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Research Paper

# PIPE FLOW ANALYSIS AND ITS INVESTIGATION FOR THE SELECTION OF WATER PIPELINE MATERIAL USING SOME PROMINENT MCDM METHODS

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Transportation of materials from place to place is an important phenomenon in terms of cost and flexibility. Different methods has been used for the transportation of water now a day's among them pipeline transport is very prominent. Different materials are being used for these purposes like Steel, HDPE, Concrete, PVC, Ductile Iron, Cast Iron, etc. In this paper an analysis has been done to select pipeline material to transport water for irrigation purposes. The selection is carried out after analyzing various criteria such as cost, failure rate, frictional losses, variation in flow velocity and water hammering effect in pipeline network system. All these criteria's are evaluated to select a water pipe of a particular material to transport water for irrigation purpose from a reservoir. In the present study, six different pipe materials are taken into consideration as alternatives from which the best pipe material is PVC is found to be the best alternative based on the ELECTRE-I and MOORA Method.

Keywords: MOORA, PVC, HDPE, MCDM (Multi-Criteria Decision Making)

## INTRODUCTION

Water transport through pipeline is an age old phenomenon. There is several research works carried out on water pipeline. One prominent aspect of water transport through pipeline is the analysis of cost involved in the process. Any project needs cost evaluation of the project at the threshold level. There are many types of application for pipeline in sewage system

(Shahram Morteza Nia and Faridah Othman, 2012). Water flow in pipeline always encounters the phenomenon of friction loss or pressure drop. Friction loss is the loss of energy or "head" that occurs in pipe flow due to viscous effects generated by the surface of the pipe (Munson, 2006). One of the accepted methods to calculate friction losses resulting from fluid motion in pipes are by using the Darcy-Weisbach equation for a

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circular pipe (Brown, 2003). There are various flow parameters and an equation for calculating the mechanical energy loss in a pipe flow (Liu Shi-he *et al.*, 2013). The study of the water hammering effect in pipeline and the empirical relations for calculating the pressure wave speed is used in this study. One major concern of water pipeline is the failure of pipeline. There are many established reasons for the failure of the pipeline has made a statistical analysis of available pipe failure data for identification of the factors leading to failure of ductile iron, cast iron and steel pipes Rajeev *et al.* (2015). Similar approach is adopted in this study to obtain failure rate of pipe by collecting the data related to failure of water pipeline and after analysis of the same; the failure rate (per year per km) for all the available pipe materials is obtained. Water hammering is a phenomenon, which always exists in case of pipe flow of water in a relatively long distant pipeline. Water hammer is a type of hydraulic transient that refers to rapid changes of pressure in a pipe system that can have devastating consequences, such as collapsing pipes and ruptured valves. Therefore, for any pipe flow of water, water hammering effect is needed to be taken into consideration. The risk assessment for water pipe network under transient condition was retrieved by various researchers (Preeji John Malppan and Sumam, 2015). Water hammering phenomenon in water pipeline is propagated as a pressure wave that is a measurable parameter in terms of velocity of flow in the pipe. Pressure waves in pipelines are generated due to different normal operations in the system such as opening and closing the valves, start up or shutting down the pumps or any sudden change in the pump rotational speed (Fennel, 2000; and Nourbakhsh *et al.*, 2007). Joukowsky produced the best known equation in transient flow theory, so well known

that it is often called the “fundamental equation of water hammer (Mohamed Ghidaoui *et al.*, 2012). Joukowsky produced the best known equation in transient flow theory, which is also known as fundamental equation of water hammer.

### **The AHP Method**

Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by Prof. Thomas Saaty. In short, it is a method to derive ratio scales from paired comparisons. The input can be obtained from actual measurement such as price, weight, etc., or from subjective opinion such as satisfaction feelings and preference. AHP allow some small inconsistency in judgment because human is not always consistent. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value.

