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## **Assessment of the Sustainability of Urban Water and Water Demand Management by using Geo-Information Technology for the Core Vientiane Municipality, Vientiane Capital, Lao PDR**

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**Dethoudom, S.<sup>\*</sup>, Nualchawee, K., Kanchanasuthum, S. and Soyong, P.**

<sup>1</sup>Faculty of Geo-Informatics, Burapha University, Chonburi Campus, Saen Sook, Mueang, Chonburi, 20131, Thailand.

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**Abstract** According to the economic and population growth and after Lao People's Democratic Republic (Lao PDR a member of ASEAN Economic Community (AEC)), the water consumption and demand from 1997 to 2016 are continuous increasing, especially the Vientiane Capital. It is a fastest-growing city in the Lao PDR by population growth rate of 1.6% in 2016, economic growth rate of over 10.98% in 2016. Due to the National Action Plan of Lao PDR, to achieve the government water supply and sanitation access targets for 2020, it was examined the priority actions on water supply development in urban area, ensured that finance is effectively turned into services, and also supported the Sustainable Development Goals (SDGs) to make sure everyone access the clean water to improve the quality of life, however, this plan is still far to achieve. The analysis of water supply demand, water resources and urban changed of the Vientiane Municipality was evaluated by using Geo-Information Technology, and created five years plan for water supply system development based on the analysis results of Vientiane Municipality. The questionnaire survey which is consisted of a series of water supply demand by collecting from 400 people (households) in the Vientiane Municipality. The results were showed that the customers required the NPNL (Nam Papa Nakhon Luang), Vientiane Capital Water Supply State-owned Enterprise to improve three issues such as 1) water volume and pressures; 2) fast water installation and repair; and 3) water quality problems. Moreover, the relation of water demand and water supply, resulted that the percentages of water supply demand were 21.4% higher than recent water supply production, especially water supply consumption at the commercial areas in the peak hours. It is needed to produce more water supply and also improved water supply pipe system by replacing the poor and small sizes of old water pipes. Furthermore, the amounts of water supply consumption would increase year by year, the ways to balance regional water supply. The water demand is needed to increase the production capacities from 280,000 m<sup>3</sup>/day into 360,000m<sup>3</sup>/day in 2020 and 460,000 m<sup>3</sup>/day in 2030, which is possible by taking raw water from Mekong River and Nam Ngum River in the present and future situations.

**Keywords:** sustainability, urban water, water demand, water supply system, geo-information technology

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<sup>\*</sup> **Coressponding Author:** Dethoudom, S.; **E-mail:** [somchaiwang2002@gmail.com](mailto:somchaiwang2002@gmail.com)

## Introduction

Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth, for drinking water also an apart of human's life, which is necessary for daily surviving (ENHEALTH, 2010). Human use water for many purposes of using such as cooking, washing their bodies, washing clothes, washing cooking and eating utensils (e.g. billies, saucepans, crockery, cutlery and so on.), keeping houses and communities clean, recreation; such as swimming pools, keeping plants alive in gardens and parks. Very well known the beginning of civilization humans were settled close to water sources, so water is essential for the life of man, plants, and animals (Lenntech, 2017). Water is at the center of economic and social development; it is vital to maintain health, grow food, manage the environment, and create jobs. Despite water's importance, over 663 million people in the world still lack access to improved drinking water sources (Water Supply and Sanitation Program, 2014).

The Lao PDR is a landlocked country in Southeast Asia, bordered by Myanmar and China to the northwest, Vietnam to the east, Cambodia to the south, and Thailand to the west. Its population was estimated to be around 6.4 million. The main issues on development are ensuring that the benefits from high economic growth, averaging more than 7 percent for the past five years, are evenly distributed and translated into inclusive and sustainable human development. The gross domestic product was estimated at \$1,270 per capita in 2011 and \$1,422 in 2012, about 58% of urban residents had access to piped water supply in 2011 (Asian Development Bank, 2013).

