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FINANCIAL SUSTAINABILITY OF WATER SUPPLY SYSTEM AT URBAN TOWNSHIPS USING SYSTEM DYNAMICS

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Abstract:- *The Sustainable Development Goals (SDGs) aims to achieve universal and equitable access to safe and affordable drinking water by 2030 (Nations, n.d.). The Khyber Pakhtunkhwa (KP) Drinking Water policy formulated in line with the SDGs iterates that drinking water tariff shall be set at a level at least to recover the operation and maintenance (O&M) costs. Currently, most of urban townships in developing countries charge a flat fee per connection which only recovers a part of, and in many cases, a very small part of the O&M expenditure. The public companies responsible for water supply in urban townships mostly rely on public exchequer for grants to cover their O&M losses. Financial self-sustainability of water supply system (WSS) is unintuitive due to its dynamic behavior ''evolving over time'' and complexity ''due to numerous interconnected feedback loops''. System dynamics approach is utilized to take into account the complex and dynamics characteristics of WSS. A causal Loop diagram is developed to identify the system boundaries followed by development of system dynamics model. The model is validated using the case study. The impacts of interconnections and feedback loops have been explored. The model results emphasize that for financial self-sustainability and water resource conservation, incremental increase in volumetric water fee may be implemented by the utility over certain period of time.*

Key Words: *System dynamics, Causal loop diagrams, Water supply system, Sustainability, Utility financing.*

I. INTRODUCTION:-

The United Nations Sustainable Development Goals (SDGs) aims to achieve universal access to affordable and safe drinking water by 2030 (Nations, n.d.) The Government of Khyber Pakhtunkhwa has formulated drinking water policy 2015 to achieve the SDGs. Drinking water tariff shall be set at a level at least to recover the (O&M) costs ("drinking_water_policy.pdf," n.d.). Water is a finite and essential and precious resource and its use shall be regulated to avoid its misuses. In most of urban towns in developing countries water are supplied to the beneficiaries/consumers through pipe network. The major sources of water supply are either surface water or ground water. WSS has weird characteristics when considered within the context of financial self-sustainability. WSS can be conceptually divided into three main sectors i-e physical infrastructure, consumer and finance sectors whereas different components of three sectors are interconnected to each other forming feedback loops thereby render WSS as complex problem. Different components of WSS are not static but rather evolve over time. Municipalities/authorities in urban townships charge consumer on flat fee basis per connection which is not capable to recover expenditure incurred on O&M. The current system may be rightly termed as financially not sustainable. Due to complex and dynamic characteristics of WSS a linear approaches may not be capable to redress the research problem.

In order to have a sustainability of WSS, system dynamics approach has been adopted to ascertain dynamic behavior of WSS components evolving over time. This study presented a novel system dynamic approach to ascertain and know the dynamic behavior of various components of water supply system. The complex interaction and feedback loops is represented by causal loop diagram, followed by application of system dynamic for integrated water supply system management. The strategy is based on the concept of 25 years' service life of water supply system as per standard engineering practices. Cause-effect relationships amongst various components of the system are typically modeled using causal loop diagrams (Choopojcharoen & Magzari, 2012). Causal Loop diagrams may be termed as a simple tool enabling the system analyst to predict and determine interaction of various components amongst the system. JW Forrester and a group of researcher developed System dynamic (SD) in the late 1950s at the MIT under the name of industrial dynamics (J. W. Forrester, n.d.) (Forrester, 1961). System Dynamics was extended to Socioeconomic Problems such as Urban dynamics (J. W. Forrester, 1968), (Forrester, 1969). Interrelationship amongst various components of the system reveals that how a feedback loops are organized and produce behavior. System dynamics provides foundation underlying all subjects. Mental model generated might have several deficiencies though system dynamic model compensate deficiencies in the mental models (J. W. Forrester & Forrester, 1994). SD models simulate the dynamic behavior of the system over time (Sterman, 2000).

(Winz, 2005) discussed sustainable urban development with focus on urban water supply using system dynamic approach. A typical system dynamic model consists of four phase's i-e system conceptualization (identifying the scope), model formulation (coding), verification & validation and implementation (Jakeman, Letcher, & Norton, 2006). (Ganjidoost et al., n.d.) developed and employed system dynamic modeling as a decision support tool for integrated and effective management of water and waste water infrastructure. (Chung, Kim, & Kim, 2008) discussed a generic water supply system to evaluate the sustainability of a hypothetical system. System dynamics is the effective methodology for monitoring of performance indicators and ensure effective and sustainable management of water supply system (Winz, Brierley, & Trowsdale, 2008).

(J. Forrester, 2009) states that conversion of mental model to system dynamic model involves, there must be no logical inconsistencies, no ambiguity in equations, units should be same on both sides of the equations. (Ahmad & Prashar, 2010) formulated a dynamic simulation model for south Florida to address and identify the interrelationship between water availability and its uses for various purpose i-e municipal, environmental and agriculture. (Rehan, 2011) developed system dynamic model for a typical Canadian municipality and obtained simulation results for water demand forecast with various scenarios like change in user fees, with considering the price elasticity of demand etc by utilizing system dynamics approach. (Clifford-Holmes, Slinger, Mbulawa, & Palmer, 2015) developed a system dynamic model to explore the challenges faced in water services sector in the context of increasing urban water demand. (Sydney & Pierce, 2017) stated that integrated modeling provides techniques and tool, that promotes dialogue among stakeholders, how a system operates and gives ideas of the various policy options and possible and acceptable interventions for solution.

Provision of clean drinking water and safe disposal of waste water is mandatory for maintaining high standard of life and effectiveness of society (Rehan, 2011). Access to safe drinking water is not only a basic need but pre-requisite for healthy life (Tahir, Rasheed, & Imran, 2010). By 2025, one-third of the developing world population will face severe water shortages (Keller, Sakthivadivel, & Seckler, 2000). (Abrams, Palmer, & Hart, 1998) refers sustainability of water supply system that ‘‘water continues to be available for the period for which it was designed in the same quantity and quality as it was designed’’. Pakistan is facing drastic decrease in water availability due to increase in population (Soomro, Hussain, & Hussain, 2011).