### **ELECTRE-1 Method**

The ELECTRE method is an optimization technique used to analyze the data of a decision matrix. The Elimination and Choice Translating Reality (ELECTRE) method was first introduced in the year 1965 at the European consultancy company SEMA. It is one of the most extensively used outranking methods reflecting the decision maker's preference in many fields (Jihong Pang *et al.*, 2011). The ELECTRE I approach was then developed by a number of variants. Teixeira used the ELECTRE I method in a repair contract problem based on utility in a multi-criteria decision making environment (Teixeira De Almeida, 2002). Esra AYTAC *et al.* (2011) used Fuzzy ELECTRE I method for selection of catering firm for a textile company. ELECTRE method depicts the dominance of relations in between various alternatives by outranking relations. It is possible

by ELECTRE method to draw a comparison between the alternatives. Concordance and discordance indexes are two types of indices pairwise comparison between alternatives in ELECTRE I (Roy, 1968). We assume that  $A_1, A_2, \dots, A_m$  are  $m$  possible alternatives for optimal selection and  $C_1, C_2, \dots, C_n$  are criteria used to describe the available alternatives. After considering the different criteria along with various alternatives, we have to find  $x_{ij}$  as the degree of alternative  $A_i$  with respect to criteria  $C_j$  and  $W_n$  be the weight of importance of  $C_n$ , which is carried out by AHP method. The computation flow process of ELECTRE I method is stated below:

**Step 1:** Normalization matrix is obtained by equation 1 and weighted matrix is determined by multiplying weight factors with  $r_{ij}$ . The normalized matrix of  $R_{ij} = [r_{ij}]$  is calculated by equation 1.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad i = 1, 2, \dots, n \quad j = 1, 2, \dots, m \quad \dots(1)$$

Thus, the weighted matrix depends on normalized matrix assigned to it is given by:

$$V_{ij} = R \times W = \begin{bmatrix} r_{11} \cdot W_1 & r_{12} \cdot W_2 & \dots & r_{1n} \cdot W_n \\ r_{21} \cdot W_1 & r_{22} \cdot W_2 & \dots & r_{2n} \cdot W_n \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} \cdot W_1 & r_{m2} \cdot W_2 & \dots & r_{mn} \cdot W_n \end{bmatrix} \quad \dots(2)$$

**Step 2:** Next step is to find out the concordance and discordance set by following the rules given in the equations 3 and 4 respectively. Let concordance set and discordance sets are represented by  $C_{ab}$  and  $D_{ab}$  respectively. The concordance set is applied to describe the dominance query if the following condition is satisfied:

$$C_{ab} = \{j | x_{aj} \geq x_{bj}\} \quad \dots(3)$$

On complementation of  $C_{ab}$ , we obtain the discordance set ( $D_{ab}$ ) using (4):

$$D_{ab} = \{j | x_{aj} < x_{bj}\} = j - C_{ab} \quad \dots(4)$$

**Step 3:** Determination of concordance matrix as obtained by the summation of weight factors based on the values of  $C_{ab}$ . The concordance interval index ( $C_{ab}$ ) between  $A_a$  and  $A_b$  can be obtained using (5):

$$C_{ab} = \sum_{j \in C_{ab}} W_j \quad \dots(5)$$

The concordance interval matrix can be formulated as follows:

$$C = \begin{bmatrix} - & c(1,2) & \dots & c(1,m) \\ c(2,1) & - & \dots & c(2,m) \\ \vdots & \vdots & \ddots & \vdots \\ c(m,1) & c(m,2) & \dots & - \end{bmatrix} \quad \dots(6)$$

**Step 4:** In calculation of the discordance interval matrix, first we consider the discordance index of  $d_{ab}$ , which can be obtained in the same way as the concordance matrix is calculated.

