households using both the sources, a better spatial pattern was found across the study area with more households performing 'Good' than 'Satisfactory'.

- Based on Engineering criterion, the performance of the piped water supply showed a better spatial pattern of performance within the whole study area with more households with 'Good' and a few with 'Satisfactory' performances.

- Based on Economic criterion, a heterogeneous spatial pattern of 'Bad' and 'Good' performances were observed in all the six urban villages with 'Bad' as dominant.

- Among the criterion maps, the Environmental criterion performed the worst as the pattern of 'Bad' performance was spatially dominant in all urban villages except Gowongan.

- However, in the Composite Index Map (CIM) the performance of groundwater in case of households using only wells showed a homogenous spatial pattern of satisfaction across the whole study area. In the households using both the sources a mixed pattern of 'Good' and 'Satisfactory' performance was found while for the households using only piped water supply a spatial pattern of heterogeneous performance was found in village Gowongan, Ngupasan and Purwokinanti.

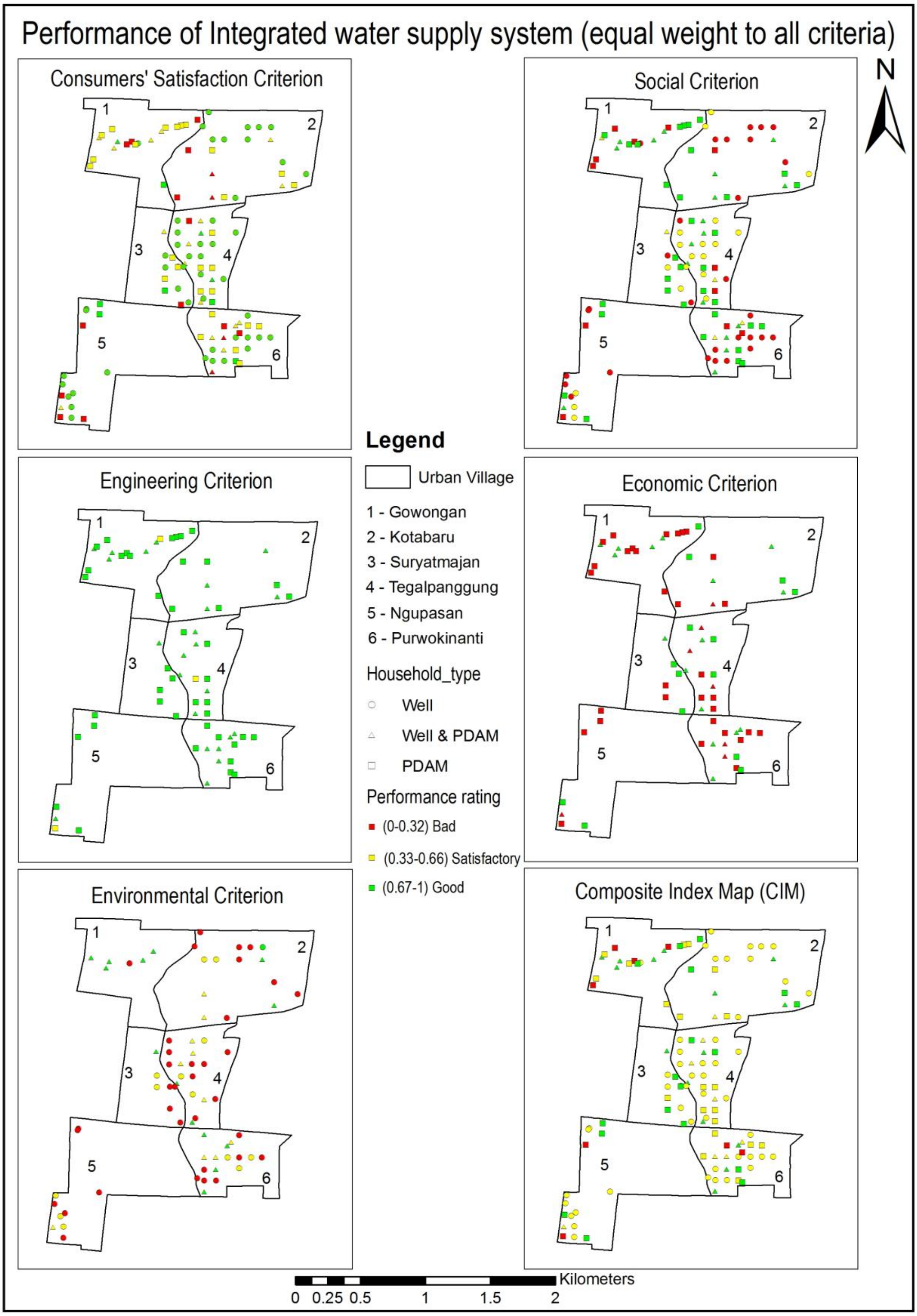

Figure 5.19: Performance maps

5.3.3. Criteria Tree for each household type with weights distributed according to the local situation

Here weights are distributed to the criteria according to the local situation. For the households using piped water supply the quality of water is a major issue so the 'Consumers' satisfaction criterion' was given higher weight with the indicator 'Perception on water quality' given priority. Since the environmentalists are more concerned about the level of water decreasing and most of the groundwater wells are contaminated by bacteria due to proximity of on-site sanitation, the environmental criterion was given more weight with the indicators 'Level of water decreasing' and 'Distance between well and septic tank' given higher priorities for the households using groundwater wells. For the households using both the sources, the environmental and engineering criteria were given higher priority. Weights were given to the criteria by 'Rank Order' method as the degree of importance of criterion was unknown. With more weights given to criteria which are locally important, Criteria Trees were developed for the three types of households which showed slightly different performance of the integrated water supply system. Figures 5.20, 5.21 and 5.22 show the criteria tree for the three types of households.