Consumers are responsive to implication of pricing policy. Strategies may be adopted to improve tariff structure in-line with the consumer’s acceptability (Arbue, 2004). Water pricing may be considered depends on the services provided, revenue structure and types of water markets (Howe, 2005). Pricing strategy is an effective tool in managing the demand and consumption of the consumers. A 10 per cent increase in the price of water is associated with a reduction in the quantity demanded of about 5 per cent(Hoffmann, Worthington, & Higgs, 2006). Municipality may raise water prices slowly and gradually with smooth gradient instead in abrupt manner(Goldani & Amadeh, 2011). Demand management and conservation measure should be adopted for long term sustainability (Xiao-jun, Jian-yun, Elmahdi, & Rui-min, 2011). (Jusof Khadidi & Hamid, 2013) developed a system dynamic model comprised of four sub-sectors a water supply sub sector, alternate water sources sub-sector, pipes maintenance sub-sector, and water supply business sub–sectors. (Dhungel & Fiedler, 2014) developed a system dynamic model with focus on price elasticity of demand like water demand/consumption may increase with decrease in water user fee and conversely water demand/consumption may decrease with increase in water user fee. (Adelere Ezekiel Adeniran, 2014) discussed a system dynamic model with focus on determination of the unit cost of domestic water. (Unger et al., 2015)(Haas & Unger, 2011) developed a system dynamic model for effective management and financial self-sustainability of the water and waste water utility. System dynamics model is concluded to be an efficient tool to assist policy makers for strategic planning and effective management of water supply system (Adelere E Adeniran & Bamiro, 2015). SD model is an effective tool to determine the local water service failure at the policy level (Clifford-Holmes et al., 2015).

The total water demand may be reduced by 17.5% if water conservation strategies applied (Wei, Lou, Yang, & Li, 2016).

A causal loop diagram is developed for case study of Hayatabad Peshawar Khyber Pakhtunkhwa Pakistan followed by development of system dynamics model. Peshawar Development Authority (PDA) is the public company responsible for O&M of WSS. Model is simulated and validated using the current data of Hayatabad. The system dynamics models depicts that current water supply system is financially not sustainable and non-imposition of volumetric billing cause the consumer to misuse precious water resources. Various policy options have been explored and the most critical policy options have been taken into account. Since price elasticity enhances volumetric billing and had major policy implications therefore Consumer behavior may be sensitized by increasing volumetric fee incrementally. As response to the increase in fee, preventive and corrective measures may be adopted by the consumer to rectify the leakages and start using controlled water flow devices. Max operation hours assumed in the study is 12 whereas minimum operational hours are 8 and household size is 8 persons. Tubewell specific yield 100 m^3/hr, minimum per capita demand is 200 LPCD and current water demand is 400 LPCD. Price elasticity is set at -0.035 (Rehan, 2011). The average flat fee at Hayatabad is 6,100/- PKR/month which is equivalent to 5 PKR/m^3. Population is growing at the rate 2.5% per annum.

II. MODELLING THE COMPLEXITY OF WATER SUPPLY SYSTEM

Causal loop diagram is developed for financially self-sustaining water utility figure1. A causal relationship is characterized by an arrow pointing from an independent to the dependent variable. Head of the arrow is assigned with the polarity sign which depicts whether the affected components is changing positively or negatively. Loops are created after link to link and according to their effect are positive (R or +) reinforcing or (B or -) negative named as balancing loop. Those loops are termed as feedback loops which “control” the value of the pointed element by either increasing or decreasing the quantity of concern (Sterman, 2000). Interaction amongst various feedback loops imparts complexity to the system behavior(“Stimulus-Response Models,” 2001). If a change in one components of the system cause change in other components of the system which strengthens the original process the feedback loop may be describe as positive or self-reinforcing loop. And vice-versa a change in components along the feedback loop counteracts the original change, negative feedback loop exists. A simple causal loop diagram (CLD) for management of water supply system of Hayatabad Township is presented at Figure 1. Nomenclature of the feedback loops are presented with reinforcing (R) and Balancing (B) to judge the number of loops and direction of the causal action and indicated by clock or counter clock wise arrow. The main objective of the causal loop diagram is to determine, develop and frame the scope of work of system dynamics model for the intended research projects.