The discordance interval matrix can be formulated as follows:

$$D = \begin{bmatrix} - & d(1,2) & \dots & d(1,m) \\ d(2,1) & - & \dots & d(2,m) \\ \vdots & \vdots & \ddots & \vdots \\ d(m,1) & d(m,2) & \dots & - \end{bmatrix} \quad \dots(7)$$

**Step 5:** Determination of the concordance index matrix

The concordance index matrix for satisfaction measurement problem can be written as follows:

$$\bar{C} = \sum_{a=1}^m \sum_{b=1}^m C(a,b) / m(m-1) \quad \dots(8)$$

Here  $c$  is the critical value, which can be determined by average dominance index. Therefore, the Boolean matrix ( $E$ ) is obtained by using the following rules:



$$\begin{cases} e(a, b) = 1 \text{ if } c(a, b) \geq \bar{c} \\ e(a, b) = 0 \text{ if } c(a, b) < \bar{c} \end{cases} \dots(9)$$

**Step 6:** Determination of the discordance index matrix

The discordance index matrix for satisfaction measurement problem can be written as follows:

$$\bar{d} = \frac{\sum_{a=1}^m \sum_{b=1}^m d(a, b)}{m(m-1)} \dots(10)$$

Based on the discordance index mentioned above, the discordance index matrix (F) is given by

$$\begin{cases} f(a, b) = 1 \text{ if } d(a, b) \geq \bar{d} \\ f(a, b) = 0 \text{ if } d(a, b) < \bar{d} \end{cases} \dots(11)$$

**Step 7:** To calculate the net superior and inferior values, i.e.,  $c_a$  and  $d_a$  be the net superior and net inferior values respectively. The more the value of  $c_a$ , better is the alternative. The  $c_a$  is given by:

$$c_a = \sum_{b=1}^n c_{(a,b)} - \sum_{b=1}^n c_{(b,a)} \dots(12)$$

On the contrary,  $d_a$  is used to determine the number of inferiority ranking of the alternatives:

$$d_a = \sum_{b=1}^n d_{(a,b)} - \sum_{b=1}^n d_{(b,a)} \dots(13)$$

The smaller the value of net inferior ( $d_a$ ) indicates the better alternative. Among the various alternatives the best can be pursued by the net superior and inferior values.

**The Moora Method**

Multi-objective optimization or multi-criteria or multi-attribute optimization, is the process of simultaneously optimizing more than one conflicting attributes subject to certain constraints. The MOORA method, first introduced by Brauers (2004) is such a multi-objective optimization technique that can be successfully applied to solve various types of complex decision making problems in the

manufacturing environment (Gadakh, 2011). It begins with a decision matrix showing the performance of different alternatives with respect to various attributes. The MOORA method is described by the following steps:

**Step 1:** In the first step, the goal is to determine the objective, and thereafter to identify the pertinent evaluation of attributes.

**Step 2:** The next step is to represent all the information available for the attributes in the form of a decision matrix. The data given in Equation (A.3) is the performance measure of  $i^{th}$  alternative on  $j^{th}$  attribute,  $m$  is the number of alternatives and  $n$  is the number of attributes. Then a ratio system is developed where each performance of an alternative on an attribute is compared to a denominator which represents all the alternatives concerning that attribute.

$$X = \begin{matrix} & x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & & x_{22} & & x_{2n} \\ \dots & & \dots & & \dots \\ x_{m1} & & x_{m2} & & x_{mn} \end{matrix} \dots(14)$$

**Step 3:** For denominator, the best choice is the square root of the sum of squares of each alternative per attribute. This ratio can be expressed as below:

$$x_{ij}^* = x_{ij} / \sqrt{[\sum_{i=1}^m x_{ij}^2]} \dots(15)$$

$$J = (1, 2, \dots, n)$$

where  $x_{ij}$  is a dimensionless number which belongs to the interval [0, 1] representing the normalized performance of the  $i^{th}$  alternative on  $j^{th}$  attributes.

**Step 4:** For multi-objective optimization, normalized performances are added in case of maximization (for beneficial attributes) and subtracted in case of minimization (for non

beneficial attributes). Then the optimization problem becomes:

$$y_i = \sum_{j=1}^g x_{ij}^* - \sum_{j=g+1}^n x_{ij}^* \quad \dots(16)$$

where  $g$  is the number of attributes to be maximized,  $(n-g)$  is the number of attributes to be minimized and  $y_i$  is the normalized assessment value of  $i^{\text{th}}$  alternative with respect to all the attributes. In some cases, it is often observed that some attributes are more important than the others. In order to give more importance to an attribute, it could be multiplied with its corresponding weight (significance coefficient) (Brauers *et al.*, 2009). When these attribute weights are taken into consideration, Equation (16) becomes as follows:

$$y_i = \sum_{j=1}^g w_j x_{ij}^* - \sum_{j=g+1}^n w_j x_{ij}^* \quad \dots(17)$$

where,

$$J = (1, 2, \dots, n)$$

where  $w_j$  is the weight of  $j^{\text{th}}$  attribute, which can be determined by applying Analytic Hierarchy Process (AHP), or entropy method.