Lao PDR has met the Millennium Development Goals (MDGs) targets for both water supply and sanitation according to UNICEF/WHO Joint Monitoring Programme (JMP). Recently there are still 1.9 million people without access to improved water supply. The main problem is especially acute in rural areas, with large inequalities in access to areas that are close to good roads and remote, inaccessible locations. Furthermore, it was inadequate water and sanitation services which have negative impacts not only on public health, but it is also an indirect impact on the economy. At the study 2 in the year, 2009 by WSP estimated that poor sanitation and hygiene including no access to water alone imposed a cost on the country equivalent to 5.6% of Gross Domestic Product (Water Supply and Sanitation Program, 2014).

Vientiane Capital is the largest city, with an estimated 800,000 inhabitants and an estimated 3,920 km<sup>2</sup> as the administrative area is now facing rapid urban development such as sprawling housing development as the population increases, continuous traffic jams, and undersupply of public infrastructure. These issues just reflect one side of urbanization, but collateral problems such as environmental degradations are also obvious

issues. Vientiane Capital has been tackling these problems ad-hoc, however, personnel and budgetary constraints mean they require considerable time and investment to become effective. The Vientiane Municipality is a part of Vientiane Capital, which is located in the center part of Vientiane Capital and it is also covered by Mekong riverside, Government administrative offices, important commercial areas, culture conservation area, as well as other public facilities, which are mostly concentrated in this area (Department of Home Affairs of Vientiane Capital, 2015).

The Vientiane Water Supply Company (VWSC), a State-owned Enterprise, formerly known as Nam Papa Lao, was established in 1959 and was turned into a business enterprise following the new economic roadmap of the Lao People's Democratic Republic (Lao PDR), introduced in 1986. The development of water supply system in Vientiane Capital City started the construction of Kaolieo water treatment plant in 1964. This was followed by the rehabilitation and expansion of the scheme in 1983. An additional water treatment plant was constructed at Chinaimo in 1980, which was rehabilitated and expanded in 1996. The total production of both treatment plants is 100,000 cubic meters per day. In 1988, the utility became a self-sustaining enterprise as part of the public works improvements (Vientiane Capital Water Supply State-owned Enterprise, 2017).

According to the Annual Report 2015 of Vientiane Capital Water Supply State Enterprise (NPNL), Vice-Governor of Vientiane Capital said that it was significant to highlight the achievement of the implementation plan of the water supply business, expressed the ability to increase water production and expand the water supply service to be up to international standards; support the development and growth of the city to achieve the Millennium's Development Goals (MDGs) from today to 2020 can serve 95% of the population living in Vientiane Capital; and raise efficiency, improve the service ready to step into an ASEAN Economic Community (AEC) at the end of the year 2015 (Vientiane Capital Water Supply State-owned Enterprise, 2015). Refer to Annual Report 2016 of Vientiane Capital Water Supply State Enterprise (NPNL), Director General of NPNL was said that to respond the Sustainable Development Goals (SDGs) of the United Nations and Party-Government, the 8<sup>th</sup> FIVE-YEAR National Socio-Economic Development Plan (2016-2020), to implement the resolutions of the 10<sup>th</sup> Lao Revolutionary People Party Congress, the NPNL must work harder to increase the water service up to 80-85% by year 2016 and 90-95% by year 2020 (Vientiane Capital Water Supply State-owned Enterprise, 2016).

From the report of the Department of Housing and Urban Planning, Ministry of Public Works and Transport (MPWT) has defined the main constraints for urban water supply sector developments that are facing in Lao PDR, it was presented at the workshop on Water and Green Growth in Asia and the Pacific 23-25 February 2015, Bangkok, Thailand. The main

constraints related urban water supply sector developments are briefly described: (1) Insufficient funds to expand coverage and/or improve service levels, and limitation of self-financing capacity; (2) Weak sector planning and implementation capacity of responsible authorities at central, regional, local and commune level and lack of qualified engineers and technicians; and (3) The absence of the so-called “enhancing environment”, often characterized by an inadequate institution and legal framework (Department of Housing and Urban Planning, 2015).

