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Research paper

Technical and Economic Synergetic Effect in Conditions of Innovative Transformation of Water Supply and Sewerage Economy

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Abstract

There has been conducted a study of interdependence between technical and economic researches of diameters calculation of water pressure supply and sewerage networks. There has been offered the method to calculate the optimal diameter of water pressure supply and sewerage networks made of polymeric pipes. This qualitative and quantity methodology includes, firstly, the observation review of Ukrainian water supply and sewerage networks and, secondly, the survey of financial and economic documents of water supply and sewerage economy. The factual basis of the study is the initial data of statistical monitoring of work conditions of water pressure supply and sewerage networks. The paper proposes using the net present value (NPV) to calculate the optimal diameter of water pressure pipes made of polymeric materials, which, finally, decreases capital and exploiting expenditures and considers the maximum income for water supply and sewerage economy (WSE).

Key words: *cost, the diameter of a pipeline, the net present value (NPV), the synergistic effect, water pressure supply and sewerage networks.*

1. Introduction

Technical and economic synergic effect in conditions of innovative transformation of water supply and sewerage economy (WSE) means the calculation the maximum profit while expenditure minimization, including the way of introduction of methodology that quantifies the optimal diameter of pipelines made of polymeric materials with the usage of economic factors for optimization or reconstruction of the water supply system.

For it there have been formed such study tasks:

 to analyze the theory of calculation of net discounted income (NPV) for enterprises of water supply and sewage economy;

 to use NPV for calculation of the optimal diameter for pipes made of polymeric materials;

 to produce and explain the methodology that quantifies the optimal diameter of pipelines with the usage of NPV, which is very essential for countries with economy in transition.

The theoretical and methodological basis for the study includes the theory founded on the synergic effect of technical and economic calculation of the pipes diameter of external water-pipeline nets with the help of NPV.

The actual research has become the method of discounting and calculating NPV that gives the possibility to go through the choice of the pipes diameter as a usual and, simultaneously, difficult economic system with allocation of detached elements and definition of links between them.

The factual basis of the research is primary data of statistic observation of external pipelines of systems of water supply and sewerage economy and theoretical scrutiny of the main economic figure of NPV.

There have been made theoretical and analytic studies for defining the main economic figure of NPV while choosing the diameter of external water pipelines made of polymeric materials.

There have been systemized the main parameters of NPV that allow determining with the assistance of technical and economic modeling the most optimal diameter of pipeline depending on the water expenditure with minimal economic losses in modern market circumstances.

To reach set goals there has been devised the math and economic algorithm of calculation of the optimal diameter with the help of NPV.

Basing on got results, there have been given the recommendations for the actuality of calculation of the optimal diameter with the aim to refine economic figures in the structure of WSE.

Having taken into account the models of economic processes there has firstly been offered the full methodology of technical and economic calculation of water supply systems for defining the optimal diameter of external water pipelines made of polymeric materials with the usage of economic factor of discounting.

While it there has been:

 defined the correlation between the diameter of a water pipeline, exploiting and capital expenditure, self-cost, tariff and NPV;

 advanced the math and economic algorithm for optimization of diameters of water supply nets made of polymeric materials;

 explained scientifically the economic and technical methodology of choosing the optimal diameter of polymeric pipelines of water supply nets.

Theoretical points of technical and economic research of water supply systems WSE have been led to the level of produced algorithm and showing the precise methodology and recommendations