**Step 5:** The  $y_i$  value can be positive or negative depending on the totals of its maxima (beneficial attributes) and minima (non beneficial attributes) in the decision matrix. An ordinal ranking of  $y_i$  shows the final preference. Thus, the best alternative has the highest  $y_i$  Value, while the worst alternative has the lowest  $y_i$  value.

## OBJECTIVE AND METHODOLOGY

The main objective of this study is to select a water pipeline of length 1 km long having an outside diameter of 250 mm to transport water from a reservoir to an irrigation field. The per day maximum water carrying capacity through

the pipeline is given as 100000 litres. There are six types of pipes are considered as options for water transportation as PVC, Ductile Iron, Cast Iron, HDPE, Concrete, Steel. As, there is no existing pipeline setup and the selection of pipeline is the primary concern of this study, therefore, we have considered the following approach to fix the criteria required for pipeline selection. This study considered the cost as one criterion for pipeline selection. In every project cost is a parameter, which is required to be optimized. In this study, an endeavour has been made to calculate the annual maintenance cost, operating cost of water transportation i.e. the cost of electric power consumption and the pipe material cost to obtain the annual cost of transporting water. Water pipeline is also subjected to failure. There are many reasons for water pipeline failure like water hammering inside pipe, erosion of pipeline, corrosion due to chemical reaction inside the pipe, weathering, iron deposit inside the pipe etc. and many others. But in the present study, we have considered the failure rate (per year per km) of pipeline as there is no existing pipeline setup for conducting any experiment or investigation of the pipeline. Another analysis we have made in the present study about the theoretical head loss that may occur during the flow of water in pipe. The rated discharge of water is 100000 liters per day. Considering this the theoretical discharge is 0.00347 m<sup>3</sup>/sec through pipeline. We have used the generalized form of Reynolds number to obtain theoretical flow velocity inside the pipe, as obtained from ([http://en.wikipedia.org/wiki/Reynolds\\_number](http://en.wikipedia.org/wiki/Reynolds_number)) which is as follows:

$$R_s = \frac{\rho V D_H}{\mu} = \frac{V D_H}{\nu} = \frac{Q D_H}{\nu A} \quad \dots(18)$$

where,

$V$  = mean velocity of fluid in pipe (m/sec)

$D_H$  = hydraulic diameter of pipe (m)

$Q$  = volumetric flow rate (m<sup>3</sup>/sec)

$A$  = cross sectional area of pipe (m<sup>2</sup>)

$\mu$  = dynamic viscosity of fluid (kg/m.sec)

$\nu$  = kinematic viscosity ( $\nu = \mu/\rho$ ) (m<sup>2</sup>/sec)

$\rho$  = density of fluid (kg/m<sup>3</sup>)

Now, this theoretical flow velocity is used for calculation of head loss in pipe during the flow. This is accomplished with the application of Darcy-Weisbach equation for pipe flow (Hany Radwan, 2013). The Darcy Weisbach Equation applies to fully developed, turbulent pipe flow. Pipe flow will be turbulent for a Reynolds number greater than 4000, which is calculated as 24748.71846 for this study. The flow velocity inside the pipe is dependent on physical properties of pipe and the pressure drop caused by friction and is determined by applying the Hazen-William empirical relation (Hazen-Williams Formula). In the present study, we have referred to this empirical relation to obtain the mean velocity of water in the pipe because the water flow velocity will be different in different pipe. Therefore, we have used this as another criterion in this study. The final criterion, we have considered in this study is the water hammering effect. As mentioned above, water hammering phenomenon is taken into consideration for long distant pipeline. The presence of stop valves, intermediate fitting joints as well as the length of the pipeline and use of centrifugal pump for driving the water into the pipe have caused the water

