Marks rating system – an approach in condition assessment and prioritization of sewer rehabilitation – a case study

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Abstract: Marks rating system is a simple system that can be used to evaluate the condition of sewer pipes and to determine the prioritization for rehabilitation purposes of sewer pipes and sewer infrastructures. The system provides a consistent approach for assessing the impact of pipe failure, coding defects and assigning priorities for rehabilitation of sewer pipes. Each sewer segment is separately evaluated based on several considerations such as inspection results, impact rating factors, frequency of defects, and engineering and administrative factors. The marks of defects were assigned in such a way that the worst condition has the highest mark. The factors considered by applying marks system were identified from questionnaires that were prepared and distributed by the author to technicians, engineers, heads of departments and managers of municipalities of several cities in Iraq. The case study includes seventeen concrete sewer pipes in the municipality of Al Diwaniyah city – Iraq. CCTV inspection was carried out to determine the marks of the structural and performance defects. Results of marking rating system applied on the seventeen sewer pipes showed that MP#12 has the worst condition with highest marks of 38. Sewer pipes MP#1 and MP#7 have the best condition with lowest marks of 18. The prioritization of rehabilitation should have descending ordered from the highest to lowest mark.

Keywords: Sewer Pipes, Rehabilitation, Priorities, Infrastructures.

1. Introduction
Countries spend hundreds billions of dollars annually in building infrastructures [1]. Projects of sewer infrastructures occupy the biggest part of the budget of the infrastructures. Although, the useful life of the sewer systems can be sometimes extended to more than fifty years, the sewer systems need to be rehabilitated and maintained periodically. The failure of the suitable and timing rehabilitation of sewer systems may result in disasters that threat the humans’ life. In USA, the annual failures of sewer pipes owing to the lack of suitable and timing rehabilitation cost about 30 billion dollars and death of some people [2]. More information about the impact of the sewer systems on the economy and life can be found elsewhere [3, 1].

The priority of rehabilitation of sewer pipes represents a substantial challenge to decision makers in municipalities especially when the budget of the rehabilitation is limited. It should be stated that there is no engineering principles can be used to determine the priority of rehabilitation [4, 5]. The use of “fix when damage” rule can be very risky when the failure occurs in critical sewer infrastructure that may threat the routine life of people. Many of municipalities rely on the experience of engineers and personnel of the municipality in determining the priority of the rehabilitation [6]. The absence of the priority system of rehabilitation can be attributed to the many factors that can affect the service life...
and the rate of degradation of the sewer pipes. These may include but are not limited to the material of the sewer pipes, the type of sewage, the location and depth of sewer pipes and others [5]. It is worth mentioning that researches about the priority of rehabilitation of sewer pipes is very limited, if any, in the open access literature. Some attempts were made to connect the failure of sewer pipes with the functionality of the pipe, burial depth and pipe size [6]. Many researches discussed the relationship between the sewage type and the rate of degradation in concrete sewer pipes [7-10]. Nonetheless, a comprehensive study about the factors that affect the useful life of the sewer pipes was carried out by others [8].

2. Factors affecting priority of rehabilitation
Based on literature review related to failures of sewer pipes, factors affect the situation of sewer pipes and those may determine the priority of rehabilitation were classified into three categories [9]:

2.1 Structural defects
Structural defects in sewer pipes can be the main factors that identify the priority of rehabilitation. These defects may include cracking in the pipes, deflection of pipes, corrosion and others. To determine the extent of these defects in pipes, many techniques of inspection can be used. One of the most common techniques used to investigate the structural defects of sewer pipes is Closed Camera Television (CCTV). Although the CCTV technique is widely used by municipalities to determine the defects, this technique is not very efficient in measuring some defects such as the corrosion extent. It may provide a relative indication of how rapidly corrosion is progressing by comparing conditions in the same segment over time [11-13].

The structural defects that may occur in the sewer pipes can include the following: a) cracking and leakage, b) deflection, c) missing bricks for brick sewer pipes, d) joint opening, and e) corrosion. It should be noted that joint opening and corrosion defects are only applied to concrete sewer pipes while brick missing is applied to brick sewer pipes.

2.2 Performance defects
Performance defects may include infiltration of pipes, root intrusion and the existing of debris. These performance defects can affect the service life of the sewer pipes and accelerate the failure. The CCTV technique is efficient in determining the debris and root intrusion while it is not very efficient in determining the infiltration of pipes.