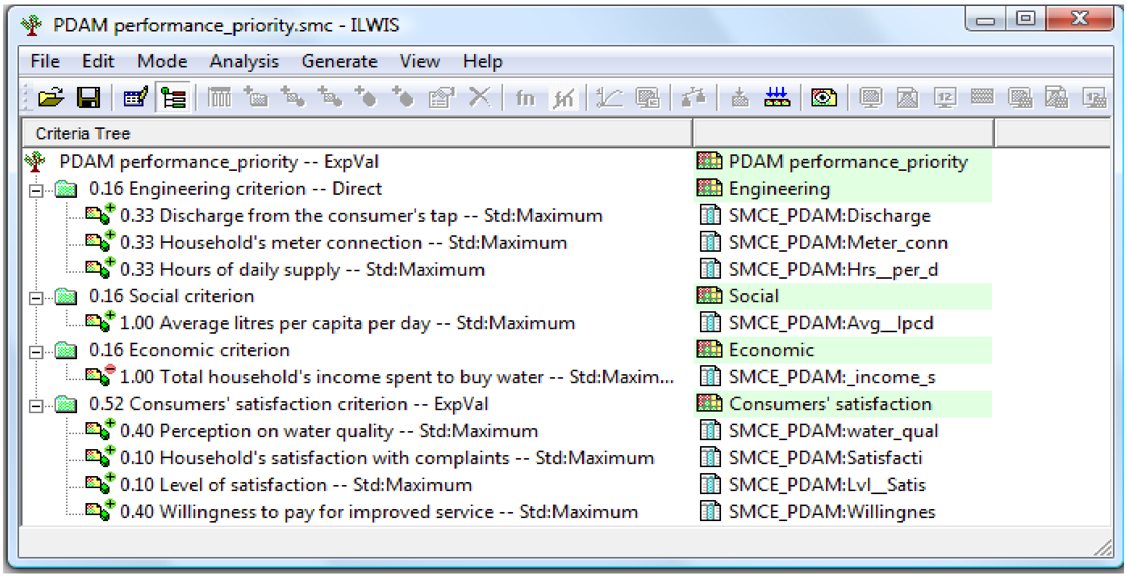

Figure 5.20: Criteria Tree for Households using piped supply only

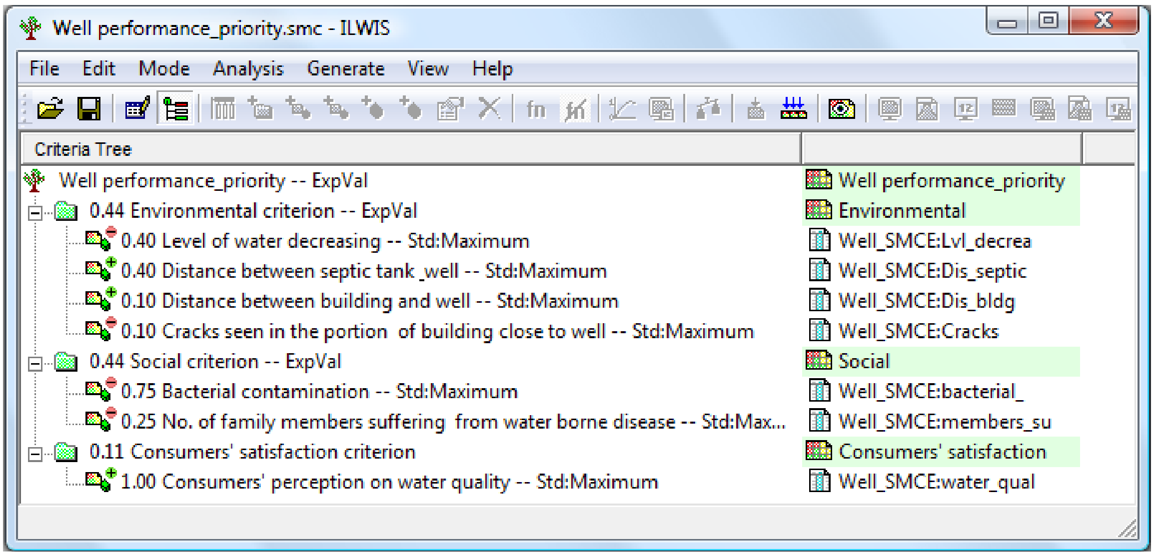

Figure 5.21: Criteria Tree for Households using groundwater only

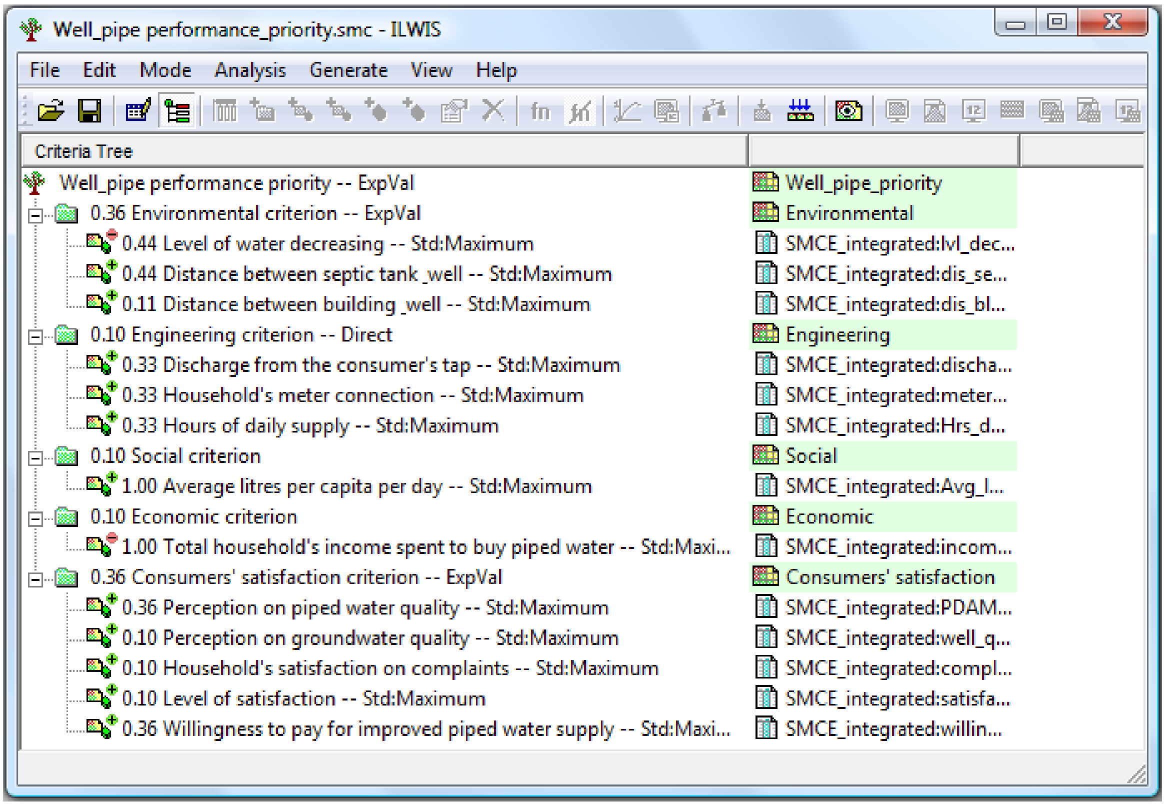

Figure 5.22: Criteria Tree for Households using both PDAM & groundwater

Similar steps were followed to produce criterion maps and the Composite Index Map as mentioned in Chapter 5.3.2.

Figure 5.23 shows the performances of the integrated water supply system in terms of each criterion and the Composite Index Map with weights prioritized to criteria and indicators. Similarly, as in Chapter 5.3.2 the three types of households were visualised with different shapes and the performance scores were ranked as 'Bad', 'Satisfactory' or 'Good' representing with colours 'Red', 'Yellow' and 'Green' respectively.