hammering phenomenon to be taken into consideration in this study when the pipeline will practically be installed. In this paper, the water hammer effect is analyzed in terms of the speed of the pressure waves or velocity of impulse waves,  $a$ , that is a function of bulk modulus of elasticity of liquid, pipe diameter, pipe wall thickness and the Young's modulus of elasticity of the pipe material and the density of liquid. The equation for calculating the pressure wave speed is as follows:

$$a = \sqrt{\frac{K_f / \rho}{(1 + \frac{K_f D}{eE})}} \dots(19)$$

where,  $D$  is the pipe diameter (m),  $e$  is the pipe wall thickness (m),  $E$  is the Young's modulus of elasticity of the pipe material,  $K_f$  is the bulk modulus of elasticity of liquid and its value is assumed to be  $2.15 \times 10^9$  N/m<sup>2</sup> for water and  $\rho$  is the density of water (kg/m<sup>3</sup>) (Saemi et al., 2014).

### ANALYSIS AND CALCULATION

- Length of the pipeline = 1 km
- Pipe diameter = 20 cm
- Thickness = 8 mm
- Pump operating at 8 hours per day

**N.B:** Thickness of the pipeline is assumed in this study as the thickness is not provided and considering the length of the pipeline and all the pipe materials viz., PVC, CI, DI, HDPE, Concrete and steel, we have taken the thickness to be 8 mm as the data required for thickness varies with particular pipe material. Therefore, we have made

Litres/s	3.6	6.3	9.3	18	36	41.5	66.3	75	84.5
m <sup>3</sup> /s	0.0036	0.0063	0.0093	0.018	0.036	0.0415	0.0633	0.075	0.0845

Table 2: Data of Flow Rate Corresponding to 12 M Head								
Litres/s	2.7	5.6	8.5	16.4	33.9	39.5	63.4	8.75
m <sup>3</sup> /s	0.0027	0.0056	0.0085	0.0164	0.0339	0.0395	0.0634	0.00875

a number of field surveys to arrive at the decision to fix the thickness of pipe at 8 mm.

**Cost Analysis**

Pump data collected from local market vendors is given below:

The theoretical discharge through the pipeline is 0.00347 m<sup>3</sup>/sec. But we have considered the pump discharge slightly higher than the theoretical flow rate inside the pipe to compensate the flow loss in the pipe.

**Electric Cost**

In this study, we have considered the cost of electricity as the operating cost. In order to obtain the same, following relation as obtained from Bureau of Energy Efficiency, Government of India, is used to obtain the electricity consumption:

$$P = \frac{\text{Pump Shaft Power } P_s}{\eta_m} \text{ KW}$$

where, P = Electric Power (KW)

$\eta_m$  = Motor efficiency

Now, the pump shaft power and hydraulic power is obtained from the following relations-

$$\text{Pump Shaft Power } P_s = \frac{\text{Hydraulic Power } P_h}{\text{Pump efficiency } \eta_{\text{pump}}}$$

$$\text{Hydraulic Power, } P_h = \frac{Q \times h \times \rho \times g}{1000}$$

where, Q = Rated discharge/mass flow rate (m<sup>3</sup>/s)

h = Total head of pump (m)

$\rho$  = Density of water (kg/m<sup>3</sup>)

Corresponding to 10 meter head, the discharge is 0.0036 m<sup>3</sup>/s. Corresponding motor power is obtained from the pump manual is 1.5 KW. Thus, the hydraulic power obtained is as follows:

$$\text{Hydraulic power, } P_h = \frac{Q \times h \times \rho \times g}{1000} = 0.61803 \text{ KW}$$

$$\text{Shaft power } P_s = \frac{P_h}{\eta_{\text{pump}}} = \frac{0.61803}{0.80} = 0.77254 \text{ KW}$$

$$\text{Electric power required } P = \frac{P_s}{\eta_m} = \frac{0.77254}{0.80} = 0.9657 \text{ KW}$$

Pump operates for an average period of 8 hours per day. Therefore, the electric energy required per day = 7.7256 KWh.