According to 58<sup>th</sup> anniversary Magazine of Vientiane Capital Water supply State Owned-Enterprise (NPNL), Director General of NPNL was brief reported that NPNL can be achieved some works and many works must be further improved and developed such as improvement of organization chart and human resources training; increasing of water production capacity, replacement of old pipeline and water meter; extension of pipeline network to suburbs; improvement of water recording and money collection system; improvement of management and materials; development of IT systems and information technology system and so on (Vientiane Capital Water Supply State-owned Enterprise, 2016).

The Vientiane Capital as well as Vientiane Municipality, currently restructuring its organization under the strong leadership of its governor, there are considering to introduce information technology such as a geographic information system (GIS) to streamline routine practices that are intensive documentation, support swift decision-making, and secure accountability and transparency (Department of Home Affairs of Vientiane Capital, 2015).

Nowadays, it is undeniable that an administrative business should require a certain accuracy of its transactions and proper monitoring and management of documentation records while the implementation of an effective policy should be taken promptly. GIS has already gained widespread use in the administrative sector even in developing countries because of its remarkable feature of visualization and operability.

Thus, Vientiane Capital is eager to accelerate the introduction of a GIS in order to strengthen its local administration performances. Target issues for applying GIS technology, it uses to finalize administrative boundary (Village level), and information collection for infrastructures and public facilities management such as roads, water supply, electricity, canals, land and etc, share land information for government’s activities (both central and local authorities) (Department of Home Affairs of Vientiane Capital, 2015).

Therefore the using of geo-information technology can be a good choices and practices to reduce these constraints that are facing and it also encourages the local authorities as well as Vientiane Municipality Administrative Authority in terms of public administration, socio-economic development planning, and implementation, to achieve the targets of the

urban water supply strategy which are to provide the coverage to 95% of the urban population by 2020 and to achieve the sustainable development in the field of urban water supply for Vientiane Capital as well as Vientiane Municipality.

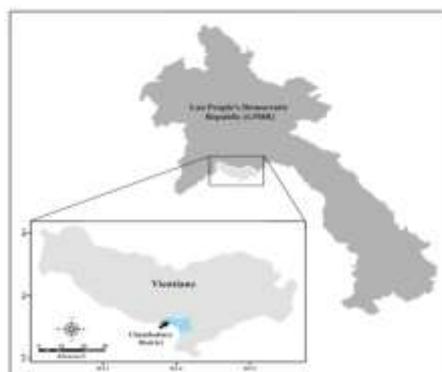
## Materials and methods

### *Materials*

The Core Vientiane Municipality is located in the center of Vientiane Capital, which covered 50 villages with a total area of 15,832.7 square kilometers by covered some parts of Sisattanak, Xaysettha, Chanthabury, and Sikhottabong Districts (see table 1), this is a fastest-growing city in the Lao PDR by population growth rate of 1.6% in 2016, the economic growth rate of over 10.98% in 2016. It is on latitude 48 Q 247515m E and longitude 1989342m N. The map of the study area is shown in the figure 1.

**Table 1.** District's name with the areas

ID	Name of Districts	Area (km <sup>2</sup> )
1	Sisattanak District	5,224.892
2	Xaysettha District	3,064.349
3	Chanthabouly District	4,521.693
4	Sikhottabong District	3,021.767
	Total	15,832.700