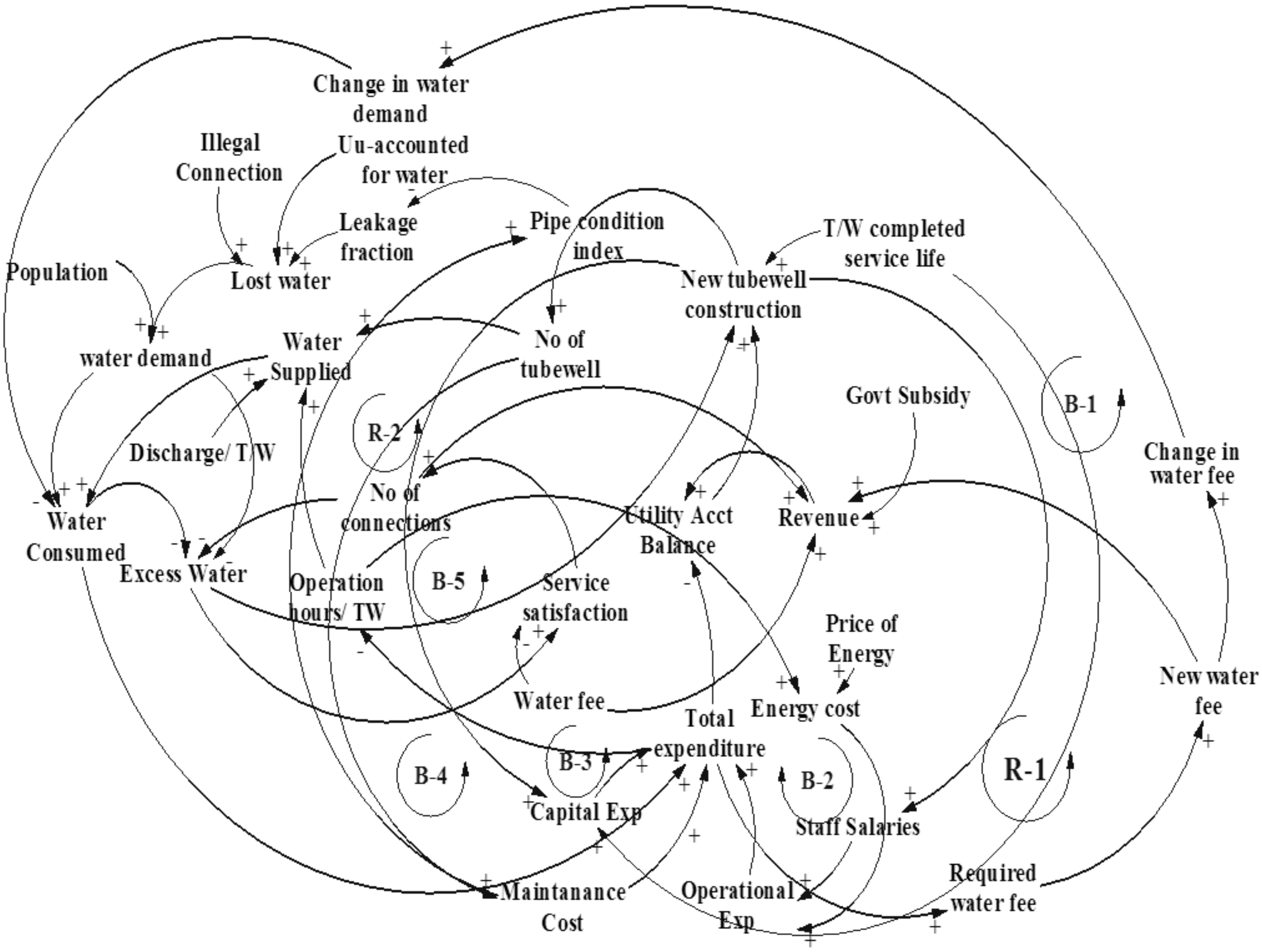

Figure 1: Causal Loop diagram for sustainable management of WSS at Hayatabad

2.1 Feedback Loop in infrastructure construction and revenue generation (R-1)

Reinforcing feedback loop (R-1) typically represents a construction process of new-tube wells required to cope the water demand of the beneficiaries. Increase in construction of tube wells results into increase in number of tube wells and will add more water into WSS that shall meet requisite demand and water consumption will increase due to more water availability. To cater the excessive use of water, volumetric fee (Rs/m^3) has been imposed. More water consumption will tend to increase the total expenditure. Required fee is calculated to cover the O&M expenditure. More water consumed will increase the total expenditure. In turn required water fee will increase. New water fee will have higher rates to attain financial self-sustainability, so it will ultimately increase revenue of the municipality and hence more funds will be available to manage water supply system and construct more tube wells to fulfill the requisite water demand if required. When revenues equal or exceed the expenditure incurred on O&M the utility may be termed as financially self-sustainable. When fund balance in the utility account drops below the threshold value, the most often step that utility may adopt is to increase revenues by increasing user fee. Standard response of the consumers to water fee increase will be regulation/reduction in water consumption.

2.2. Feedback Loop in price induced reduction in demand (B-1)

The operation of a reinforcing feedback loop (R-1) may be constrained by the existence of the balancing feedback loop (B-1). This feedback loop is constituted by the strategy that increases in volumetric fee rate (Rs/Cumecs) cause decrease in water demand and water consumption. Water consumption of the consumer may not drop below the minimum per capita water demand even if water fee increases. More water consumption will increase total expenditure of the utility incurred on O&M of water supply system which can be recovered from the consumers in terms of volumetric fee rate to ensure financial self-sustainability. The expenditure incurred will increase the required water fee which causes extensive change in water demand. Price induced reduction in demand is the strategy which causes the demand to drop if fee increase. The demand may not drop below from the minimum per capita demand. Greater the price induced reduction in demand the water consumption by the consumer may drop. This constitutes the Ist balancing feedback loop (B-1).

2.3. Feedback Loop in operational expenditure (B-2)

To cater the requisite demand of beneficiaries the tube-wells yield/discharge may be increased by increasing the operational hours of the tubewell. Operation of the pumping machinery for longer duration/time will tend to increase the energy unit in Kilowatt-hours. Though tariff for water supply system is subsidized, still more energy units consumption will lead to increase in the energy cost of the tube-wells. More energy cost will tend to increase the total expenditure and finally operational hours of the tube-well may get decreased. This constitutes the 2nd balancing feedback loop (B-2).

2.4. Feedback Loop in maintenance expenditure (B-3)

The operation of a reinforcing feedback loop (R-1) may be constrained by the existence of the balancing feedback loop (B-3). The standard response of the system to fulfill the desired demand of the population is to increase number of tube-wells through infrastructure construction. Infrastructure may be constructed due to availability of more funds in the utility account. Addition of more tube-wells in the system will tend to increase the maintenance cost of the system. This in turn will increase the operational cost as more number of staff will be required to operate water supply system. Total expenditure incurred will be increased and will lead to low fund balance.

2.5. Feedback Loop in capital expenditure (B-4)

The operation of a reinforcing feedback loop (R-1) may also be constrained by the existence of the balancing feedback loop (B-4). The desired demand of the population of Hayatabad Peshawar may be fulfilled by increase in number of tube-wells through infrastructure construction. Infrastructure may be constructed due to availability of more funds in the utility account. Addition of more tube-well in the system will tend to increase the expenditure incurred on infrastructure construction i-e capital expenditure. Total expenditure incurred will be increased and will lead to low fund balance.

2.6. Feedback Loop in water supply management (R-2)

Addition of more tubewells in system as a result of infrastructure construction will increase number of tubewells and in turn more water will be added in the system. More water will be consumed as required to cater water demand of the beneficiaries. Excessive consumption of water available in system will reduced the excess water stock and will tend to increase water consumption Hence pressure will be increased on the municipality to add more tube well by construction of new infrastructure to fulfill the desired demand. This constitutes the 2nd reinforcing feedback loop (R-2).

2.7. Feedback Loop in service satisfaction (B-5)

The operation of reinforcing feedback loop (R-2) may be constrained by the existence of balancing feedback (B-5). Utility having excess water in stock will tend to satisfy the costumers in terms of water availability in terms of quality and quantity. This will increase attraction and will promote legal connections. More the number of connections more water will be consumed rendering less excess water in the stock.