as for defining the optimal diameter of polyethylene pipes for water supply nets WSE.
There have been suggested the quantity rate of the synergic effect as an instrumentality to influence the pipes cost with the goal to account the synergic effect while calculating the self-cost of water.
Offered methodology can be used in conditions of innovative transformation of WSE and applied by workers of the WSE field, as well as, specialists of economics and management on enterprises.
The optimal eventual result, including choosing the optimal diameter of pipes with the best prices figures is to be reached while the process of receiving the synergic effect from technical and economic decisions of investing project of water supply and sewerage economy with the choice of the optimal diameter of pipeline systems of water supply depending on water expenditure.
One of the main peculiarities of modern science (finances) implicates the synergic correlation of two components: economic and technical [5-7].
In the view of the economic component, during projecting and reconstructing of water supply nets a responsible stage is to calculate the financial figure NPV with the help of technical hydraulic calculation of water pipelines. The better there has been done the hydraulic calculation and chosen pipes materials, the better not only is its successive work, but its financial component also is, including the increasing of work efficiency of water supply and sewerage economy (WSE).
In these theoretical studies there are investigated polyethylene pipes typed PE 80 and PE 100 according to the standards, which are currently being introduced in WSE.
The appearance of pipes made of polymeric materials signifies changes in calculation that must be rated with the assistance of economic factor. The definition of efficient correlation between water expenditure, the pipes diameter and pipes material gives the feasibility to reduce expenditure on materials highly and diminish self-cost.
It confirms one more time the actuality of an issue and necessity of future scientific and theoretical calculations directed to reduction of capital and exploiting expenditures, self-cost, water tariffs and increasing of NPV particle on enterprises.
Diverse aspects of the problem of economic factor influence on the choice of the water pipelines diameter were analyzed in the works [1, 3]. There has been analyzed the usage of discounting for optimization of water supply nets in the works of Tkachuk O., Orlov V. and Kalyuzhniy A.[2, 9, 4, 8].
Mentioned works attest the fact of permanent attention to importance of economic factor while calculation water supply nets, but the question of the choice of effective economically profitable diameter of water pipelines made of modern materials leaves not fully solved.
The income for enterprises of WSE depends on the resources market and available raw base. The introduction of innovative equipment and materials for water supply nets implies changes in hydraulic calculation of pipelines.
The choice of the optimal diameter of pipes made of polymeric materials with consideration of economic factor is very significant. Now these questions are not researched in the literary sources.
There have been probed economic and technical components of cost of water supply for population, public establishments and industrial enterprises with account of NPV.
The task of this analysis is to look through possible technical and economic decisions for provision of explained projecting or reconstructing of water supply nets WSE.
Also it implies the theoretical research of economic factor and feasibility to select working parameters of the system, which will let provide positive result for definition of the optimal diameter with the help of economic criterion NPV.
Besides pointed higher, we intend to determine the optimal diameter of water pipelines made of polymeric materials and compare the effectiveness of this methodology for the diameter choice with available ones.
This issue is observed and resolved with the reduction of cost of exploitation or reconstruction of water supply systems WSE.

2 Main Body

Water supply nets in Ukraine were set, generally, in last century, the pipes material was, in major cases, steel and cast iron. That's why, the deterioration of nets in Ukraine is 30-40%, because the term for metal pipes exploitation occupies about 50 years. So, the important question to solve the problem of qualitative water provision with optimal cost of water is the state of water supply nets. Very important point is to replace old metal pipes with new ones made of contemporary materials and less lively cutting.
Currently, there are popular pipes of polymeric materials, especially polyethylene ones [10, 11].
Polyethylene is an alternative for traditional materials for pipes – cast iron, steel or cement – according to technical and economic reasons. Vast spreading and technical development of polyethylene pipes are unraveled with particular characteristics of materials.
Polyethylene water pressure pipes are used during building and reconstructing of external pipelines that give water for accommodative and public economic of cities and villages as well as industrial consumers. Polyethylene pipelines can transport other gas and liquid combinations for which polyethylene is chemically adjusted. These water pipelines are produced according to standards. Labels of polyethylene, according to which they are divided, are such:
PE 63 (was invented firstly, not being almost used now);
PE 80;
PE 100.