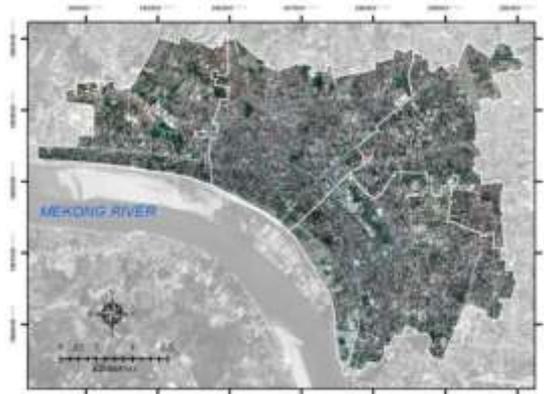


**Figure 1.** Study area

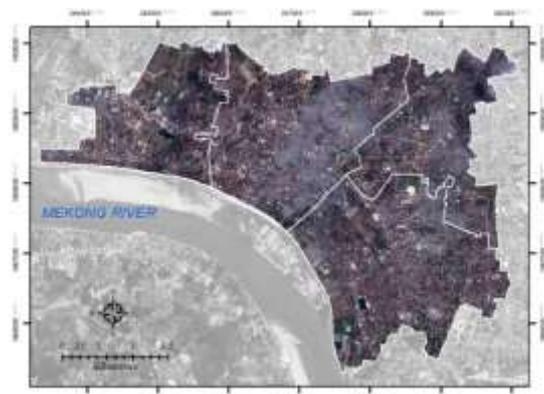
### *Methods*

This study was primarily to determine the urban change of urban water consumption and water supply demand including water sources. The evaluation criteria to assess urban change during 2013 to 2017, urban water consumption and water supply demand of this study are used questionnaires

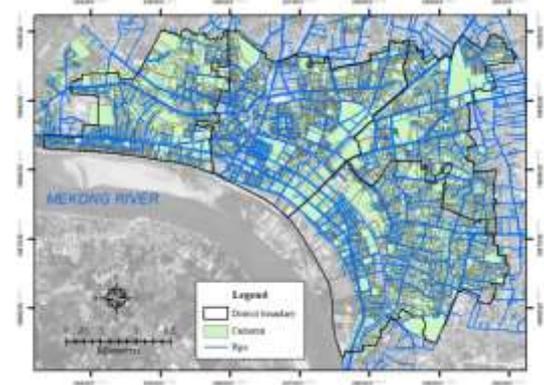
to 400 customers; geographic maps which consisted of roads, land parcels, buildings, contours, water supply pipeline system and so on; aerial photos (it was taken and completed in 2013) (see in the figure 2), satellite images (it was taken from 2017) (see in the figure 3) and digital water supply pipeline system map (see in the figure 4); and field survey conduction. The conceptual framework of this study is shown in the figure 5 as below:



**Figure 2.** The aerial photo which was taken in 2013

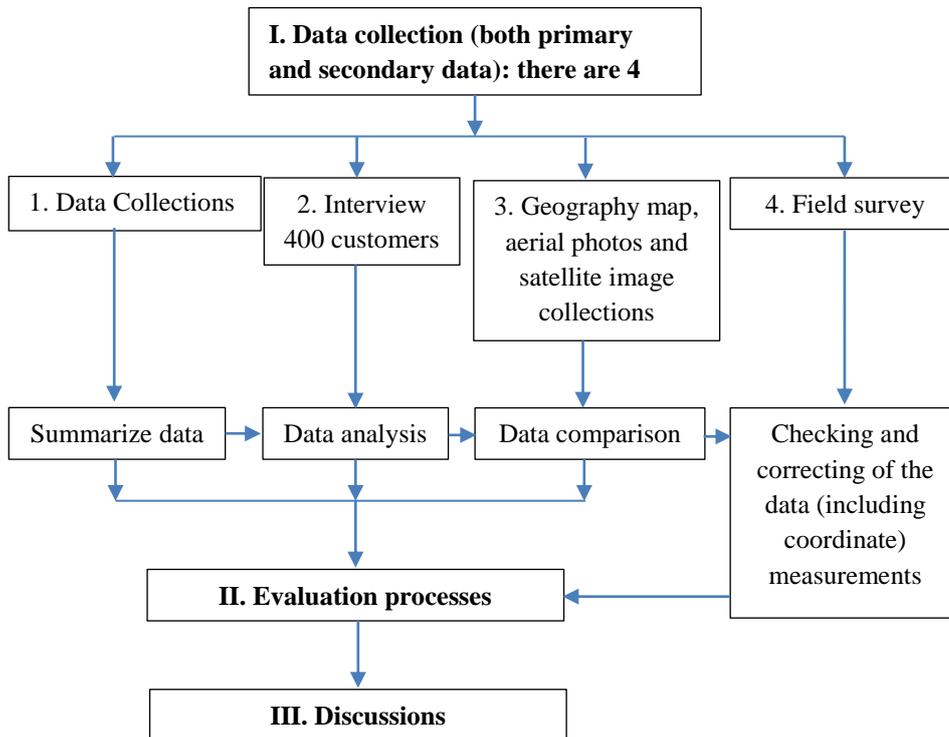


**Figure 3.** The satellite image which was taken in 2017



**Figure 4.** The digital water supply pipeline system map

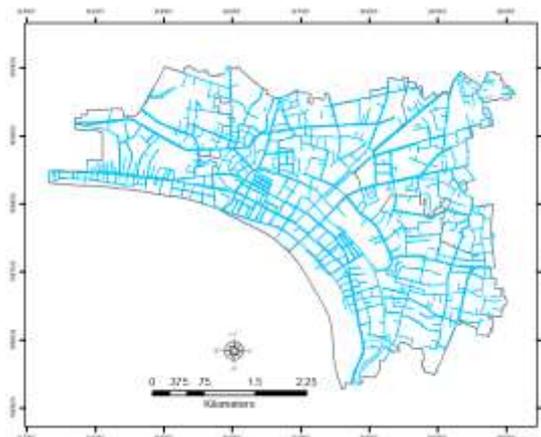
**Conceptual Framework of the study**



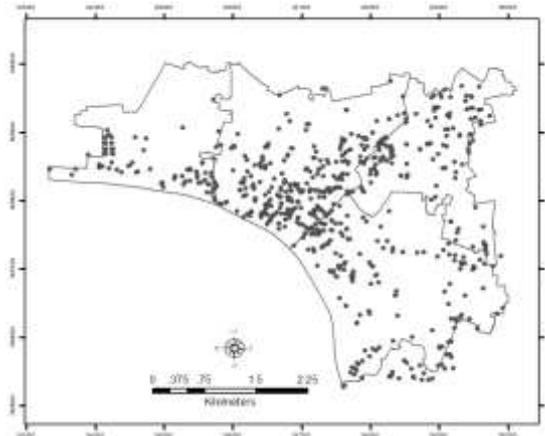
**Figure 5.** The conceptual framework of the study

**Results**

The digital water supply pipeline system map including water meters map were provided the water supply technical division from the NPNL (see in figure 1-6 and 1-7 respectively). The researcher was corrected the digital water supply pipelines system and maters.



**Figure 6.** The water supply pipeline system map is based on the water supply pipeline map from NPNL which was digitized in 2017



**Figure 7.** The water meters map is based on the meter map from NPNL which was digitized in 2017

The water supply pipeline system map that was received from NPNL was a poor database. It found many water pipelines were not connected together and data missing. So, the researcher must take time to correct it. This kind of GIS database was used to support to further process regarding an integration of geo-information technology and EPANET.

Both water supply pipelines network and water meters were adapted from the observation of all building where the building was located. In addition, the researcher was also added some missing water pipelines and meters as well.

The Core Vientiane Municipality is the areas of the urbanized areas are mainly part of Chanthabouly, Sisattanak, Sikhottabong and Xaysetha Districts which are located on the natural plain formed by the Mekong River at an elevation of 160 m-180 m. It has high economic and demographic growth potential. It is thus quite likely that the urban area would rapidly expand toward the suburbs along the arterial roads with inadequate infrastructure facilities, creating the problem of urban sprawl with bad living conditions and inappropriate social services, and the pastoral charms of the city might be lost. The used of water supply in this area was high in the peak hours, which was around 3945.98 m<sup>3</sup>/hour from 6:00 to 9:00 am in the morning and around 3125.94 m<sup>3</sup>/hour from 6:00 to 9:00 pm. In addition, the Lao PDR, as well as the Core Vientiane Municipality, is a distinct rainy season from May to November, followed by a dry season from December to April. Local tradition holds that there are three seasons (rainy, cold and hot) as the latter two months of the climatologically defined dry season are noticeably hotter than the earlier four months. So, the high users of water supply in the Core Vientiane Municipality during March to May. It covers both rainy and dry season, which was around 899,021 m<sup>3</sup>/day.