As per the Tariff policy of Govt. of Tripura, connection used for irrigation purpose is divided in two segments i.e. the motor capacity up to 5 hp and above 5 hp. As the pump selected in this study is having a motor capacity less than 5 hp, cost incurred per month on electricity consumption due to pump operation is obtained as follows: Fixed Charge @ Rs. 30/KWh/month + Gross Energy Charge @ Rs. 3.55/KWh x 30 = Rs. 1054.54.

Therefore, the annual cost of electricity consumption = Rs. 1054.54 x 12 = Rs. 12654.53

**N.B:** Generally, motor efficiency for a centrifugal pump varies in the range of 85 to 90%. It can be taken at 85% for motors up to 15 kW and 90% above 15 kW. Overall efficiency of centrifugal



pump varies in the range of 65 to 80%. For the ease of calculation, we have assumed that the selected pump is working at maximum efficiency, i.e., at 80%.

**Maintenance Cost**

The no of days required for scheduled regular maintenance is different for different pipe materials is tabulated below:

**Pipe Material Cost**

To obtain the pipe material cost, we have used the Material density (kg/m<sup>3</sup>) to obtain the mass of material required and thus multiplied the same with market price of pipe material (Rs/kg) to reach the material cost of pipe line for six different materials.

Type of Pipe	Total No of Working Hour per Year	Labour Charge per Hour	Annual Maintenance Cost
PVC	57	Rs. 75	Rs. 4275
Ductile Iron	47	Rs. 75	Rs. 3525
Cast Iron	53	Rs. 75	Rs. 3975
HDPE	43	Rs. 75	Rs. 3225
Concrete	25	Rs. 75	Rs. 1875
Steel	28	Rs. 75	Rs. 2100

Note: The annual maintenance cost is based on survey of local condition but may vary according to the change in location. The data pertaining to the above table is collected from Labor department of Government of Tripura.

Data required for the computation of pipe material cost are as follows:

Length of the pipeline = 1 km, Diameter of the pipeline (d<sub>1</sub>) = 20 cm Thickness = 8 mm

Therefore, outer diameter of pipe (d<sub>2</sub>) = 200 mm + 16 mm = 216 mm

Cross sectional area of the pipe material  $\pi \times \frac{d_2^2 - d_1^2}{4}$  m<sup>2</sup>

Volume of pipe material for the whole pipe =  $\pi \times \frac{d_2^2 - d_1^2}{4} \times 1000$  m<sup>3</sup> = 5.2276m<sup>3</sup>

Mass of material required = density × volume.

**Failure Rate Analysis**

In this study, the failure rate (per year per km) for a specific pipe material is obtained using the total number of failures divided by number of years in the observation period and length of the pipeline in km. The pipe failure data is collected from the PWD; Government of Tripura provided and is given in the Table 6.

Based on the above data, the estimated failure rate is given in Table 7.

**Frictional Head Loss or Pressure Drop Calculation**

Dary-Weisbach equation  $h_f = \frac{fLV^2}{2gD}$  is used in this

Different Pipe Material	PVC (Rs)	Ductile Iron (Rs)	Cast iron (Rs)	HDPE (Rs)	Concrete (Rs)	Steel (Rs)
Material density (kg/m <sup>3</sup> )	1.39×10 <sup>3</sup>	7.1×10 <sup>3</sup>	7.2×10 <sup>3</sup>	0.96×10 <sup>3</sup>	1.75×10 <sup>3</sup>	7.85×10 <sup>3</sup>
Market price of pipe material (Rs/kg)	Rs. 27	Rs. 35	Rs. 37	Rs. 25	Rs. 3.50	Rs.40
Cost of pipe materials	196191.83	1299058.6	1392632.64	125462.4	32019.05	1641466.4

Table 5: Total Cost (Annual Electric Cost + Annual Maintenance Cost + Pipe Material Cost)