Table 1: The comparison of PE-80 and PE-100

The material properties	The unit of measurement	Value	
		PE-100	PE-80
Thickness	Kg/m^2	935 - 960	
MRS (minimal longtime strength)	MPa	10	8
The scope of strength	N/m^2	18 - 29	
Relative prolonging while separating	%	>350	
The temperature of fragile destruction	°C	< - 70	
Solidness	SHORE D	55-60	
Hitting strength	kJ/m^2	Not destroyed	
The coefficient of temperature widening	mm/m °C	0,15 - 0,20	
Loading on rubbing	Н/м2	>15	

One of the main figures, which characterize polyethylene pipes, is Standard Dimension Ratio or SDR.

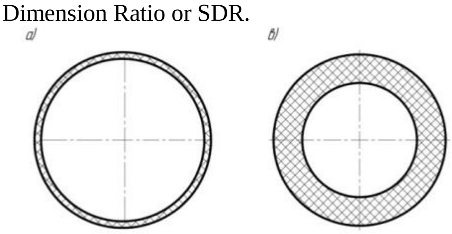

Fig.1: The connection between SDR and thickness of a pipe side
a) PE100 SDR41 b) PE 100 SDR6

This parameter is ratio of external diameter (nominal) and the side thickness (nominal too):

$$SDR = dn / en \tag{1}$$

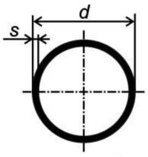

Fig.2: The correlation of SDR

It is obvious that with increasing of SDR the thickness of a pipe side cuts down and, in the contrary, the bigger the thickness of a PE-pipe side is, the smaller SDR value is. However, practically, SDR figure is a standard parameter.
To calculate the nominal thickness of a PE-pipe side is possible with help of such a formula:

$$en = dn / SDR, \quad (2)$$

SDR is up to the series of polyethylene pipes (S):

$$SDR = 2S + 1, \quad (3)$$

where *S* is the value that corresponds with typing size of an available polyethylene pipe.
The series of a polyethylene pipe shows how many times the voltage appearing in a pipe side under the maximum operation pressure (MOP) is stronger that this pressure. However, the definition "a pipe series" is not actual in a practical way, so long as it is an ephemeral characteristic, which does not contain physical content.
The maximum operation pressure is such pressure during which the term of operation of a pipeline is not less than 50 years if all conditions of pipes exploitation (and also their transportation and saving) are followed. MOP is calculated according to the formula:

$$MOP = 2\, MRS / C(SDR - 1), \quad (4)$$

where *MRS* is the minimum value of polyethylene tightness;
C is the coefficient of pipeline installation (it is also called as "the coefficient of tightness saving"), which depends on conditions of pipes installation and takes different values (1,25 is for polyethylene pipes providing with cold water and 2 ÷ 3,15 is for pipes that transport combustible gases).
The necessity of this issue observation is dictated not only by financial requirements, but also by attempt to refine accommodative and public circumstances of population.
Let's go through the fact of synergism and its influence on the total effect that boosts the action of each component detachedly more precisely.
The synergic effect from union of economic and technical decisions for systems of water economy is demonstrated on the fig. 3.
The efficiency of investing projects is an essential stage during the process of investments management. The correctness of final decision making is up to excellence of this rate making.
One of methods to explain investing projects that includes discounting usage is the method of the net present value (NPV) calculation. As money income is divided in time, it is discounted with the help of the coefficient being set by investor who takes into account the annual percentage of returning that he wishes or can have on invested by him capital.
The net present value is defined by known formula:

$$NPV = NI - IE, \quad (5)$$

where *NI* is the net income (being for current cost) for the whole period of investing project exploitation.
IE is the sum of investing expenditures directed to realize the investing project