- With higher priority given to the 'Consumers' Satisfaction Criterion', households using only piped water showed a slightly different heterogenous spatial pattern than before, comparing the two the performance was better this time within the whole study area. Unlikely was the case of households using both the sources, as more 'Bad' performance was seen in the villages Gowongan and Tegalpanggung. While a similar spatial pattern of homogeneity was observed with the whole study area.

- Based on social criterion, the performance of piped water supply showed a variation in space with either 'Good' or 'Bad' performance in all villages except Suryatmajan where a homogenous pattern of 'Good' performance was found. The performance of the groundwater in case of households using only wells showed a better spatial performance in Tegalpanggung where as in other villages the pattern was a mixture of satisfactory and good performances. While in case of households relying on both the sources, a pattern of variation of performance was found within the study area.

- Based on Engineering criterion, the performance of the piped water supply showed a homogenous spatial pattern of performance within the whole study area with one household showing 'Satisfactory' performance in Gowongan, Tegalpanggung and Ngupasan.

- Based on Economic criterion, a heterogeneous spatial pattern of 'Bad' and 'Good' performances were observed in all the six urban villages with 'Bad' as dominant.

- With the Environmental criterion given higher priority, the performance was better this time for the households using only groundwater in the villages Kotabaru, Tegalpanggung, Ngupasan and Purwokinanti though spatial heterogeneity was observed. Similarly, performance was found better in the households relying on both the sources in the villages Kotabaru and Tegalpanggung.

- In the Composite Index Map (CIM) a heterogeneous spatial pattern was shown in all the villages with the 'Satisfactory' performance dominant in all.

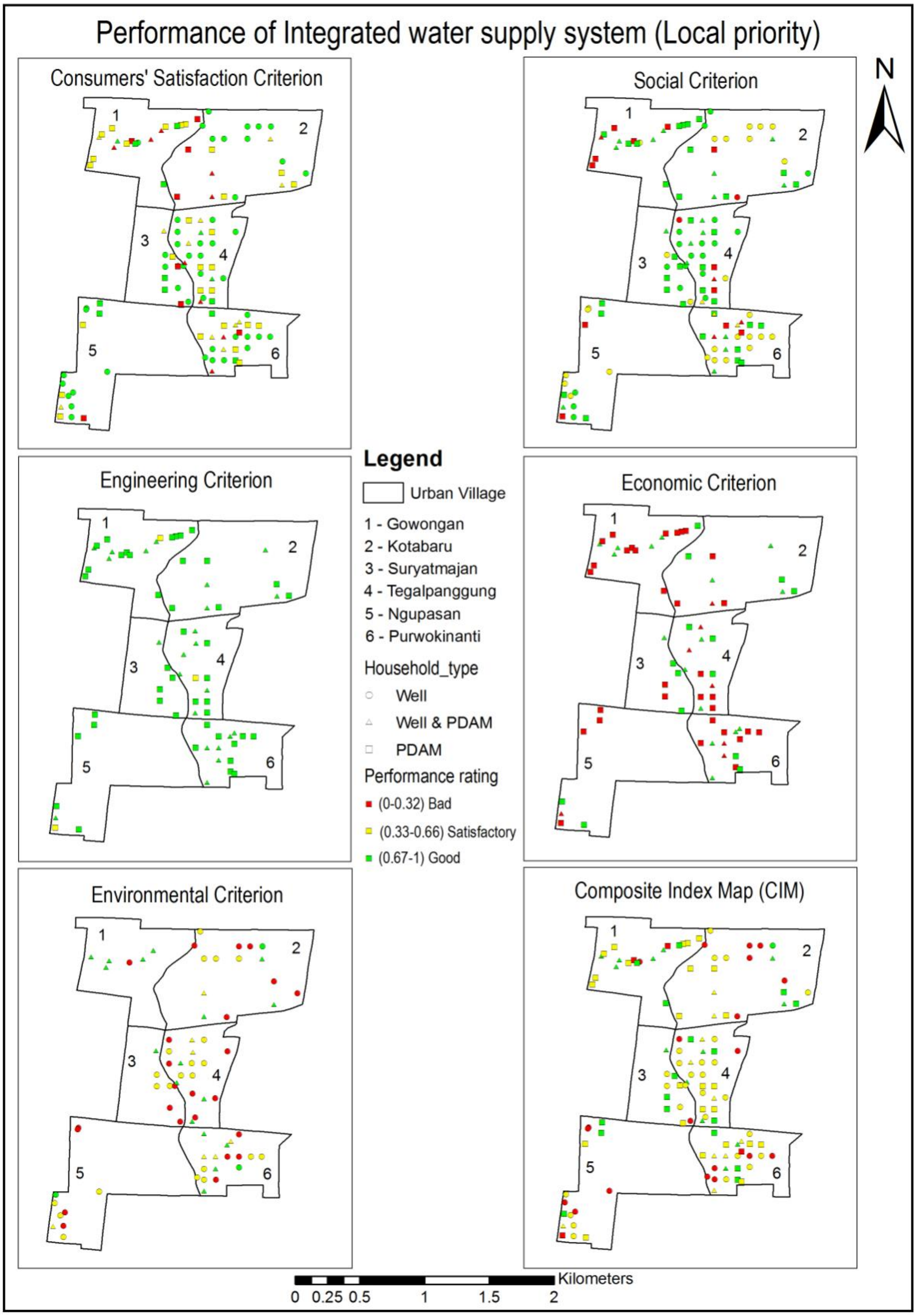

Figure 5.23: Performance maps based on local priority

A Composite Index Map (CIM) shows the overall performance for all criteria as standardized and weighed in the criteria trees. Figure 5.24 shows the two CIMs. While comparing the CIMs for the cases; (i) equal weight to all criteria and equal weight to all the indicators within a criterion and (ii) weights prioritized to some criterion/criteria and some indicators within the criterion some spatial variations are found. In the first case for the households using only groundwater a homogenous spatial pattern of satisfactory performance over the entire study area was found whereas in the second case a heterogeneous spatial pattern with 'Bad' performance as dominant was found in the villages Kotabaru, Ngupasan and Purwokinanti. Unlikely, for the households using only piped water the performance was better in the second case than the first one as less number of households were seen performing 'Bad' though the pattern was heterogeneous in space. For the households using both the sources the performance was similar in both the cases as they showed a mixture of 'Good' and 'Satisfactory' performances spatially.