III. SYSTEM DYNAMICS MODELLING:-

System dynamics is a feedback based modeling approach developed by J.W. Forrester in 1956. The building block of system dynamics are stock, flows, connecter and converter Figure 2 to Figure 5

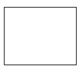

Figure 2: Stock

Figure 3: Connector

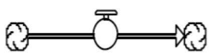

Figure 4: Flow

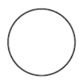

Figure 5: Converter

Mathematical representation of Stock and Flows:-

The conventions of stock and flow diagram (J. W. Forrester, 1968), was based on hydraulic metaphor, water flowing into and out of the reservoir. Stock resembles as a reservoirs/tank/tub. The quantity of water at any time is the accumulation of water in the reservoir less the water flowing out through the drain. In exactly the same way, the quantity of material at any time in the stock is the accumulation of the flows of material into and less the flows of material out. The stock and flow diagram can be precisely represented in the following mathematical forms. The flows (Inflow and outflow) are integrated by the stocks. The rate of change of the stock is the net flow (inflow-outflow) of the stock. (Sterman, 2000).

$$Stock(t) = \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds + Stock(t_0)$$

Stock has the initial value of $Stock(t_0)$whereas t_0 & t is the initial and current time. The flow rates are the inflow into the system and outflow to the system at any time s in the interval between initial time and current time (to &t). The units of inflow and outflow are the units of the stocks divided by time. The net rate of change of stock can be determined by its derivative (inflow less the outflow), as below(Sterman, 2000):-

$$d\ (Stock)/dt\ =\ Inflow(t)\ -\ Outflow(t)$$

State of the system is characterized by the stock and provide basis for the actions. Stock guides the decision maker whether they are providing the stock with the requisite information or otherwise. The system is provided with inertia and memory by the stock, the past event is accumulated by the stock and stock can only be changed due to inflow and outflow. Without any changes in the stock the past accumulation persists. (Sterman, 2000).SD model for sustainable management of water supply system at Hayatabad is presented at Figure Figure 6 through 9

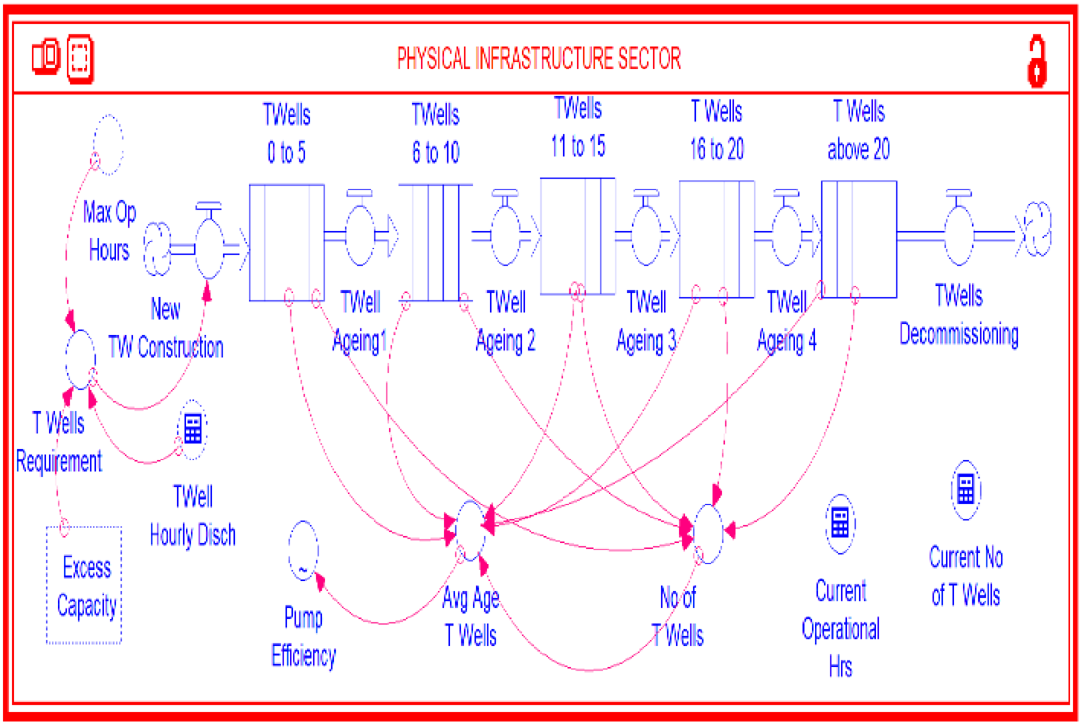

Figure 6: SD Model (Physical Infrastructure Sector)