2.3 Impact factors
Impact factors refer to those factors that are related to the installation of pipe and its function. The impact factors may include a) location of pipe, b) burial depth, c) pipe size, and d) functionality. The location factor can be subdivided into land use, traffic intensity, access for repair, and environmental effect.

3. Marks rating system
The marks rating system applied for each type of defects were mainly obtained from the art-of-state especially research performed by Zhao and McDonald [10-15]. The author also prepared a questionnaire that was distributed to technicians, engineers, heads of sewer departments and mangers of municipalities. The questionnaire is simply including questions about the probable defects and about marking range of each possible factor that may affect the prioritization of rehabilitation of sewer pipes. The details and the statistical analysis of the questionnaire can be found elsewhere [16]. However, results of the questionnaire were gathered with those obtained from the literature review to identify the marking rating of each factor:

3.1 Marking rating system of structural defects
Table 1 shows the marking rating system of structural defects that may affect the prioritization of sewer pipe rehabilitation. As previously discussed, the inspection technique of CCTV is not very efficient to determine the extent of some defects. Thus, it was proposed to multiply the marks of each
defect by an Inspection Method Factor (IMF) which ranges from 1.0 to 1.2. The IMF of 1.0 should be used when the results of inspection technique is perfect while IMF of 1.2 should be used when the inspection results are not clear enough to accurately evaluate the defects.

Table 1. Marking rating system of structural defects

| Defect          | Description                                                                                   |
|-----------------|------------------------------------------------------------------------------------------------|
| Corrosion       | • 10 marks for minor corrosion (less than 10% of concrete thickness)                           |
|                 | • 10 – 50 marks for moderate corrosion (steel reinforcement of pipe is not visible)           |
|                 | • 50 – 100 marks for severe corrosion (steel reinforcement of pipe is visible)                |
| Joint Opening (JO) | • 10 marks for JO up to 10 mm                                                                |
|                 | • 10 – 50 marks for JO between 10 – 50 mm                                                    |
|                 | • 70 marks for JO more than 50 mm                                                            |
|                 | • 10 marks for gasket off                                                                    |
|                 | • 10 marks for leakage related to JO                                                         |
| Cracks and leakage | • 5 marks for each crack (longitudinal, diagonal or circumferential)                         |
|                 | • 15 marks for each leakage related to cracks                                                |
| Deflection      | • 10 marks for change in diameter up to 5%                                                    |
|                 | • 10 – 20 marks for change in diameter between 5% and 10%                                     |
|                 | • 20 – 50 marks for change in diameter between 10% and 25%                                    |

3.2. Marking rating system of performance defects

The performance defects included in this study are debris and root intrusion and infiltration. As it can be seen in Table 2, both defects were ranked from 0 to 100. The IMF can also be applied for marks of performance defects because it is difficult to measure the reduction in diameter of pipes owing to stagnation of debris and root intrusion.

Table 2. Marking rating system of performance defects

| Defect            | Description                                                                 |
|-------------------|-----------------------------------------------------------------------------|
| Debris and root intrusion | • 0-20 marks for reduction in dia. less than 10%                             |
|                   | • 20-50 marks for reduction in dia. between 10% and 25%                      |
|                   | • 50-100 marks for reduction in dia. more than 25%                           |
| Infiltration      | • 0-20 marks for seeping and dripping                                       |
|                   | • 20-50 marks for running and trickling                                      |
|                   | • 50-100 marks for gushing and spurting                                      |

3.3. Marking rating system of impact factors

Table 3 depicts the marking assigned to each of the four impact factors. The marks of each factor were ranged from 0 to 100. The IMF is not applied to impact factors as information related to these factors can be accurately obtained from the municipality office. Because the location factor includes many sub-factors including traffic intensity, land use and others, it was proposed that the location factor to have its own marking rating system which also ranged from 0 to 100 as shown in Table 4.