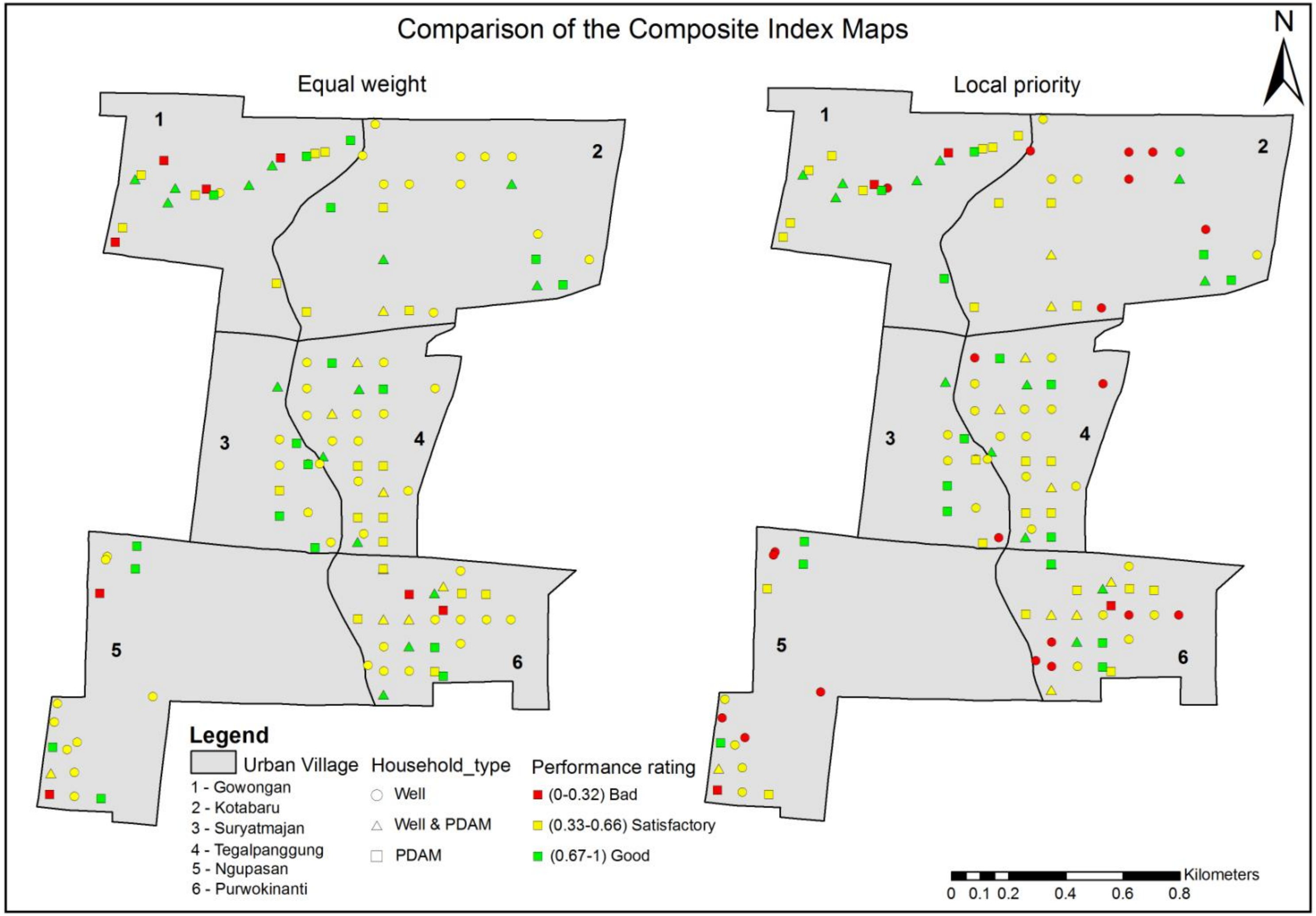

Figure 5.24: Composite Index Maps

5.4. Gauging the performance by comparing with appropriate benchmarks

In this section comparison of some selected parameters of the integrated water supply system with local or international standards is done to know the level of performance. Figure 5.25 shows the benchmarking of the parameters.

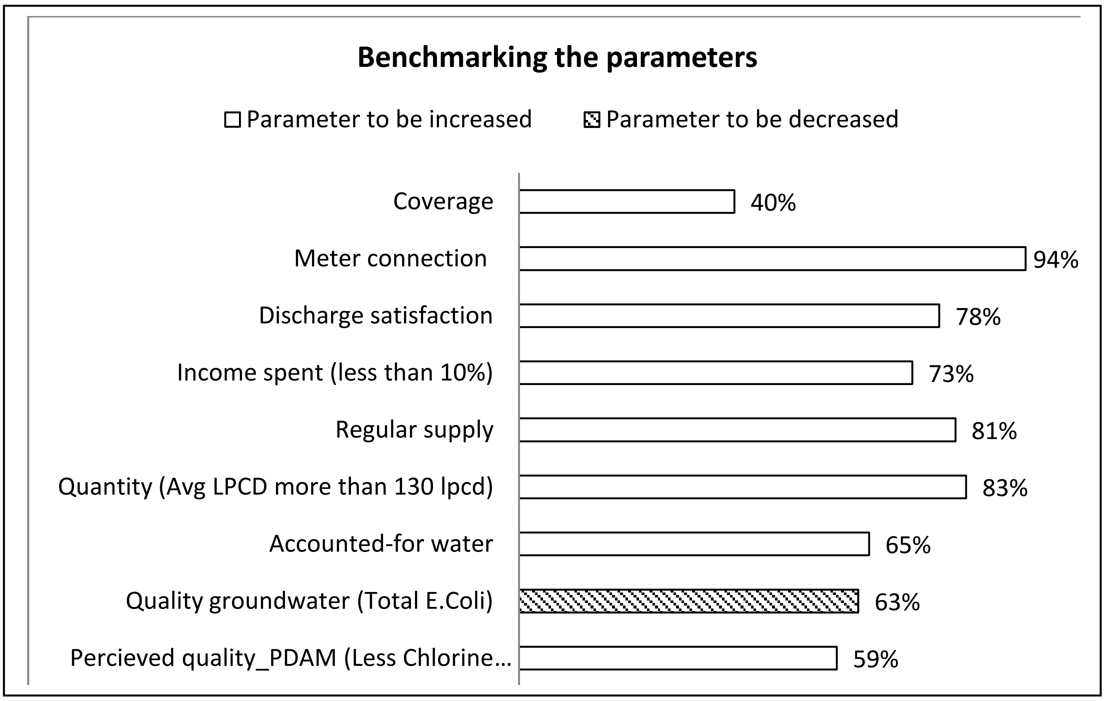

Figure 5.25: Benchmarking the Integrated water supply

Coverage

The coverage of piped water supply in case of Yogyakarta city is 40%. Tynan & Kingdom (2002) say that in developing countries coverage rates range from 100% to a low of 18%, the top quartile of developing countries has achieved the target of 100% coverage.

Meter connection

In the study area, among the households surveyed 94% of them had meter connection. Since proper metering of water helps to reduce unaccounted-for water, every household should be metered i.e. it should be increased to 100%.