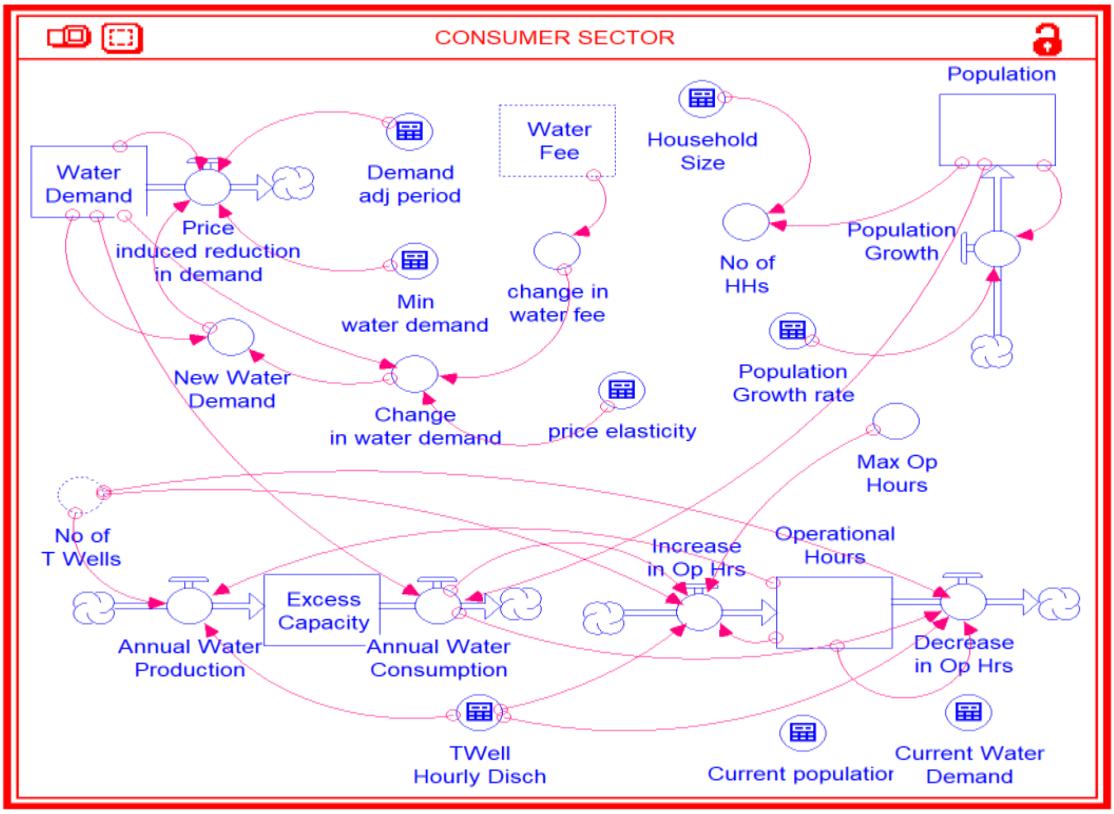

Figure 7: SD Model (Consumer Sector)

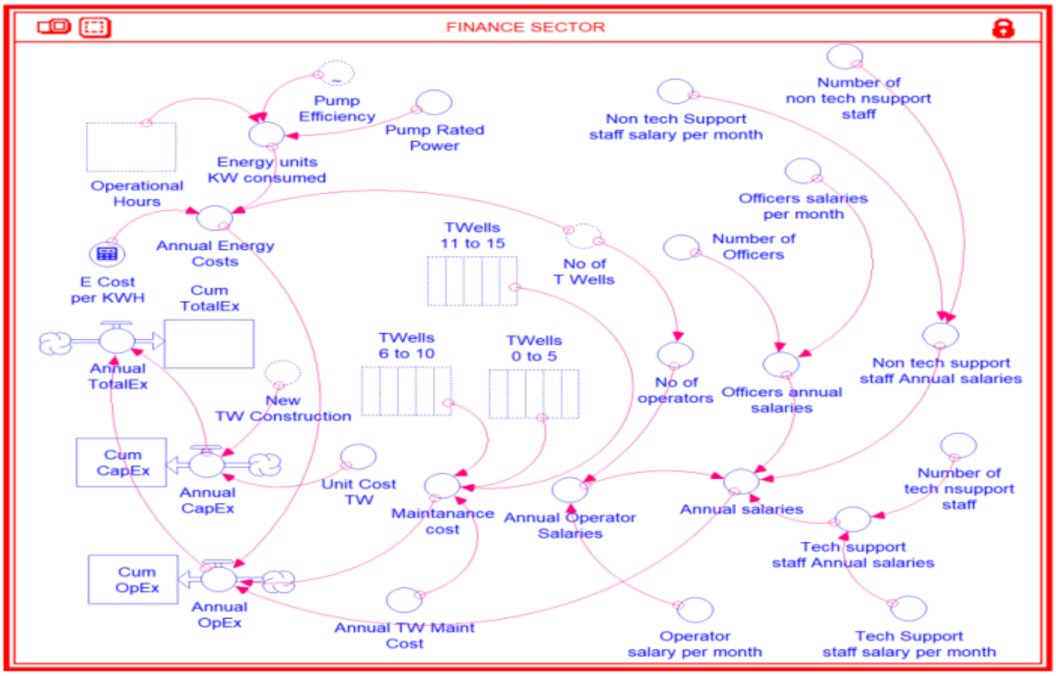

Figure 8: SD Model (Finance Sector)

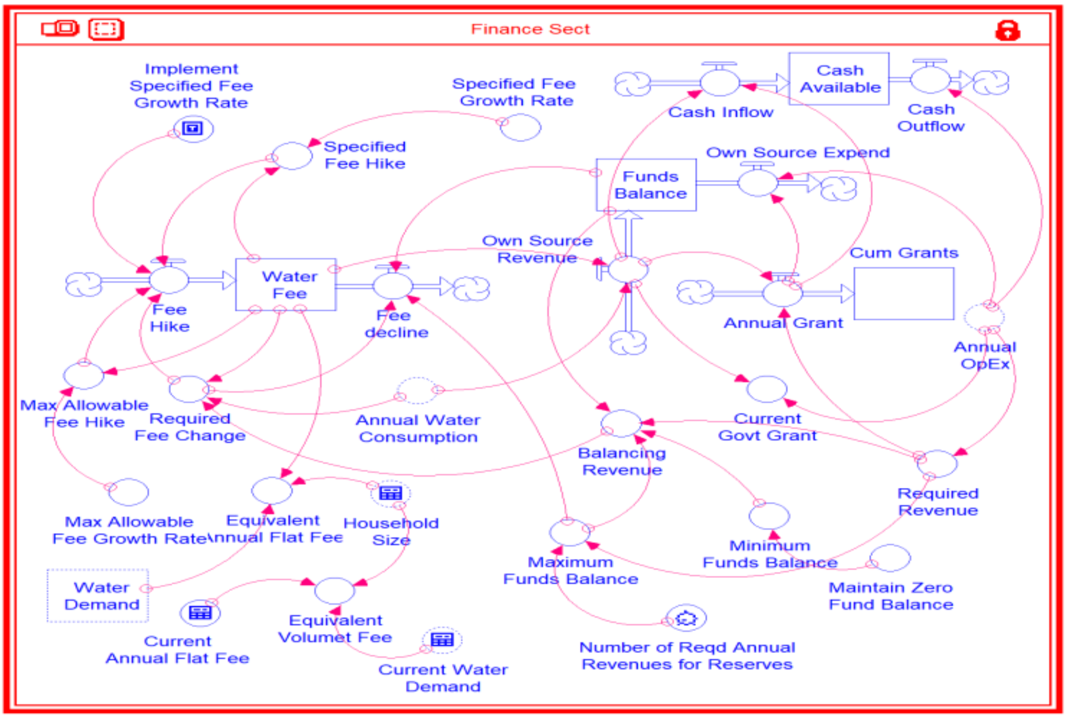

Figure 9: SD Model (Finance Sector)

3.1 System Dynamics model demonstration

4.1 The system dynamic model of water supply system of Hayatabad is presented at Figure 6 through 9 which consist of several interconnected feedback loops amongst physical Infrastructure, water supply & consumer sector and finance sectors as detailed below:-

3.1.1 Physical infrastructure sector:-

The Physical infrastructure sector includes tubewells, pipe networks, pumping machinery and water reservoir etc. Water is pumped from tubewells into piping network through pumping system and then supplied to houses. The SD Frame work consists of conveyor structure introduced to take into account the designed life of tubewells. Tubewells are designed for 25 years as per standard engineering practices. After completing the service life the tubewells gets decommissioned. In some rare cases the tubewells are functional after passing the service life with a low specific yield. Total numbers of tubewells at Hayatabad are 73. Tubewells are divided into five age groups (0-5 years), (6-10 years), (11-15 Years), (16-20 Years) and (21-25 Years). The average life of each age group is 2.5, 7.5, 12.5, 17.5 and 22.5 years.