Table 3: 100 Marks rating system of impact factor

| Factor         | Description                                                                 |
|----------------|-----------------------------------------------------------------------------|
| Burial Depth   | • 10-20 marks for depths less than 3 m                                      |
|                 | • 20-50 marks for depths between 3 and 10 m                                 |
|                 | • 50-100 marks for depths more than 10 m                                    |
| Pipe Diameter  | • 10-20 marks for dia. less than 900 mm                                      |
|                 | • 20-50 marks for dia. between 900 and 1800 mm                              |
|                 | • 50-100 marks for dia. more than 1800 mm                                   |
| Functionality  | • 10-30 marks for collectors sewer and storm sewer                           |
|                 | • 30-60 marks for major trunk, sanitary and combined                        |
|                 | • 60-100 marks for major interceptor and from to wastewater plant            |
Table 4: 100 Marks rating system of location factor

| Factor          | Description                                                                 |
|-----------------|-----------------------------------------------------------------------------|
| Land Use        | • 30 marks for industrial use  
• 60 marks for residential use  
• 100 marks for commercial use |
| Traffic Intensity | • 0-30 marks for 1 to 2 traffic lanes (15 marks for each lane)  
• 30-75 marks for 3 to 5 traffic lanes  
• 75-100 marks for 6 traffic lanes or more |
| Under or adjust to | • 0-30 marks area clear of low risk utilities  
• 30-60 marks area of high risk utilities  
• 60-100 marks area of railway, canals, building, rivers and etc. |
| Access for repair | • 30 marks for unrestricted access  
• 60 marks for limited access  
• 100 marks for restricted access |
| Environment     | • 0-30 marks for non-sensitive area  
• 30-60 marks for environmental conservation zones  
• 60-100 marks for environmental protected zones |

It should be stated that the weight of impact factors are different depending on the case of rehabilitation. Based on results of the questionnaire, the weight of each factor was assigned as follows: Weight of burial depth is 28%; Weight of location is 30%; Weight of pipe size 25%; and Weight of functionality is 17%. These weights were identified based on the experience of the participants in the questionnaire.

3.4. Engineering and administrative factors

It can be noticed that some engineering factors were not included in the assessment of sewer. These may include; historical data of sewer, frequency of defects, progress of the problem and previous inspection. In addition, the experience of the municipal engineer and staff can be an important factor in identifying the priority of rehabilitation. Hence, an Engineering Factor (EF) was proposed to be used to correlate the final marks of sewer. The EF ranges and from 0.8 to 1.2 and can be applied on all or some of the sewer depending on the available data.

The future plans of expanding and the point of view of the decision-maker should also be considered in the assessment and prioritization of the sewer rehabilitation. Hence, an Administrative Factor (AF) can be applied to correct the final marks of sewer. The AF ranges from 0.8 to 1.2 and can be applied on some or all sewer.

4. Case study

Al Diwaniyah city in governorate of Al Qadisiyah – Iraq was considered as a case study for the purpose of condition assessment and prioritization of rehabilitation of sewer pipes. Al Diwaniyah city is located about 180 km south of Baghdad and it is the capital city of Al Qadisiyah governorate. The population of the city is about 250,000. The city is not entirely served by a sewer system. The investigated area is located south-east of the city and include five sectors with a population of approximately 100,000. The investigated area is classified as a residential area with some commercial areas. Figure 1 shows the location of Al Diwaniyah city and the location of the investigated area. The sewer system of the investigated area is consisted of force main and gravity concrete pipes of different diameters, uplift stations and two sewage treatment plants. The sewer system was installed in early eighties of the last century. The entire sewer system is currently suffering from repeated blockage and major structural and performance defects. The city spent a lot of money in rehabilitation of the sewer system. These include replacing of some old and broken pipes, in addition to the replacement of mechanical instruments of the lift stations and treatment plants. Because the limited earmarked budget of the maintenance and rehabilitation, the municipality is following the rule of "fix when damage".
In 2014, the municipality decided to assess the sewer system using CCTV technique. The assessment included seventeen concrete pipes of various sizes. The main purpose of the assessment was to identify the breakage of pipes and investigate the main reasons of the repeated blockage in the sewer system. The movies of the CCTV were analyzed by the author with the assistance of the municipal engineers to determine the marks of the structural and performance defects. Information related to impact factors was provided by the municipality office while the engineering and administrative factors were determined by the former engineer and the manager of the municipality, respectively.

**Figure 1.** Locations of Al Diwaniyah city and investigated area

### 4.1 Structural defects

Based on results of the CCTV techniques, marks of the structural defects were determined as shown in Table 5. It should be stated that corrosion of concrete pipes was occurred in the invert of pipes.