The results showed that the customers require the NPNL to improve 3 issues such as 1) water volume and pressures with 49.1% of the total

interviewed customers; 2) fast water installation and repair with 51.2% of the total interviewed customers; 3) water quality problems with 40.9% of the total customers.

The water supply production capacity, NPNL could produce 280,000 m<sup>3</sup>/day, but the water supply demand was required 320,000 m<sup>3</sup>/day in 2016 and 340,000 m<sup>3</sup>/day in 2017. It means that the water supply demand is covered 14.3% in 2016 and 21.4% in 2017. But currently NPNL able to produce water supply 180,000 m<sup>3</sup>/day (see table 2). So, NPNL needs to produce more 50% of water supply production capacity design in 2016 and 57.14% of water supply production capacity design in 2017.

The NPNL was installed the water meters to customers in different types, which divided into 3 customer categories i.e. the first category is domestic used; the second category is consisting of bureaus, state organizations, diplomats used; and the last one is included business, commerce, industrial used. The NPNL is increased water meters as following: category 1 from 92,314 meters to 111,489 meters in 2016; category 2 from 1,684 meters to 1,882 meters in 2016; and category 3 from 3,509 meters to 3,651 meters. But NPNL does not create the water production, which causes high water demand in those three category groups. It means that NPNL could not serve enough water supply to people in the service area.

**Table 2.** The summarize of water production of each water treatment plant

No.	Water Treatment Plant	Year	Content	Production Capacity on Design (m <sup>3</sup> /day)	Current Production Capacity (m <sup>3</sup> /day)
1	Kaolieo	1963	Construction water treatment plant	20,000	60,000
2		2007	Increasing of water production	40,000	
3	Chinaimo	1980	Construction water treatment plant	40,000	80,000
4		1996	Increasing of water production	40,000	
5	Dongmarkkhai	2005	Construction water treatment plant	20,000	20,000
6		2012	Increasing of water production	100,000	
7	Dongbang	2010	Construction water treatment plant	20,000	180,000
Total				280,000	180,000

The comparison between aerial photos in 2013 and satellite image in 2017, the research found that the Vientiane Municipality has many buildings and activities occurrence, especially hotels, shopping mores, office

buildings, markets and apartments including the economic development zone around the Vientiane Municipality such as Xaysettha Comprehensive Development Zone, Nongtha Economic Zone, Thatluang Economic Zone and so on.

The calculation of the population or water consumers in the water supply service area in the year 2015 to 2016 based on data survey and the statistic from National Statistics Center in 2015. The populations in the water supply service area were 692,645 persons in 2013, 766,449 persons in 2015, and 778,710 persons in 2016. The population or water consumer served in the water supply service area were calculated 540,327 persons, 512,317 persons, and 541,312 persons in the year 2013, 2015, and 2016 respectively. So, the percentage of populations between 3 years in the service area was increased 12.43 percentages and in the same way, the percentage of the population served was also increased 0.18 percentages.

## **Discussion**

The survey questionnaire is a research instrument consisting of a series of water supply demand; this research collected the questionnaire from 400 people (households) in the Vientiane Municipality. The results were shown that the customers require the NPNL to improve 3 issues such as 1) water volume and pressures; 2) fast water installation and repair; 3) water quality problems.

The relation of water demand and water supply, the research found that the percentages of water supply demand are 14.3 - 21.4%, which is higher than recent water supply production, especially water supply consumption at the commercial areas in the peak hours (Japan International Cooperation Agency, 2015), it needs to produce more water supply and also improve water supply pipe system by replacing the poor and small sizes of water pipe.