Discharge

The consumers of piped water supply were asked whether the discharge from the taps was enough or not. It was found that 78% households surveyed had sufficient discharge from the tap while the rest had to use generators to pump water. This shows the variation of the pressure of water within the network.

Income spent

Water is a basic necessity not a luxury, so the income spent to buy residential water should not exceed 10% of the total household's income. In the study area, it has been found that about 73% of the respondents perceived that the amount they pay for piped water supply is less than 10% of their total household income.

Hours of daily supply

Based on the performance of the top quartile of developing country utilities, the recommended target is 24 hours a day (Tynan & Kingdom, 2002). Among the households connected with piped water supply, it was found that 81 % of the households receive water supply 24 hrs a day.

Accounted-for water

Accounted-for water means the amount of water billed, the reverse is unaccounted-for water. The high levels of unaccounted-for water indicated poor system management and/or poor commercial practice as well as inadequate pipeline maintenance (Lin, 2005). Tynan and Kingdom (2002) recommend a target of 23 % or less for unaccounted-for water, on the basis of performance of the top 25 percent of developing countries. The average unaccounted-for water ratio for Yogyakarta city is 35%, which is significantly higher. Therefore the accounted-for water is 65%.

Quantity

Analysis on the quantity of water used by the households using groundwater wells was a bit difficult. So during the data collection for the households using piped water supply, they were asked whether the quantity of water supplied is enough for their household's requirements or not. Based on the average quantity of water use by households in Salatiga City which is near to Yogyakarta, an average of 130 litres per capita per day was set a benchmark. It showed that 17% of the households are not provided with enough quantity. But it is a very subjective matter as it also depends upon other factors like family size, culture and the respondents' individual perception.

Quality of drinking water

According to WHO standards there should be 0 MPN/ 100 ml of total E.Coli in drinking water. In case of Yogyakarta city, the laboratory results showed that the total E.Coli in the groundwater wells are above the WHO standards and reason being the distance between the wells and the septic tank. A value of more than 0 MPN/100 ml indicates that the water is unsafe to drink.

Chlorine Concentration in piped water supply

Tamminen *et al.* (2008) say that the chlorine concentrations on drinking water must be 0.2 mg/l and lesser than 0.5 mg/l according to World Health Organisation Standards. Though chlorine tests were not conducted, consumers' perception on the taste quality of piped water was asked. It was found that around 41% of them perceived it as higher chlorine concentration.

Gauging the performance

By comparing the performance of various parameters with the standards, the performance of the system is known. It is found that the performance of the integrated water supply on the selected parameters is below the satisfactory level with only one parameter performing beyond 90%. Hence knowing the existing level of performance and examining the performance every year, it will be easy to know the trend of performance and identify which parameters to be focused for further improvement. This makes the performance assessment easy as well as measurable.

5.5. To demonstrate how the procedure leads to performance measurement

This section describes the process of performance measurement from the development of framework, selection of criteria and indicators, analysing and mapping to benchmarking.

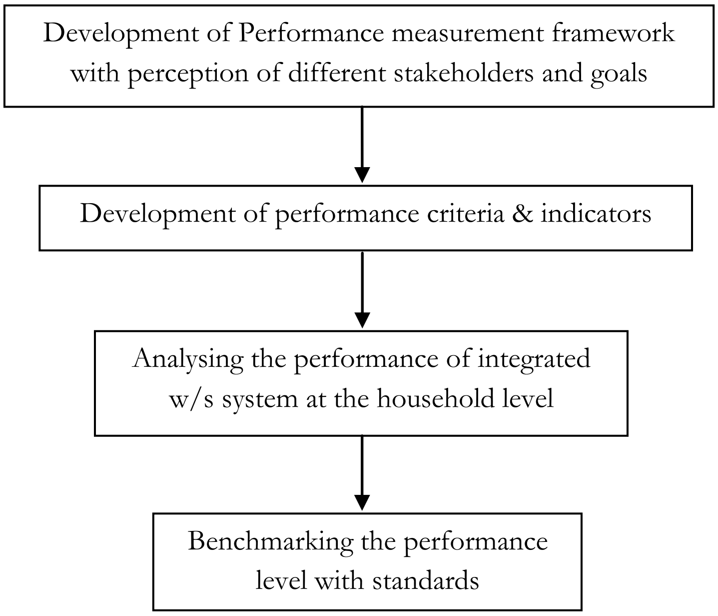

Figure 5.26: Flowchart showing the procedure for performance measurement

Figure 5.26 shows the procedure for performance measurement. First, a performance measurement framework was developed for the performance assessment of integrated water supply system which focuses on two types of improved water sources, different stakeholders involved, their perspectives on the performance and goals to be achieved. Though different stakeholders act in different levels, scales and have different importance to different parameters, perception of each is important in the framework. The goals formulated should be such that the consumers' needs are fulfilled and healthy living is upgraded while improving the piped water supply to minimize the environmental impacts.

After knowing the real situation in ground and to simplify the complexity of measuring performance, criteria and indicators were developed. The indicators were grouped under each criterion.

To analyse the performance, indices were developed based on the criteria and SMCE was performed such that the performance of the integrated water supply system at the household level was achieved. Performance (intermediate) map for each criterion and CIM showed the performance of the water supply for each household. Each criterion map depicted the performance with respect to the related criterion, which is important to the related stakeholders. The CIM is the aggregation of the intermediate maps and showed the overall performance. By comparing these different maps, it is easy to figure out the areas of low performance with respect a criterion so that it is easy to find out the factors affecting. These maps play as a medium to inform the consumers about the level of performance of their water supply system and help to create necessary awareness among them.

Benchmarking the performance of existing condition of integrated water supply system against some established standards gives the insight of the level of performance and helps to judge how well or poorly the performance is so that it will be easy to formulate corrective actions to achieve a satisfactory level. Thus by documenting the present performance level, a baseline can be established for future and develop policies. Trends over time can be used to evaluate performance and change the policies accordingly.

6. DISCUSSION OF THE FINDINGS

This chapter mainly discusses the main findings of the results achieved in chapter 5. The first section discusses about the developed performance measurement framework, the related stakeholders, their perceptions, causes and effects and the goals set. The second section is the discussion on performance criteria and their relation to the different types of households. The third section discusses about the process of representing the existing performance level by Spatial Multicriteria Evaluation, the reasons of variation in the results and their importance to the related stakeholders. The fourth section discusses about the results of benchmarking of the parameters and the short-comings of the collected data.