The age group (0-5), (6-10), (11-15) and (16-20) consists of 15 tubewells each whereas age group (21-25) consists of 13 tubewells. After each simulation the highest age group moves to the next age group. It is assumed that after completion of the useful service life the tubewells get out of order and got decommissioned. A variable tubewell requirement is introduced to add tubewells in the system if required. A function average tubewell age and pump efficiency is introduced to take into account the aging impacts of pumping machinery. Figure 6

3.1.2 Consumer sector:-

Water supply and demand is estimated in the consumer sector during the simulation period. The volume of water consumed is determined through the stock water demand. The flow price induced reduction in demand causes change in the stock water demand. Price induced reduction in demand is a function of minimum water demand, demand adjustment period, price elasticity and new water demand. Price elasticity is the percentage change in the demanded quantity of good divided by the corresponding percentage change it its prices (Lipsey and Chrystal (1999). Water demand is reduced by the price induced reduction in demand when the water fee increases. In Hayatabad flat water fee per connection per year is applicable. In order to ensure sustainability and impose water conservation measure volumetric water fee is introduced and proposed. Volumetric water fee is calculated based on the existing linear rates per connection. When municipality starts charging water on volumetric rates the price elasticity of demand may reduce water demand as fee increase in (Rs/m^3). As water fee increases the consumer will tend to adopt water conservation measure by retrofitting the plumbing fixtures and installation of payroll valve/controlled flow devices to reduce water bills. Water demand is assumed to be constant at minimum water demand even water fee increase. Price induced changes in water consumption occurs over time and not instantaneous.
The converter minimum water demand is set at a min water demand limit of 200 LPCD. Price induced reduction in demand is estimated using the pricing elasticity over the demand adjustment period. Water consumed is calculated from multiplication of water demand and population. In case excess capacity stock is declining toward negative values the variable tubewell requirement will add requisite new tubewells into the system. When price induced reduction in demand is employed the response of the consumers will be decrease in water demand which is not instantaneous but occurs over time. A demand adjustment period of 10 years is taken in this study. The stock operational hours is introduction to calculate the desired operational hours due to variation in water demand after application of price induced reduction in demand. Figure 7

3.1.3 Finance sector:-

The finance sector consists of several inter-connected stocks and flow structures. Stock of cumulative operational expenditure is introduced which is replenished through the inflow annual operational expenditures whereas annual operational expenditures is a function of annual energy cost, maintenance cost incurred on maintenance of machinery and civil work, and annual salaries of the staff. Annual energy cost is calculated from multiplication of energy cost per kilowatt hour and energy unit's kilowatt consumed whereas energy unit's kilowatt consumed is a function of pump rated power, operational hours and pump efficiency. Pump efficiency is a graphical function of the age of pumping machinery as age advance pump efficiency drops and consume more energy in KWH. Maintenance cost is a function of annual tubewell maintenance cost and tubewells with age group (0-5), (6-10) and (11-15).
The stock of cumulative capital expenditure is introduced which is replenished through the inflow annual capital expenditure. The annual capital expenditure is a function of new tubewell construction and unit cost per tubewell. A stock of cumulative total expenditure is introduced which is replenished through the inflow annual total expenditure whereas annual total expenditure is a function of annual capital expenditure and annual operational expenditure. Equivalent volumetric fee is introduced which is a function of current annual flat fee, house hold size and current water demand. A volumetric fee is calculated which is taken into account in further calculations.
The Stock funds balance is introduced which represents funds balance at each time step which is replenished through the inflow own source revenue and reduced by the outflow own source expenditures. The stock cumulative grants is introduced which is replenished through the inflow annual grant. The required revenue is a function of annual operational expenditure. PDA relies on government of KP for grants to cover O&M expenditure. The Stock cash available is introduced which is replenished by cash inflow and reduced by the cash outflow**.** The convertor balancing revenues is introduced which is a function of funds balance, minimum funds balance, required revenue and maximum funds balance. Maximum funds balance is a function of required revenue and number of required annual revenues for reserves. Whereas minimum funds balance is a function of maintain zero funds balance. A stock water fee is introduced which track the price per unit volume of water charged to the consumers. The utility may be termed as financially self-sustainable when the revenue equals or exceeds exceeds O&M expenditures. Figure 8 and 9

IV. MODEL SIMULATION:-

A number of simulations were performed to ascertain the impacts of feedback loops on water supply system. Summary of simulation Scenarios are presented at Table 1. Results of simulation are presented are presented in Figure 10 through 15. Tabular summaries of these results are presented in Tables 2 and 3.

Table 1: Summary of Simulation Scenarios

Scenario	Specified fee growth rate (%)	Maximum Allowable fee growth rate (%)	Implement specified fee growth rate	Zero Funds balance enforced	Price Elasticity of demand
I	0	0	Yes	No	0
II	10	0	Yes	No	0
III	10	0	Yes	No	-0.35
IV	0	10	No	Yes	0
V	0	15	No	Yes	-0.35
VI	*0*	*100*	*No*	*Yes*	*-0.35*

Results of Simulation

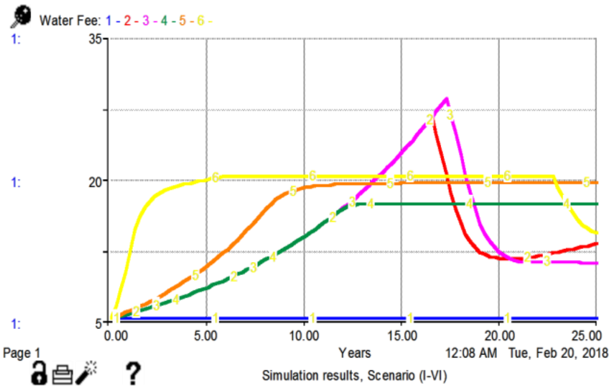

Figure 10: Simulation results, Water Fee (Scenario I-VI)