**Table 5.** Marks of structural defects of the seventeen sewer pipes

| Pipe ID | Corrosion Marks | Joint Opening Marks | Cracks and Leakage Marks | Deflection Marks | Structural Rating Marks |
|---------|-----------------|---------------------|--------------------------|-----------------|------------------------|
|         | IMF             | IMF                 | IMF                      | IMF             | IMF                    |
| MP #1   | 10              | 1.1                 | 0.0                      | 1.0             | 10                     | 1.1                    | 8                       |
| MP #2   | 15              | 1.1                 | 0.0                      | 1.0             | 20                     | 1.0                    | 10                      | 1.1                    | 12                     |
| MP #3   | 40              | 1.1                 | 15                       | 1.0             | 35                     | 1.0                    | 10                      | 1.1                    | 26                     |
| MP #4   | 30              | 1.1                 | 10                       | 1.0             | 15                     | 1.0                    | 10                      | 1.1                    | 17                     |
| MP #5   | 30              | 1.1                 | 10                       | 1.0             | 30                     | 1.0                    | 10                      | 1.1                    | 21                     |
| MP #6   | 20              | 1.1                 | 0.0                      | 1.0             | 15                     | 1.0                    | 10                      | 1.1                    | 12                     |
| MP #7   | 15              | 1.1                 | 0.0                      | 1.0             | 15                     | 1.0                    | 10                      | 1.1                    | 11                     |
| MP #8   | 45              | 1.1                 | 20                       | 1.0             | 25                     | 1.0                    | 15                      | 1.1                    | 28                     |
| MP #9   | 25              | 1.1                 | 15                       | 1.0             | 25                     | 1.0                    | 10                      | 1.1                    | 20                     |
| MP #10  | 45              | 1.1                 | 20                       | 1.0             | 25                     | 1.0                    | 15                      | 1.1                    | 28                     |
| MP #11  | 45              | 1.1                 | 20                       | 1.0             | 30                     | 1.0                    | 15                      | 1.1                    | 29                     |
| MP #12  | 60              | 1.1                 | 25                       | 1.0             | 60                     | 1.0                    | 15                      | 1.1                    | 42                     |
| MP #13  | 60              | 1.1                 | 25                       | 1.0             | 35                     | 1.0                    | 15                      | 1.1                    | 36                     |
| MP #14  | 60              | 1.1                 | 20                       | 1.0             | 35                     | 1.0                    | 15                      | 1.1                    | 34                     |
| MP #15  | 40              | 1.1                 | 20                       | 1.0             | 30                     | 1.0                    | 15                      | 1.1                    | 28                     |
| MP #16  | 45              | 1.1                 | 15                       | 1.0             | 25                     | 1.0                    | 15                      | 1.1                    | 27                     |
| MP #17  | 60              | 1.1                 | 20                       | 1.0             | 30                     | 1.0                    | 15                      | 1.1                    | 33                     |

Structural Rating Mark = Σ(defect mark x IMF)/Number of defects
4.2 Performance defects
Marks assigned to structural defects of the seventeen concrete pipes were relied on results of CCTV inspection. Table 6 shows the final marks of performance defects of the inspected pipes.

| Pipe ID | Debris and Root Intrusion Mark | IMF | Infiltration Mark | IMF | Performance Rating Marks |
|---------|--------------------------------|-----|-------------------|-----|--------------------------|
| MP #1   | 15                             | 1.1 | 25                | 1.0 | 21                       |
| MP #2   | 15                             | 1.1 | 30                | 1.0 | 23                       |
| MP #3   | 20                             | 1.1 | 30                | 1.0 | 26                       |
| MP #4   | 20                             | 1.1 | 40                | 1.0 | 31                       |
| MP #5   | 20                             | 1.1 | 45                | 1.0 | 34                       |
| MP #6   | 30                             | 1.1 | 20                | 1.0 | 27                       |
| MP #7   | 20                             | 1.1 | 10                | 1.0 | 16                       |
| MP #8   | 30                             | 1.1 | 30                | 1.0 | 32                       |
| MP #9   | 25                             | 1.1 | 30                | 1.0 | 29                       |
| MP #10  | 25                             | 1.1 | 20                | 1.0 | 24                       |
| MP #11  | 30                             | 1.1 | 45                | 1.0 | 39                       |
| MP #12  | 30                             | 1.1 | 20                | 1.0 | 27                       |
| MP #13  | 30                             | 1.1 | 20                | 1.0 | 23                       |
| MP #14  | 30                             | 1.1 | 15                | 1.0 | 21                       |
| MP #17  | 25                             | 1.1 | 20                | 1.0 | 24                       |