6.1. Sub-objective 1: Development of a performance measurement framework

A performance measurement framework of the integrated water supply system was developed for Yogyakarta city. It shows the sources of integrated water supply, the perception of different stakeholders on the performance of the water supply, the causes and their effect on human health and the surrounding environment and the goals to be achieved to reach a satisfied level of performance. Different stakeholders have importance on the different parameters of water supply so to measure the performance of the integrated water supply, first their perceptions have to be known. Interviews were conducted with the piped water supply company (PDAM Tirthamarta) and the Environmental Agency to know their perceptions on the performance of piped water and groundwater respectively. From the interview with the Environmental Agency, it came into light that another stakeholder the 'Heath Agency of Yogyakarta City' performs water quality tests for groundwater wells in different locations of the city every year. Household survey was conducted to know the consumers' perceptions on the source of water supply they rely on.

In the perception of the supplier of piped water supply since the coverage is only 40% of the population of the city, they want to increase it but due to financial conditions it is impossible. Also they could not replace the old pipes so the supplier's perception is that even if the water at the plant is of good quality the deteriorated pipelines within the network degrades the quality of drinking water. So in order to improve the service and minimize the financial problems, a prime priority should be financial sustainability of the PDAM.

Doria (2010) states that there has to be the integration of perspectives from the general public otherwise it can lead to public discontentment and implementation problems, so the consumer groups were in-corporated in the framework. For the consumers the outcome measures are important among which water quality is found to be the most important parameter. Dupont (2005) says that in terms of quality of water, consumers commonly remark upon the importance of attributes such as odor, appearance and taste which they use as indicators to judge the safety of their supply. So the analyses on the perceptions of these three attributes for the elements of integrated water supply; the piped water and the groundwater were done for the different consumer groups. A better understanding of the processes involved in public perception of water quality may provide a contribution to multi-stakeholders processes, help them to improve consumer services and satisfaction, foster communication, promote cooperation and prevent conflict (Doria, 2010).

The environmentalists have noticed that the water level is decreasing, if the process of abstraction is continued in the same manner then the aquifers will deplete in near future followed by land subsidence causing major problems like in other parts of Indonesia like Jakarta. Though some consumers have found the level of water decreasing in their wells they are not aware that this valuable natural resource will deplete one day. So in order to check this problem the excessive abstraction has to be stopped for which public awareness is necessary.
Another group of stakeholder involved actively in the outcome of the performance of groundwater is the Health Agency which is conducting the water quality tests to find the bacterial contamination of the shallow wells in different locations within the city. They have found that the water in most of the shallow wells is contaminated with faecal bacteria (E.coli), the probable reason being the proximity between the wells and septic tanks. According to the bye-laws of Yogyakarta city a minimum distance of 10 meters has to be kept between a well and septic tank but in the study area most of the households disobey the bye-laws which can be due to lack of awareness, smaller plots, high density, etc.

An important stakeholder to be considered in the framework is the Local Government of Yogyakarta City. Violation of bye-laws has been found in the ground. So in order upgrade the performance of water supply the Local government must act strongly so that bye-laws are implemented strictly in ground.

Since the process of performance measurement begins with the statement of the agency's mission and goals (TERI, 2004), the goals for Yogyakarta's integrated water supply formulated are; (i) financial sustainability for the piped water company (PDAM), (ii) improve service and upgrade healthy living and (iii) create awareness for environmental sustainability.

6.2. Sub-objective 2: Development of a set of performance criteria

By choosing a set of performance criteria and indicators-, and assessing them the level of performance can be known. After setting the goals for the performance measurement of the integrated water supply for Yogyakarta city, the performance criteria were identified. The indicators were developed according to the selected parameters. An indicator captures the concept to be measured and is easy to operationalize with the available information (TERI, 2004), and a criterion is the yardstick against which an indicator is measured so the selected indicators are grouped under the related criterion. Since measuring performance is a complex process, indicators and criteria help to simplify the process. Each stakeholder has priority to the set of criteria and not all the criteria are applied to every stakeholder and household, as the households are classified into three groups according to the source of water they use. Like the environmental criterion is very importance to the households using groundwater and the engineering criterion applies to the households using piped water. By identifying key indicators of performance more accuracy of performance can be known.

6.3. Sub-objective 3: Assessing and mapping the performance of integrated water supply

After the identification of performance criteria and indicators, performance indices were developed for the different types of households. Spatial multicriteria evaluation (SMCE) was performed for each household type defining each indicator as a 'Benefit' or 'Cost' and standardising them. First SMCE was performed giving equal weights to each criterion. Maps for each criterion and Composite Index Map (CIM) were produced which showed the performance of the integrated water supply at the household level. The performances were in numerical values from '0' to '1', 0 showing low performance and 1 showing high performance. The performances were recorded as 'Bad', 'Satisfactory' and 'Good' for values rating '0 – 0.32', '0.33 - 0.66' and '0.67 – 1' respectively.

Secondly, according to the existing condition in the study area weights were prioritized to the criteria. As the environmental condition is being degraded due to the over-abstraction of groundwater and proximity of on-site sanitation with the groundwater wells, the 'Environmental criterion' was given higher weights with the indicators 'Level of water decreasing' and 'Distance between well and septic tank' higher priority in case of households using groundwater wells. For the piped water users the 'Consumers' satisfaction criterion' was important as the consumers mostly complained about the quality of water regarding its colour, odor and taste so with the indicator 'Perception on piped water' given higher weight. For the households relying on both the sources, the 'Environmental criterion' and 'Consumers' satisfaction criterion' were given equal and higher weights. Similar rating of performances was adopted in this case.

The Composite index maps gave different spatial patterns in the above two cases, comparing the two CIMs the former showed the piped water supply performing bad in some households and all the wells performing satisfactory while the latter showed some wells performing bad. In case of households using piped water supply only, though the source is the same for all there was heterogeneity as it was totally based on the consumers' perceptions. While in case of groundwater wells as the households are relying on individual wells and the performance is a combination of the consumers' perception, physical measurements and laboratory results, heterogeneity is not a major concern.

The developed sets of criteria maps are important to the related stakeholders. The engineering criterion map is important to the supplier (PDAM) as it shows the performance of the water supply in engineering view, so the area of low performance can be identified easily and the problems solved. The environmental criterion map shows the households where the bye-laws have been violated though it merely shows the level of groundwater decreasing as people are not much concerned about it. The economic criterion map showed heterogeneity, as it consisted of only one indicator 'Total household's income spent to buy piped water'. As it was confidential to ask the household's income and the respondents were asked whether they pay more or less than 10% of the total household income. Since it was a qualitative answer 'Yes' or 'No', the map showed either low or high performance. The heterogeneity can be either due to the mixed kind of settlement or biasness of the respondents.

6.4. Sub-objective 4: To gauge the performance by comparing with appropriate benchmarks

By measuring some selected parameters of the integrated water against some local or international standards the performance level was known.