The formula (4) can be transformed in such a way:

$$NPV = \frac{NI}{(1+i)^t}, \quad (6)$$

i is the percent rate for discounting of sums of money flow of this project that is quantified on record to discount rate of NBU, %;
t is the term of project realization.
For water supply nets we accept the average term of building as t = 7 years.
The net income is the product of self-cost of general amount of goods *C*, which are sold on the norm of enterprise profitability *Ep*:

$$NI = C \cdot E_p, \quad (7)$$

where *Ep* is the norm of enterprise profitability,
C is self-cost of goods.
The norm of profitability is one of the main figures of expenditure efficiency. It is calculated during project development according to complicated calculations and then it must be approved by administration of an enterprise depending on economic factors but not more than 20%.
The self-cost is a synthetic figure of efficiency, that's why during its calculation and usage in management system of production it is needed to be very attentive. It is one of the most significant levers in economical mechanism of production management [59]. The eventual figure of enterprise activity (profitability) depends on the self-cost.
For water supply and sewerage economy the self-cost of the general amount of used by consumers water can be accepted as the sum of exploiting expenditures of an enterprises divided by the general amount of used water per year.
So, the self-cost is calculated by the formula:

$$C = \frac{Э}{Q \cdot 365} \quad (8)$$

where Q is daily water expenditure, m^3/day,
$Э$ is the sum of exploiting expenditures.
Exploiting expenditures are the sum of expenditures on electricity, salary, amortization and unit deductions:

$$Э = Э_{el} + Э_{am} + Эu.e. + Эs \quad (9)$$

where $Э_{el.}$ is expenditure on electricity and is calculated by the formula:

$$Э_{el} = 8760\sigma \cdot \gamma \cdot Q \frac{9{,}81}{\eta_{ps}} \left(H_0 + k \frac{Q^{\beta}}{D^m} l \right), \quad (10)$$

where 8760 is the annual amount of working hours of a pump station, *year*;
σ expresses tariff on electricity for public establishments of companies in water supply and sewerage economy that 0,18 *c.u./kW*;
γ is the coefficient of inequality of electricity usage, we accept steady daily work of a pump station, $\gamma = 1$;
η_{ps} is the energy conversion efficiency (ECE) of a pump station, η_{ps} it is accepted as 80%;
k, n, m are the coefficients and figures of power in the formula of pressure losses according to the length for i field,
D is the diameter of a pipeline, *m*;
l is the length of a pipeline, *m*;
H_o is the free pressure that means the height of water pillar under surface, which is set in a piezometric tube put through to any points of sewerage net.
The figure of necessary free pressure for water supply to the farthest and situated on the highest point water storage appliance is calculated according to the formula. But during calculations it is simplified.