Performance rating marks = \( \sum \) (defect mark x IMF)/number of defects

4.3 Impact factors
Prior to assigning the marks of impact factors, marks of location factors including land use, traffic intensity, location (under or adjust to), access for repair, and environment were determined. No correction factor was applied on the location factor because this data was accurately obtained from the municipality. Table 7 depicts marks of location factors assigned to the seventeen sewer pipes.

| Pipe ID | Land Use | Traffic Intensity | Location (adjust to or under) | Access for repair | Environment | Location Factor Mark |
|---------|----------|-------------------|-------------------------------|-------------------|-------------|----------------------|
| MP #1   | 60       | 15                | 30                           | 30                | 10          | 29                   |
| MP #2   | 60       | 15                | 30                           | 60                | 10          | 35                   |
| MP #3   | 60       | 30                | 60                           | 60                | 10          | 44                   |
| MP #4   | 60       | 30                | 60                           | 60                | 10          | 44                   |
| MP #5   | 60       | 15                | 30                           | 30                | 10          | 29                   |
| MP #6   | 60       | 15                | 30                           | 30                | 20          | 31                   |
| MP #7   | 100      | 30                | 60                           | 60                | 30          | 56                   |
| MP #8   | 100      | 30                | 30                           | 60                | 30          | 50                   |
| MP #9   | 60       | 15                | 30                           | 60                | 30          | 39                   |
| MP #10  | 60       | 15                | 30                           | 30                | 30          | 33                   |
| MP #11  | 60       | 15                | 30                           | 30                | 10          | 29                   |
| MP #12  | 60       | 30                | 60                           | 60                | 10          | 44                   |
| MP #13  | 100      | 30                | 100                          | 60                | 10          | 60                   |
| MP #14  | 60       | 30                | 60                           | 30                | 10          | 38                   |
| MP #15  | 60       | 15                | 30                           | 30                | 10          | 29                   |
| MP #16  | 60       | 15                | 30                           | 30                | 10          | 29                   |
| MP #17  | 100      | 30                | 30                           | 60                | 30          | 50                   |
Subsequently, marks of impact factors were assigned based on information provided by the municipality. Table 8 shows the marks of the impact factors accompanied by the weighting factor (WF) of each impact factor.

**Table 8. Marks of impact factors of the seventeen concrete sewer pipes**

| Pipe ID | Location Mark | Burial Depth WF | Pipe Size WF | Functionality WF | Impact Rating Mark |
|---------|---------------|-----------------|--------------|------------------|-------------------|
| MP #1   | 29            | 0.30            | 10           | 0.28             | 15                | 0.25              | 30                | 0.17              | 20                |
| MP #2   | 35            | 0.30            | 10           | 0.28             | 15                | 0.25              | 30                | 0.17              | 22                |
| MP #3   | 44            | 0.30            | 15           | 0.28             | 20                | 0.25              | 30                | 0.17              | 28                |
| MP #4   | 44            | 0.30            | 15           | 0.28             | 20                | 0.25              | 30                | 0.17              | 28                |
| MP #5   | 29            | 0.30            | 20           | 0.28             | 15                | 0.25              | 23                | 0.17              | 23                |
| MP #6   | 31            | 0.30            | 20           | 0.28             | 20                | 0.25              | 30                | 0.17              | 25                |
| MP #7   | 56            | 0.30            | 15           | 0.28             | 25                | 0.25              | 40                | 0.17              | 34                |
| MP #8   | 50            | 0.30            | 15           | 0.28             | 20                | 0.25              | 30                | 0.17              | 29                |
| MP #9   | 39            | 0.30            | 20           | 0.28             | 15                | 0.25              | 26                | 0.17              | 26                |
| MP #10  | 33            | 0.30            | 10           | 0.28             | 20                | 0.25              | 30                | 0.17              | 23                |
| MP #11  | 29            | 0.30            | 15           | 0.28             | 15                | 0.25              | 22                | 0.17              | 22                |
| MP #12  | 44            | 0.30            | 15           | 0.28             | 15                | 0.25              | 26                | 0.17              | 26                |
| MP #13  | 60            | 0.30            | 20           | 0.28             | 25                | 0.25              | 37                | 0.17              | 37                |
| MP #14  | 38            | 0.30            | 20           | 0.28             | 25                | 0.25              | 28                | 0.17              | 28                |
| MP #15  | 29            | 0.30            | 20           | 0.28             | 15                | 0.25              | 19                | 0.17              | 19                |
| MP #16  | 39            | 0.30            | 20           | 0.28             | 20                | 0.25              | 25                | 0.17              | 25                |
| MP #17  | 50            | 0.30            | 20           | 0.28             | 20                | 0.25              | 32                | 0.17              | 32                |