- In Yogyakarta, the coverage of the piped water supply is 40%, which is an unsatisfactory performance. As piped water is considered a safe source of drinking water as it is protected from external contamination, its coverage should be increased.
- Among the surveyed households, about 6% of the houses were not connected with meter while in the interview with the Engineering head of PDAM, it was told that all the households within the city are connected with meter.
- Since the equipments to measure the pressure from the consumers' taps were not available, the consumers were asked whether the pressure was sufficient or not. For further simplification, 'sufficient' meant 'no electricity used to withdraw water' and vice-versa. About 22% of the respondents told that the pressure from their taps is insufficient i.e. they have to use additional energy to fulfil their demands.
- Respondents were asked about the total household income spent to buy piped water. Around 27% of the respondents answered that they pay more than 10% of their total household income. But in the interview with the Engineering head of PDAM, it was found that the PDAM Tirthamarta has its own tariff design set for the different socio-economic groups of consumers.

- About 81% of the surveyed households have regular supply of water which showed quite good performance for a developing country. But in some households the supply was around 3 hrs a day, which is insufficient.
- From the interview with the head of PDAM, it was found that unaccounted-for water for Yogyakarta is 35% which can be due to unmetered connections, illegal connections, leakages from the old deteriorated pipes, etc.
- In order to know whether the quantity of water supplied by the PDAM is enough or not, the respondents were asked whether the supplied water is enough for daily household use. About 17% of the respondents answered that it is not enough. But it is rather a subjective issue, as the water needed for a household depends upon the number of family members, their characteristics, culture, etc.
- Among the households surveyed, water from 30 groundwater wells were tested for bacterial contamination. As per WHO standards drinking water should have 0 (MPN/100 ml) E.coli but about 63% of the wells were not qualified for drinking. One of the reasons can be the proximity of septic tanks as E.coli is itself an indicator of faecal pollution.
- Since it was not feasible to measure the chlorine concentration from the piped water, the consumers' perception on this attribute of piped water supply was asked. About 41% of the consumers perceived the chlorine concentrations to be high, which they considered as 'bad'. But in the interview with the Engineering head of PDAM Tirthamarta, it was found that the amount of Chlorine added at the production plant is such that when it reaches the consumers' taps it will be at the acceptable level. But the production plant for PDAM Tirthamarta is in Seleman District and some pipes within the network are very old though (according to the engineering head of PDAM Tirthamarta) though the pipes within the study area are of Polyvinyl Chloride (PVC). The cast iron network requires higher initial chlorine concentrations than the polyethylene (PE) network to maintain the required minimum chlorine concentration throughout the whole network (Tamminen, *et al.*, 2008). So the reason can be to overcome the chlorine decay problem in the old CI pipes the amount of chlorine added in the plant is high, so when the water reaches the consumers' taps the amount of chlorine is high.

7. CONCLUSION AND RECOMMENDATIONS

This chapter consists of the general conclusion of the research, brief conclusion on each sub-objective. It suggests some guidelines for policy developments for further improvement of the performance of the integrated water supply towards achieving goals. It also highlights some limitations faced during this research followed by recommendations for further researches.

7.1. Conclusions

This research was performed to find out the performance level of water supply system focusing on two improved sources; the piped water supply and the groundwater wells in Yogyakarta city. For assessment of performance a hierarchy was followed; development of a performance measurement framework, development of a set of performance measurement criteria, analysis of the performance at the household level by the application of SMCE tool and comparison of the overall performance of some parameters of the integrated water supply with some standards.

From the results obtained it showed that the performance of the integrated water supply system showed spatial variation with respect to each criterion as well as the CIM. Among the parameters compared with the benchmarks most of them were below satisfaction level. So improvement of the performance is necessary to satisfy the consumers, minimize the impacts on human health as well as the environment so that goals can be achieved.

7.2. Specific Conclusions

Development of performance measurement framework

A performance measurement framework for Yogyakarta city was developed based on the components of integrated water supply, the stakeholders involved and their perceptions and goals to be achieved. The goals formulated are such that the performance of the water supply is upgraded with piped water supply in a healthy condition, the people satisfied with the service and the environment impacts are minimized by creating awareness among the related stakeholders.

The two improved sources of residential water supply are considered in the framework; the piped water supply and the groundwater wells; both private and communal. The stakeholders involved are the supplier of piped water supply PDAM Tirthamarta, the different groups of consumers, the Environmental Agency and the Health Agency. As the perceptions of the related stakeholders are necessary for the judgement of the performance of the utility, their perceptions are incorporated within the framework. Since the bye-laws had been found violated in the ground the Local Government of Yogyakarta has to be included within the framework to upgrade the performance of groundwater wells. As the consumers' perceptions are central to the performance measurement of a utility the perceptions of different consumer groups are incorporated. Goals are set after the identifications of the existing performance level from the stakeholders' perceptions. This framework was developed for Yogyakarta city, but can be applied to other locations or cities having similar type of integrated water supply system.

Development of a set of performance criteria

A set of performance measurement criteria were developed and by creating a balance between them a desired level of performance can be achieved. The indicators identified were grouped under each criterion as criteria are the basis for measuring the indicators.

Analysing and mapping the existing performance

Spatial multicriteria evaluation (SMCE) was performed to analyse the existing performance level by developing performance indices based on the criteria and indicators. Two conditions were applied, first giving equal weight to each criterion as well as to the indicators within each criterion. Secondly weights were prioritized to the criteria and indicators according to the local situation. Spatial performance patterns varied according to each criterion as well as the CIMs. CIM according to the first condition showed the piped water supply performing badly in some households while the CIM according to the second condition showed more households using only groundwater performing bad spatially.

Application of SMCE has helped to develop a map for each criterion and CIM under different weighting conditions which are important for the related stakeholders and the policy makers so that they can identify the areas of low performance and adopt necessary actions to improve the performance there. Since the performance was analysed and mapped at the smallest geographical unit i.e. the household level, detailed information are achieved on the performance of integrated water supply system.

Gauging the performance by adopting some suitable benchmarks

Some selected parameters of the integrated water supply were measured against some local and international standards to identify the level of performance. It showed that the level of performance of the integrated water supply is quiet low so much improvement is needed for a satisfied level of performance.

Procedure of performance measurement

The complexity of performance assessment is simplified by the adoption of performance measurement system which consisted of a performance measurement framework, selection of criteria and indicators, analysing the performance, mapping it and benchmarking some parameters with standards. Thus a baseline can developed so that by assessing the performance on timely basis a trend can be observed which shows the direction of performance and necessary actions can be undertaken.

7.3. Development of guidelines for policy

Some guidelines for policy development are proposed for Yogyakarta city from the findings of this research:

- To improve the performance of the existing integrated water supply system there is a need to integrate the perceptions of the related stakeholders with the local level planning and operational processes, where the developed performance measurement framework works as a medium.
- The performance maps can be used as a basis to inform the related stakeholders about the existing performance level as visual interpretation helps towards easy understanding.