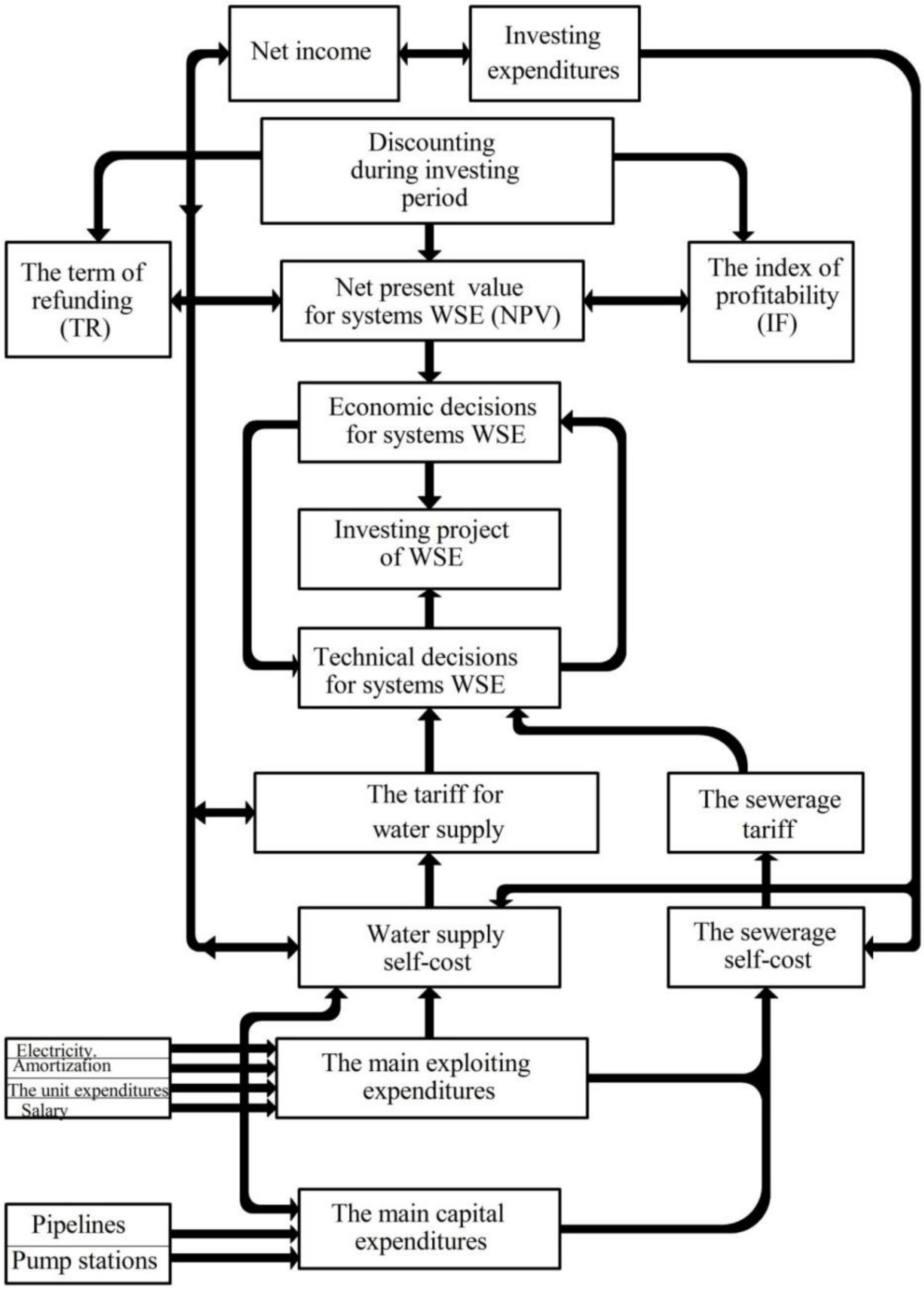

Fig. 3: The process of acquirement of the synergic effect from technical and economic decisions of the investing project of water supply and sewerage econom

The sum of depreciation and unit expenditures:

$$Э_{am} + Э_{u.e.} = p_1\left(a + bD^{\alpha}\right)l + p_2 fr\frac{9{,}81}{\eta_{ps}}Q\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right),$$

(11)

where p_1, p_2 are the norms of depreciation, the size of depreciation deductions expressed in percentage to primary cost of main funds;

a, b, α are the coefficients and figure of power for i field of nets and water pipes.

The norm of depreciation is periodically being specified and changed. For water economic complex the norm of depreciation is accepted: for constructions and buildings of the pump station it is 8%, and for water pipes there is 24%;

$Э_s$ is the expenditure on the workers' salary. While comparing of variants we deem salary the same, that's why we neglect it in calculation.

Investing expenditure includes building and servicing the pump station and water pipes:

$$IE = K_{ps} + K_{pipe} == frN + K_{pipe} =$$

$$= fr\frac{9{,}81}{\eta_{ps}}Q\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right),$$

(12)

where f is the toll of the pump station referred to the unit of set power;

r –is the coefficient that includes the role of i field in work of water pipelines nets, it's accepted as 1.

We put calculating formulas (7)-(12) in the general formula NPV (5).