Impact rating mark = Σ(impact factor x WF)

**4.4 Final condition assessment**

The final condition assessment of prioritization of rehabilitation was determined based on the average marks of structural defects, performance defects and marks of impact factors. The average rating marks of the sewer pipes were corrected using the engineering factor (EF) and administrative factor (AF) which were determined by the former engineer and the manager of the municipality, respectively. Table 9 depicts the final marks of the seventeen sewer pipes.

**Table 9. Final rating marks of the seventeen concrete sewer pipes**

| Pipe ID | Structural Rating Marks | Performance Rating Marks | Impact Factor Rating Marks | EF | AF | Final Rating Marks |
|---------|-------------------------|--------------------------|---------------------------|----|----|--------------------|
| MP #1   | 8                       | 21                       | 20                        | 1.1| 1.0| 18                 |
| MP #2   | 12                      | 23                       | 22                        | 1.0| 1.2| 23                 |
| MP #3   | 26                      | 26                       | 28                        | 1.0| 1.0| 27                 |
| MP #4   | 17                      | 31                       | 28                        | 1.0| 1.0| 25                 |
| MP #5   | 21                      | 34                       | 23                        | 1.2| 1.0| 31                 |
| MP #6   | 12                      | 27                       | 25                        | 1.0| 0.9| 19                 |
| MP #7   | 11                      | 16                       | 34                        | 1.0| 0.9| 18                 |
| MP #8   | 28                      | 32                       | 29                        | 1.0| 1.0| 30                 |
| MP #9   | 20                      | 29                       | 26                        | 1.2| 1.0| 30                 |
| MP #10  | 28                      | 24                       | 23                        | 1.0| 1.0| 25                 |
| MP #11  | 29                      | 39                       | 22                        | 1.0| 1.0| 30                 |
| MP #12  | 42                      | 27                       | 26                        | 1.2| 1.0| 38                 |
| MP #13  | 36                      | 24                       | 37                        | 1.0| 1.0| 32                 |
| MP #14  | 34                      | 27                       | 28                        | 1.0| 1.0| 30                 |
| MP #15  | 28                      | 27                       | 23                        | 1.0| 1.0| 26                 |
| MP #16  | 27                      | 21                       | 25                        | 1.0| 1.0| 24                 |
| MP #17  | 33                      | 24                       | 32                        | 1.1| 1.1| 36                 |

Final Rating Marks = (Structural Rating +Performance Rating +Impact Rating) x EF x AF/3
As it can be seen in Table 9, the sewer pipe (MP#12) has the highest final rating marks of 38 while sewer pipes MP#1 and MP#7 have the lowest final rating marks of 18. This means that the prioritization of rehabilitation should be given to sewer pipe MP#12 because it has the worst condition while sewer pipes MP#1 and MP#12 have the best condition and should occupy the end of the prioritization list.

5. Conclusions
In this study, factors that may affect the condition of the sewer system were determined based on information available in the open access literature and questionnaires prepared by the author. Factors were divided into three main categories including structural defects, performance defects and impact factors. Marking system was assigned on the factors in such a way that the sewer with the worst condition has the highest marks. The marking system was applied on seventeen concrete sewer pipes in Al Diwaniyah city – Iraq as a case study. The marks of the structural and performance defects were selected based on results of CCTV inspection while those of the impact factors were determined based on information provided by the municipality of Al Diwaniyah city. The final rating marks of the seventeen concrete sewer pipes ranged from 18 to 38. The highest mark refers to the worst condition while the lowest mark refers to the best condition of sewer pipes. Accordingly, sewer pipe MP#12 comes first while sewer pipes MP#1 and MP#7 come last in the prioritization of rehabilitation of the seventeen concrete sewer pipes.

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