- The Environmental criterion map serves as a tool to inform the consumers/citizens about the degrading environment spatially and help to create awareness among them which in turn helps towards achieving the goals.
- Though the Engineering criterion map shows a healthy performance of PDAM in space, the consumers' satisfaction map shows the level of satisfaction of the consumers at the household level from the service provided. Comparing these two maps can help to minimize the gap by improving the performance of the piped water supply in the locations where necessary.
- Both presentation and analysis of spatial information can contribute to dissemination and preparation of performance improvement. Performance maps are important during various consultations like for consumer groups to understand easily and local government to identify areas of low performance.
- There is a need to benchmark the integrated water supply system not only with the parameters related with the operational issues but by the incorporation of the parameters related to the other stakeholders, it can help much better towards upgrading the performance.
- The results of performance assessment will provide support to the local government to develop performance improvement plans for achieving the goals.
- The performance maps and benchmarking show the present situation of the integrated water supply system, by reviewing the maps and benchmarking on periodic basis the prevailing situations can be analysed and change the policies accordingly.

7.4. Limitations of the research

Some limitations were faced during this research which are:

- Since the laboratory tests were conducted only for 45% of the surveyed households using groundwater due to limited budget and time, the results would have been much better if the groundwater from all the surveyed households have been tested for bacterial contamination.
- In the households having private wells and using communal toilets though the distance between them seemed quite far, there must be other septic tanks in the proximity.
- The data collected was more qualitative than quantitative for the respondents to give the answers easily so the performance level for each household was a bit exaggerated. For example, in the case of Economic criterion the spatial pattern showed heterogeneity of either 'Bad' performance with performance value '0' or 'Good' performance with value '1'.
- Inclusion of more indicators covering other parameters of the integrated water supply could have given more accurate map/picture of reality.

7.5. Further Research

In future further researches on integrated water supply of Yogyakarta City can be conducted considering the following points:

- In this research, the distance between the well and septic tank related to each household was considered but the neighbours' septic tanks were not considered which in some cases might have been even closer. In further researches this shortcomings can be considered.

- This research considered only the residential water; piped water supply and groundwater wells. Since the policy of Yogyakarta city for non-residential water use i.e. for business and commercial purpose is to use deep wells, further research can be done in-corporating the deep wells as well as the related stakeholders.

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APPENDICES

Household Questionnaire

Village name:………………………….
Date:……………………………
Household no.:……………………….
Surveyor: ……………………………….
Questionnaire no.:………………….
GPS pt.
X – Coordinate: …………………………
Y – Coordinate: ……………………….

A. Household data

1. Details of respondent:
   Position in the family: Husband ☐ Wife ☐ Other ☐ Specify:

2. Number of persons in household:

B. Water supply provision

1. Which source of water supply does the household rely on? (can be more than 1 answer)

Source	Circle the answer	Purpose
Provider (PDAM)	A	
Private well	B	
Communal well	C	
Buying from vendors	D	
Rain water	E	
River	F	
Other sources, specify:		

<table>
<tr><th>No.</th><th>Question (For piped water /PDAM)</th></tr>
<tr><td>1.</td><td>How many hours per day piped water is supplied to the household?
1 hr
Upto 3 hrs
More than 3 hrs
24 hrs</td></tr>
<tr><td>2.</td><td>How many times per day piped water is supplied to the household?
1 time
2 times
More than 2 times</td></tr>
<tr><td>3.</td><td>What is the average litre per capita per day for the household members?
Less than 123 lpcd
More than 123 lpcd</td></tr>
<tr><td>4.</td><td>Please indicate the water supply quality:
<table>
<tr><th>Odor</th><th>Taste</th><th>Colour</th></tr>
<tr><td>Smell/Not smell</td><td>Strong taste/Good/Chlorine</td><td>Colour/Colourless</td></tr>
<tr><td>Specify:</td><td>Specify:</td><td>Specify:</td></tr>
</table></td></tr>
<tr><td>5.</td><td>Does the household have meter connection?
Yes No</td></tr>
<tr><td>6.</td><td>What is the actual average monthly domestic tariff?</td></tr>
<tr><td>7.</td><td>Is the discharge (pressure) of the piped water satisfactory? (‘No’ if generator has to be used)
Yes
No</td></tr>
<tr><td>8.</td><td>How much percentage of total income the household spends for water supply?
Less than 10%
More than 10%</td></tr>
<tr><td>9.</td><td>Are the complaints satisfactorily attended by the local water company?
Yes No</td></tr>
<tr><td>10.</td><td>What is the level of satisfaction of the household with the piped water supply service?
Highly satisfied
Satisfied
Not satisfied</td></tr>
<tr><td>11.</td><td>Within how many days the complaints are attended?
Within 3 days
In 4 -7 days
Not attended for more than 1 week</td></tr>
<tr><td>12.</td><td>Are you willing to pay more for improved piped water service?
Yes No</td></tr>
</table>

No.	Question (For groundwater wells)
1.	Do you have a private well? Yes No
2.	If 'No' in Q.1, do you rely on communal groundwater well? Yes No
3.	How much quantity of water is withdrawn daily?
4.	What is the depth of the well from the ground level?
5.	What is the distance of the well from the on-site sanitation?
6.	What is the distance of the well from the building?
7.	Has any cracks been seen in the portion of the building near to the well? Yes No
8.	Has the level or quantity of water been decreasing every year? Yes No
9.	Please indicate the water quality:
10.	Have you or any of your household members ever suffered from any of these diseases? Diarrhea Cholera Typhoid Others
11.	Which year did you have the well dug?

Question 9 – water quality:

Odor	Taste	Colour
Smell/Not smell	Strong taste/Good/Chlorine	Colour/Colourless
Specify:	Specify:	Specify:

Questions asked in the interview with PDAM Tirthamarta

1. How many hours per day is water supplied to each village?
2. Do all the households have meter connection? If 'No', what is the percentage of households with meter connection in each village?
3. What is the length of newly built pipelines (km/m) in each village?
4. What is the percentage of cast iron (CI) pipes in the total length of distribution in each village?
5. What is the Unaccounted for water (UFW) for (each village)?
6. What is the average daily production of water?
7. What is the amount of gas Chloride used during the purification process?
8. What is the average revenue collected per unit of water sold?
9. What is the total number of staff trained for 1000 population?
10. What is the percentage of complaints received per month?
11. What is the average time taken to repair major leakages?
12. What is the percentage of complaints attended per month?

Questions asked in the interview with Environmental Agency of Yogyakarta City

1. Are there any cases of land subsidence in Yogyakarta city?
2. Are there any regulations to check land subsidence in future?
3. Is there any bye-law to control the land subsidence, like distance between house and groundwater wells?
4. Are there any findings about the decrease in the water level?
5. Is there any policy to control the depletion of aquifers?
6. In there any bye-law to control the pollution of underground wells due to the encroachment of on-site sanitation?
7. What is the approximate number of private wells in the city?