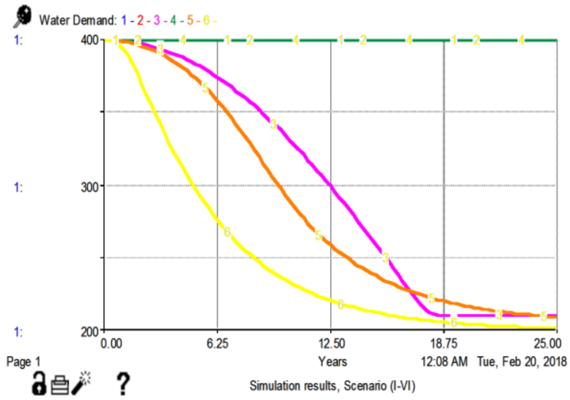

Figure 11:Simulation results, Water demand (Scenario I-VI)

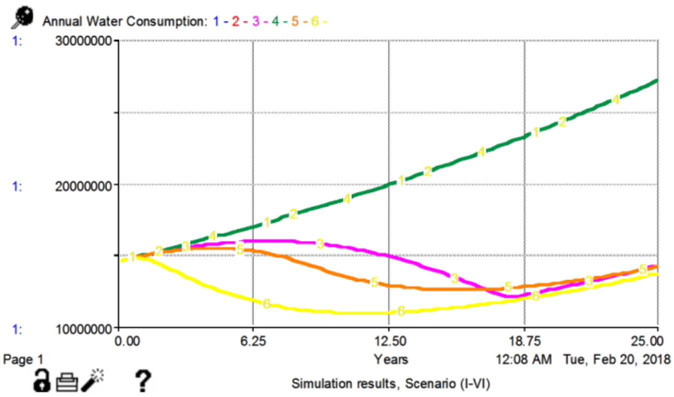

Figure 12: Simulation Results, Annual water consumption (Scenario I-VI)

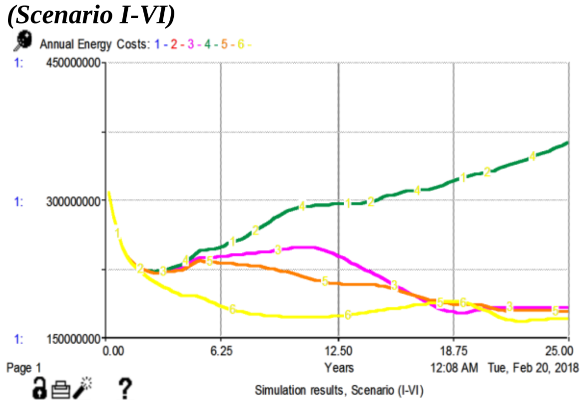

Figure 13:Simulation results, Annual Energy Cost (Scenario I-VI)

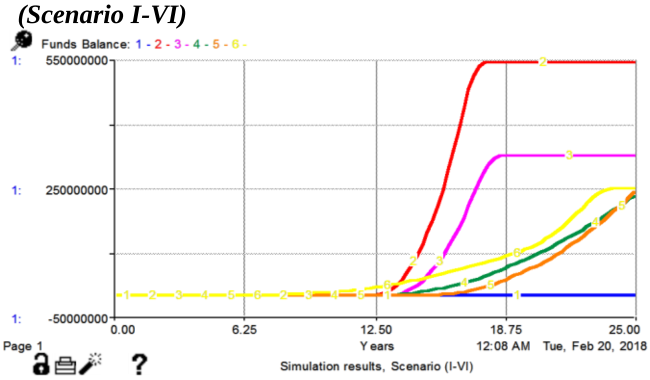

Figure 14: Simulation results, Funds Balance (Scenario I-VI)

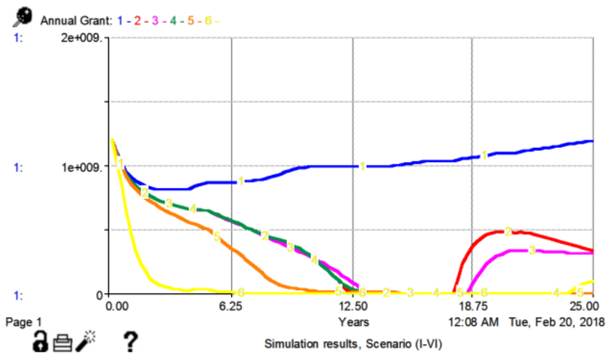

Figure 15: Simulation results, Annual Grant(Scenario I-VI)

Figure 10show simulation results of water fee of the scenarios (I-VI). In Scenario-I, water fee is kept constant at flat fee Rs 6,100 per connection per year and not allowed to increase. Water fee graph shows a constant trend. Flat fee is converted into equivalent volumetric water fee i-e 5 Rs/m^3. In Scenario-II, Water fee is allowed to increase at the rate of 10% per annum. The Graph shows an increasing trend and reaches from 5 Rs/m^3 to 27 Rs/m^3 at the year 16.5. The funds balance exceeds the maximum funds balance at year 16.5 and the fee starts decline and reach to 12 Rs/m^3 in the years 23.25 and again starts increasing and reaches 13 Rs/m^3 at year 25. In Scenario-III, water fee is allowed to increase at the rate of 10% per annum. The graph shows an increasing trend and reaches from 5 Rs/m^3 to 29 Rs/m^3 at the year 17.5. The funds balance exceeds the maximum funds balance at year 17.5 and the fee starts decline and reach to 11 Rs/m^3 in the years 25. In Scenario-IV, Water fee is allowed to increase at the rate of 10% per annum. The Graph shows an increasing trend and reaches from 5 Rs/m^3 to 17 Rs/m^3 at the year 12 and then remains constant at Rs 17 Rs/m^3 upto year 25. In Scenario-V, Water fee is allowed to increase at the rate of 15% per annum. The graph shows an increasing trend and reaches from 5 Rs/m^3 to 20 Rs/m^3 at the year 13.25 and then remains constant at 20 Rs/m^3 upto years 25. In Scenario-VI, Water fee is allowed to increase at the rate of 100% per annum. The graph shows an increasing trend and reaches from 5 Rs/m3 to 20 Rs/m3 at year 4 and remains constant upto year 22.75 and then declines to 15 Rs/m3.