Exploiting expenditures:

$$Э = 8760\sigma\cdot\gamma\cdot Q\frac{9{,}81}{\eta_{ps}}\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right) + p_1\left(a + bD^{\alpha}\right)l +$$

$$+ p_2 f\cdot r\frac{9{,}81}{\eta_{ps}}Q\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right).$$

(13)

The self-cost of used water for population and industrial establishments will be so:

$$C = \frac{8760\sigma\cdot\gamma\cdot Q\frac{9{,}81}{\eta_{ps}}\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right) + p_1\left(a + bD^{\alpha}\right)l}{Q\cdot 8760\cdot 3600}\cdot E_p +$$

$$+ \frac{p_2\cdot f\cdot r\frac{9{,}81}{\eta_{ps}}Q\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right)}{Q\cdot 8760\cdot 3600}\cdot E_p.$$

(14)

Let's put C (14) and IE (12) in the formula NPV (15):

,

$$NPV = \frac{\frac{\left[8760\sigma\gamma Q\frac{9{,}81}{\eta_{ps}}\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right) + p_1\left(a + bD^{\alpha}\right) + p_2 fr\frac{9{,}81}{\eta_{ps}}Q\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right)\right]}{Q\cdot 8760\cdot 3600}E_p}{(1+i)^t} -$$

$$- \frac{fr\frac{9{,}81}{\eta_{ς^3}}Q\left(H_0 + k\frac{Q^{\beta}}{D^m}l\right)}{(1+i)^t} - \frac{\left(a + bD^{\alpha}\right)l}{(1+i)^t}$$

(15)

We get rid of three-level fraction, open brackets and divide a fraction on three. Then we simplify and put the common multiplier beyond the brackets.

During projecting or reconstructing a water pipelines net it is needed to consider economic factor NPV. If NPV during calculations is positive, then projecting productions are worth realizing. Such a project is efficient and leads to increasing of the investor's income and calculated diameter will be optimal in this case. So, we take the first fraction derivative through NPV and equalize to 0:

$$\frac{dNPV}{dD} = D^{\alpha-1}\frac{E_p(1+i)^t\alpha\cdot b\cdot l\cdot p_1}{8760Q\cdot 3600} - \frac{D^{\alpha-1}\alpha\cdot b\cdot l}{(1+i)^t} -$$

$$- \frac{E_p(1+i)^t Q^{\beta}\frac{9{,}81}{\eta_{ps}}\cdot k\cdot l\cdot m\left(\frac{\sigma\cdot\gamma}{3600} + \frac{p_2\cdot f\cdot r}{8760\cdot 3600}\right)}{D^{m+1}} +$$

$$+ \frac{Q^{\beta+1}\frac{9{,}81}{\eta_{ps}}f\cdot k\cdot l\cdot m\cdot r}{D^{m+1}(1+i)^t} = 0 \qquad 16)$$

We put the third and fourth fraction to the right part. Then we simplify left and right parts and put the common multiplier beyond the brackets in the right part. We multiply left and right parts by D^{m+1}:

$$D^{\alpha+m}\alpha\cdot\beta\cdot l\left(\frac{8760Q\cdot 3600 - E_p(1+i)^{2t}p_1}{8760Q\cdot 3600(1+i)^t}\right) =$$

$$= Q^{\beta}\frac{9{,}81}{\eta_{ps}}k\cdot l\cdot m\left[Q\cdot f\cdot r - E_p(1+i)^{2t}\left(\frac{\sigma\cdot\gamma}{3600} + \frac{p_2 f\cdot r}{8760\cdot 3600}\right)\right]$$

(17)

We express the equation through $D^{\alpha+m}$:

$$D^{\alpha+m} = \frac{Q^{\beta}\frac{9{,}81}{\eta_{ps}}k\cdot m\left[Q\cdot f\cdot r - E_p(1+i)^{2t}\left(\frac{\sigma\gamma}{3600} + \frac{p_2\cdot f\cdot r}{8760\cdot 3600}\right)\right]}{\alpha\cdot b\left(\frac{8760Q\cdot 3600 - E_p(1+i)^{2t}\cdot p_1}{8760Q\cdot 3600(1+i)^t}\right)}$$

(18)

We express the equation through D and get the eventual formula for calculation of the optimal diameter:

$D =$

$$= \left[\frac{8760\cdot 3600(1+i)^t Q^{\beta+1}\frac{9{,}81}{\eta_{ps}}k\cdot m\left[Qfr - E_p(1+i)^{2t}\left(\frac{\sigma\gamma}{3600} + \frac{p_2 fr}{8760\cdot 3600}\right)\right]}{\alpha\cdot b\left(8760Q\cdot 3600 - E_p(1+i)^{2t}\cdot p_1\right)}\right]^{\frac{1}{\alpha+m}}$$

(19)

Therefore, defining the diameter of water pipelines for pipes PE 80 can be described with the cubed formula:

D = 8E-06Q^3 - 0,0097Q^2 + 3,7119Q

(20)

For convenience of usage there has been made the chart of dependence between the diameter of polyethylene pipes PE 80 and water expenditure in the program Microsoft Office Excel (fig.4).
For defining of the diameter for PE 100 pipes there has been deducted the formula:

$$D = 8E\text{-}06Q^3 - 0{,}009Q^2 + 3{,}5508 \quad (21)$$

The chart (fig.5) permits to find out the economically explained diameter of polyethylene pipes PE 100 depending on water expenditure.

3. Conclusions

As a result of the studies there has been proved the actuality of usage of synergic approach for economic as well as technical decisions of systems WSE and got the methodology to calculate the optimal diameter allowing us to account the importance of economic factor for water pipelines made of polymeric materials.
1. There has been shown our own interpretation of NPV calculation taking into account all different calculations of exploiting expenditures and capital investments. There have been analyzed NPV formulas and deducted the calculation formula for defining the optimal diameter of polyethylene pipelines.
2. There has been systemized the parameter of defining the pipes diameter that fully lets rate the synergic effect of economic and technical decisions. There has been explained the choice of the optimal diameter for polyethylene pipes of water supply systems WSE.
3. For reduction of capital and exploiting expenditures of water supply nets and increasing of NPV for enterprises there has been put forward to use in technical and economic calculations this methodology for defining the optimal diameter of pipelines and the chart of dependence between the pipelines diameter and different types of polyethylene pipes; that is very essential for countries with economy in transition.
4. The positive factors while applying polyethylene pipes PE 80 and PE 100 depending on water pressure in the pipeline are the reduction of the pipes diameter on 15…25% comparing with available tables.
5. Given recommendations are desired to be considered during projecting and reconstruction of WSEs.
In the future it is being planned to produce a program complex for calculation of the optimal diameter for pipes made of polymeric materials for pressure water pipes where there will be accounted economic factor and the possibility to pick on working parameters of the system.

References

[1] Vorotintsev V. A. Kontseptsiya strategicheskogo upravle niya ínnovatsíynimi mekhanízmami pídpriêmstv zhitlovo-komunal'nogo gospodarstva // Yekonomíchniy analíz: zb. nauk. prats' / TNEU - Ternopíl': Vidavnicho-polígrafíchniy tsentr TNEU «Yekonomíchna dumka», 2014. - Tom 15. - № 2. - S. 257-267.

[2] Tkachuk A.A. Optimizatsiya setey vodosnabzheniya goroda. - Motrol. Komissiya motorizatsii i energetiki v sel'skom khozyaystve. - Universitet ekonomiki i ekonomiki Akademii nauk v Zheshuvskom universitete nauk o zhizni na Lyublinskom fakul'tete proizvodstvennoy inzhenerii. - 2014, vol.16, no. 6, 85-92.

[3] Novokhatníy V.G. Porívnyannya metodik gídravlíchnogo rozrakhunku rozgaluzhenikh vodoprovídnikh merezh / V.G. Novokhatníy, O.V. Matyash // Sbornik nauchnykh trudov (galuzeve mashinobuduvannya, budívnitstvo). - Vip. 2 (24). - 2009. - PoltNTU. - S. 3-9.