Different Pipe Material	PVC (Rs)	Ductile Iron (Rs)	Cast iron (Rs)	HDPE (Rs)	Concrete (Rs)	Steel (Rs)
	213121.36	1315238.13	1409262.17	141341.93	46548.58	1656220.93

Table 6: Table Shows the Failure Rate of Pipe Material

No. of Years of Observation	Length of the Pipeline	Failure Data					
		PVC	Ductile Iron	Cast Iron	HDPE	Concrete	Steel
2000-2012 (13)	25	354					
1993-2010 (18)	23					1,052	
1998-2012 (15)	17		923				
1996-2009 (14)	15			809			
1997-2012 (16)	11						426
2004-2011 (8)	10				412		

Source: DWS, Government of Tripura

Table 7: Estimated Failure Rate in per year per km

Pipe Material	Failure Rate (per Year per km)
PVC	1.089
Ductile iron	3.619
Cast iron	3.852
HDPE	5.15
Concrete	2.541
Steel	2.42

study to obtain the Frictional head loss or pressure drop in the pipe.

where,

$h_f$  : Head loss (m)

L : Pipeline length (m)

V : Average pipeline velocity (m/s)

g : Acceleration due to gravity (m/s<sup>2</sup>)

D : Hydraulic diameter of the pipe (for a pipe

of circular section, this equals the internal diameter of the pipe) (m).

f : Friction factor

For pipe flow, the friction factor (f) is a function of Reynolds number and the relative roughness ( $\epsilon/D$ ), where  $\epsilon$  is the internal pipe roughness.  $R_E = \frac{VD}{\nu}$ , where,  $R_E$  is the Reynolds number,  $\nu$  is the kinematic viscosity and is  $0.8925 \times 10^{-6}$  m<sup>2</sup>/sec at 25 °C, which is close to average temperature of the study area and D is the internal pipeline diameter. Colebrook-White equation gives a correlation between Reynolds number, pipe diameter, relative roughness and friction factor, which is used in this paper to find out the friction factor. Colebrook-White equation is as follows:

$$\frac{1}{\sqrt{f}} = -2 \log_{10} \left( \left( \frac{\epsilon}{3.7D} \right) + \left( \frac{2.51}{R_E \sqrt{f}} \right) \right) \quad \dots(20)$$

where,

f : Friction factor in pipe

$\epsilon$  : Internal pipe roughness

Table 8: Friction Factor and Head Loss in Different Pipe

Different Pipe Material	PVC	Ductile Iron	Cast iron	HDPE	Concrete	Steel
Absolute Roughness (mm)	0.0015	0.061	0.26	0.007	0.3	0.045
Darcy friction factor ( $\lambda$ )	0.031034	0.212339	1.210922	0.059861	1.625303	0.168576
Head loss (m)	0.0965	0.6601	3.7646	0.1861	5.0528	0.5241

D : Inner pipe diameter

$R_E$  : Reynolds number

**N.B:** In the calculation, we have used inner pipe diameter as because the friction will take place inside the pipe as well as the roughness values are internal surface roughness.

**Variation of Velocity in Pipe**

The mean flow velocity of water through the pipe can be obtained from the Hazen William empirical formula,  $V = KCR^{0.63}S^{0.54}$ , where, V is the velocity of flow (m/s), k is a conversion factor and its value is 0.849 in SI units. S is the slope of energy grade line and is dimension less equal to head loss/ pipe length ( $h_f/L$ ), C is a roughness coefficient, dependent on the pipe material. R is the hydraulic radius. The head loss is given in the table 8. The

Table 9: Shows The Pipe Material Properties

Pipe Material	Roughness Coefficient (C)	Slope of Energy Grade Line (S)	Mean Velocity (m/s)
PVC	150	$0.0965 \times 10^{-3}$	0.2024
Ductile Iron	140	$0.6601 \times 10^{-3}$	0.5341
Cast Iron	100	$3.7646 \times 10^{-3}$	0.9768
HDPE	150	$0.1861 \times 10^{-3}$	0.2888
Concrete	100	$5.0528 \times 10^{-3}$	1.145
Steel	110	$0.5241 \times 10^{-3}$	0.3705

Note: Hazen William empirical formula for water flow rate calculation is applicable with an ambient temperature in the range of 60 °F or 15.56 °C, but it is quite applicable for a reasonable range of water temperatures above or below 60 °F. The present study is conducted with a mean average ambient temperature of 24.5 °C. Therefore, in the present study, it is applied to obtain the flow velocity in pipe.

following table represents the values of roughness coefficients of different pipe material along with the slope of energy grade line (S) and the calculated flow velocity (m/sec) pertaining to the six designated pipe materials are given in the Table 9.