The NPNL was classified that there are 5 water treatment plants in Vientiane Capital which are serving to people in Vientiane Capital including the Core Vientiane Municipality (Vientiane Capital Water Supply State-owned Enterprise, 2016) such as Chinamo Water Treatment Plant with a capacity of 80,000 m<sup>3</sup>/day, Kaolieo Water Treatment Plant with a capacity of 60,000 m<sup>3</sup>/day, Dongmarkkhai 1 Water Treatment Plant with a capacity of 20,000 m<sup>3</sup>/day, Dongmarkkhai 2 Water Treatment Plant with a capacity of 100,000 m<sup>3</sup>/day, and Dongbang Water Treatment Plant with a capacity of 20,000 m<sup>3</sup>/day. There is total water distribution from 6 branches and 1 commercial section is 60,240,119 m<sup>3</sup> which are an average 90% of the annual plan 2016. Recently, the total water production capacity was 280,000 m<sup>3</sup>/day, but the actual water supply need was calculated around 320,000 - 340,000 m<sup>3</sup>/day, it means that NPNL needs to produce more 40,000 - 60,000 m<sup>3</sup>/day which is sufficient for consumer's need. The water supply

production is expected to increase the capacity of 280,000 m<sup>3</sup>/day to 340,000 m<sup>3</sup>/day in 2017, after the completed Hadxayfong and Sandin Water Treatment Plant with a capacity of 20,000 m<sup>3</sup>/day and 40,000 m<sup>3</sup>/day respectively. There are several reasons why NPNL could not service enough water supply to the consumers (Vientiane Capital Water Supply State-owned Enterprise, 2017) due to the population growth rate of 1.6% in 2016, economic growth rate of over 10.98% in 2016, high percentage of water loss (with non-revenue water of 29%), poor water supply pipelines, poor water meters, no access to water supply systems, and so on. In addition, the study found that the most of the urban areas are part of Vientiane Municipality, which has many buildings and activities occurrence, especially hotels, shopping mores, office building, markets and apartments including the economic development zone around the Vientiane Municipality.

The water sources are taken from three sources such as Mekong River, Nam Ngum River, and groundwater. The water sources and water quality are quite enough and good quality (Vongsayalath, 2015), but only facing the water quality in the rainy season and water shortage in the dry season.

## **Conclusion**

The total water production capacity was 280,000 m<sup>3</sup>/day, but the actual water supply need was calculated around 320,000 - 340,000 m<sup>3</sup>/day, it means that NPNL needs to produce more 40,000 - 60,000 m<sup>3</sup>/day which is sufficient for consumer's need.

The 400 questionnaires were shown that the customers require the NPNL to improve 3 issues such as 1) water volume and pressures; 2) fast water installation and repair; 3) water quality problems with the percentages of 49.1%, 51.2%, and 40.9% respectively. It means that NPNL must emphasize on more water production, service improvement, old water pipeline replacement, and meter replacement including transition and distribution pipeline.

The water sources are taken from three sources such as Mekong River, Nam Ngum River, and groundwater. The water sources and water quality are quite enough and good quality, but only face the water quality in the rainy season and water shortage in the dry season.

The water supply system management has some weak management and maintenance systems, which can see poor water transmission and distribution pipelines, too old water meters and valves (including illegal water meters), improper size water transmission and distribution pipelines, it means that is too small size water pipelines, late water pipe fixing when is found water leaking (including there is no monitoring system), low budgets for maintenance, water pipe pressure are not stable or uncertain, it causes

low water pressure and water shortage in some areas, less water supply volume is also caused water pipe pressure control.

The NPNL had poor water supply system databases related to water pipelines (both transmission and distribution pipelines), water pressures (fewer examples of water pressure measurement points), water pipe ages, connection points (junctions), sizes of water pipelines, and so on.

The ways to balance water supply and water demand are needed to increase the water volumes (exclusive for the Core Vientiane Municipality area) from 1,248.64 m<sup>3</sup>/day into 1,455.42 m<sup>3</sup>/day in the present time and increase the water production at water treatment plants from 280,000 m<sup>3</sup>/day into 360,000 m<sup>3</sup>/day in 2020 and 460,000 m<sup>3</sup>/day in 2030. The amount of water supply consumption will increase year by year.

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