[4] Kalyuzhniy A. P. Yekonomíchne porívnyannya varíantív gídravlíchnogo rozrakhunku merezhí vodovídvedennya / A. P. Kalyuzhniy, L. L. Zubricheva, O. O. Krivenko // Nauk. vísnik budívnitstva: zb. nauk. pr. - Kharkív: KHNUBA, KHOTV ABU, 2016. - Vip. №1 (83). - S. 193-196.

[5] Pozos-Estrada, O.; Sánchez-Huerta, A.; Breña-Naranjo, J.A.; Pedrozo-Acuña, A. "Failure Analysis of a Water Supply Pumping Pipeline System", *Water*, No. *8 (2016)*, pp. 395-400, http://dx.doi.org/ 10.3390/w8090395

[6] Wei1 T., Chen G. "Optimal selection on water-supply pipe of building based on analytic hierarchy process", *IOP Conf. Series: Earth and Environmental Science*, 61 (2017), pp. 1-6, http://dx.doi.org/ 10.1088/1755-1315/61/1/012108

[7] Venkatesh G., Brattebø H. "Assessment of Environmental Impacts of an Aging and Stagnating Water Supply Pipeline Network", *Journal of Industrial Ecology*, Vol.16, pp.722-734, http://dx.doi.org/ 10.1111/j.1530-9290.2011.00426.x

[8] Kalyuzhniy A.P., Comparison of the hydraulic calculations tables networks sewerage» A.P.Kalyuzhniy L.L. Zubricheva, O.O. Kryvenko // Sbornik nauchnyh trudov «Energy, energy saving and rational nature use», PoltNTU, 2015,- Vyp. №2 (5). - S.32-35.

[9] Orlov V.O. Vodopostachannya ta vodovídvedennya: pídruchnik. - K .: Znannya, 2011. - 359s.

[10] Shevelev F. A. Tablitsy dlya gidravlicheskogo rascheta vodoprovodnykh trub / F. A. Shevelev, A. F. Shevelev // Sprav. posobiye. - 8-ye izd., Pererab. i dop. M: OOO «BASTET», 2007. - 336 s.

[11] Yatsyshyn T., Mykhailiuk Yu., Liakh M., Mykhailiuk I., Savyk V., Dobrovolsky I. "Establishing the dependence of pollutant concentration on operational conditions at facilities of an oilandgas complex", *Eastern-European Journal of Enterprise Technologies*, No. 2/10 (2018), pp. 56-63.

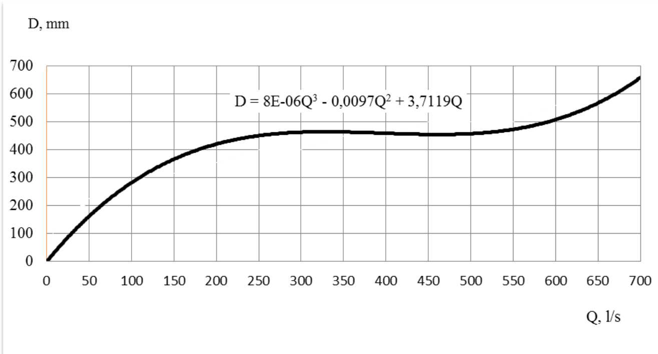

Fig. 4: The chart of dependence between the diameter of polyethylene pipes PE 80 and water expenditure

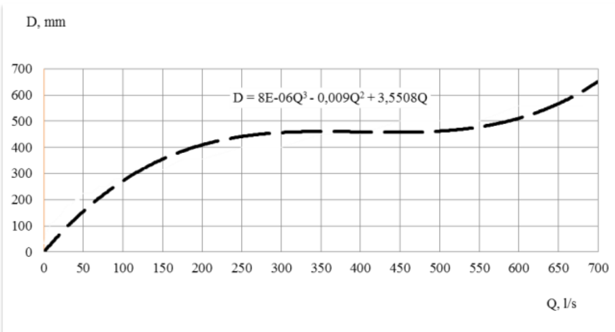

Fig. 5: The chart of dependence between the diameter of polyethylene pipes PE 100 and water expenditure