**Water Hammer in Pipe**

As discussed above, water hammer is taken as a criterion in this study and the effect of water hammer is calculated in terms of the speed of the pressure waves or velocity of impulse waves and is tabulated in the following table. The values are obtained using Equation (19), where we have taken into consideration the outer diameter of pipe as the equation involves thickness of the pipe.

**RESULTS**

The results obtained by ELECTRE-I and MOORA method.

Table 10: Elasticity of Pipe Materials

Pipe Material	Elasticity Modulus of the Pipe Material (N/m <sup>2</sup> )	Pressure Wave Speed (m/s)
PVC	$2.75 \times 10^9$	713.7
Ductile iron	$165 \times 10^9$	1106
Cast iron	$103 \times 10^9$	963.49
HDPE	$0.8 \times 10^9$	21.5
Concrete	$8 \times 10^9$	189.96
Stainless Steel	$200 \times 10^9$	625.62

Note: In this study, one of the most crucial parts is the collection of data. For some data like elasticity of pipe material, bulk modulus of water, roughness coefficient of water, absolute roughness of inner surface of pipe, viscosity of water etc, we have exclusively relied upon web portal like Engineering Tool Box, Engineering Encyclopedia and Wikipedia, etc.

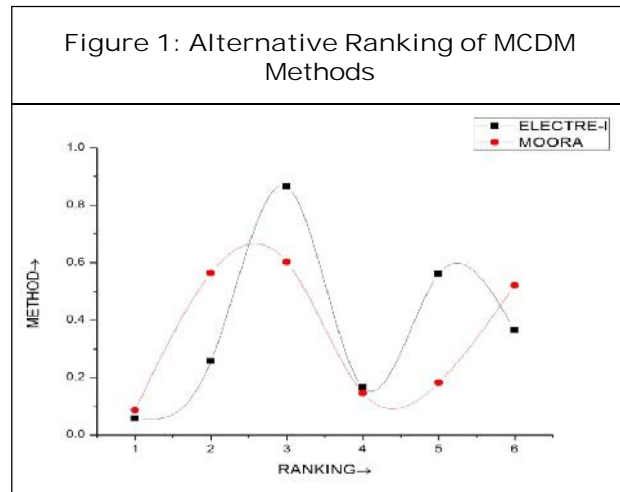


Table 11: Ranking by MCDM Approaches

Types of Pipe Material	Moora Method (Rank)	Electre-I Method (Rank)
PVC	1 <sup>st</sup>	1 <sup>st</sup>
Ductile iron	5 <sup>th</sup>	3 <sup>rd</sup>
Cast iron	6 <sup>th</sup>	6 <sup>th</sup>
HDPE	2 <sup>nd</sup>	2 <sup>nd</sup>
Concrete	3 <sup>rd</sup>	5 <sup>th</sup>
Stainless Steel	4 <sup>th</sup>	4 <sup>th</sup>

### CONCLUSION

In the present study the selection of pipeline material has been analyzed based on the prominent MCDM method MOORA and ELECTRE-I. The present study collates an accurate results to select the pipe material .Both the MCDM methods allocates the PVC as the best material for water transportation. This study compile the two MCDM techniques to a specific case study to find out the best material for transporting water from place to place and also explored the authentic materiality and cogency of these decision making method for this particular task and also signifies the various aspects for selecting the best pipe material based on the situation. The results are more focused on the decision

making analysis. Both the ELECTRE and MOORA method optimize towards the best result validate the obtained result. Although the other MCDM methods can be used to move towards best solution .They also collate the analysis of various aspects for the optimal selection.

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