Figure 11show simulation results of water demand of the scenario (I-VI). In Scenario-I, price elasticity of demand is taken is zero therefore water demand show a constant trend. The consumer is using max water as water fee is constant and the consumers have the freedom to use excess water. In Scenario-II, price elasticity of demand is taken is zero therefore water demand show a constant trend. In Scenario-III, price elasticity of demand is taken as -0.35. Increase in water fee is causing decrease in water demand. Water demand may not drop below the minimum water demand of 200 LPCD even water fee increase. When price elasticity of demand in imposed water demand starts decreasing from 400 LPCD and at year 18.5 water demand drop to 209 LPCD. In Scenario-IV, Price elasticity of demand is taken is zero therefore water demand show a constant trend. The consumer is using max water as water fee is constant and the consumers have the freedom to use excess water. In Scenario-V, Price Elasticity of demand is taken as -0.35. Increase in water fee is causing decrease in water demand. When price elasticity of demand in imposed water demand starts decreasing from 400 LPCD and at year 25 water demand drop to 208 LPCD. In Scenario-VI, Price Elasticity of demand is taken as -0.35. Increase in water fee is causing decrease in water demand. When price elasticity of demand in imposed water demand starts decreasing from 400 LPCD and at year 25 water demand drop to 201 LPCD.

Figure 12show simulation results of water consumption of the scenarios (I-VI). In Scenario-(I & II), Water consumption graph show an increasing trend as there is no restriction on water usage. In Scenario-III, Water consumption show a decreasing trend when price elasticity of demand is imposed. In response to increase in prices the consumer behavior toward water usage is sensitized and water consumption starts decreasing. In Scenario-IV, Water consumption graph show an increasing trend as there is no restriction on water usage. In Scenario-(V & VI), water consumption is decreased when price elasticity of demand is imposed.

Figure 13show simulation results of annual energy cost of the scenarios (I-VI). In Scenario (I & II) annual energy cost show decreasing trend upto year 3 and then starts increasing. In Scenario (III, IV, VI & VI), with increase in water fee, water consumption is decreased which cause decrease in energy consumption.

Figure 14show simulation results of the utility account balance of the scenarios (I-VI). . In Scenario-I, The utility account balance is fluctuating between 0 and negative values which means the revenue collected in terms of Water fee is not capable to cover the O&M expenditure. In Scenario-II, at year 12.5 funds balance is 0 and starts increasing and reach max at year 17.5 and then remain constant upto year 25. In Scenario-III, at year 12.5 funds balance is 0 and starts increasing and reach max at year 18.5 and then remain constant upto year 25. In Scenario-IV, at year 13.25 funds balance is 0 and starts increasing and reach max at year 25. In Scenario-V, at year 12 funds balance is 0 and starts increasing and reach max at year 25. In Scenario-VI, at year 6.5 funds balance is 0 and starts increasing and reach max at year 25

Figure 15show simulation results of cumulative grants at year 25 of the scenario (I-VI). In Scenario-I, the cumulative grants show an increasing trend. The utility is relying on government for grants to cover the expenditure incurred on O&M. In Scenario-II, the utility is relying on grants upto year 12. At year 12 to 18 no grants are received. At year 18 to 25 the utility relies on grants again to cover the expenditure incurred on O&M. In Scenario-III, the utility is relying on grants upto year 13.25. At year 13.25 to 18.75 no grants are received. At year 18.75 to 25 the utility relies on grants to cover the expenditure incurred on O&M. In Scenario-IV, the utility is relying on grants upto year 12. At year 12 to 17.75 no grants are received. At year 17.75 to 25 the utility relies on grants to cover the expenditure incurred on O&M. In Scenario-V, the utility is relying on grants upto year 10. At year 10 the utility is turned to financial self-sustainable utility and produced revenues, sufficient to cover expenditure incurred on O&M. In Scenario-VI, the utility is relying on grants upto year 3.5. At year 3.5 the utility is turned to financial self-sustainable utility and produced revenues, sufficient to cover expenditure incurred on O&M.

Table 2: Summary of Simulation Results

Scenario	**Initial Water Fee (Rs)**	**Max Water Fee(Rs)**	**Final Water Fee at year 25(Rs)**	**Max Water demand (LPCD)**	**Final Water dem at year 25 (LPCD)**	**Cum Water Consumption at year 25 (m^3)**
I	5	5	5	400	400	498,703,353
II	5	27	13	400	400	498,703,353
III	5	29	11	400	209	360,364,143
IV	5	17	17	400	400	498,703,353
V	5	20	20	400	208	346,237,771
VI	5	20	15	400	201	302,682,761

Table 3: Summary of Simulation Scenario at Year 25

Scenario	Cumulative Operational Expenditure Billion (Rs)	Cumulative Capital Expenditure Millions (Rs)	Cumulative Total Expenditure Billion (Rs)	Cumulative Grants Billions (Rs)	Funds Balance Millions (Rs)	Own Source Revenue Billions (Rs)	Cumulative Energy Cost (Rs)
I	8.742	308.00	9.050	6.137	0	2.604	7.184
II	8.742	308.00	9.050	2.947	386.312	6.181	7.184
III	7.106	84.00	7.190	2.758	428.660	4.776	5.758
IV	8.742	308.00	9.050	1.868	380.212	7.254	7.184
V	6.523	156.00	6.679	1.322	239.939	5.440	5.249
VI	5.869	136.00	6.005	0.487	308.013	5.689	4.633

V. CONCLUSIONS

5.1 The System Dynamic (SD) model is a convenient decision support tool to explore different policy options for resource conservation and financial sustainability. The SD model developed can be easily used by decision makers.

5.2 Non adoption of water metering and charging the consumer on per connection/flat fee the consumers enjoys the freedom of misuse of precious water resources.

5.3 Increase in water fee sensitize the consumers to controlled/nominal water usage and tends the system toward water conservation.

5.4 The utility is financially non-sustainable as the expenditure on O&M exceeds the revenue.

VI. POLICY PROPOSALS

6.1 Adoption of water metering, charging the consumer on volumetric fee basis (Rs/m^3) and incremental increase in fee may be adopted for financial self-sustainability of the utility.

6.2 Withdrawal of the grants/subsidy given by government of KP when the utility is financially self-sustainable.

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