Rationality Analysis of Channel Maintenance Scale in Long River Section

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Abstract. Based on the actual maintenance scale of the waterway of Changjiang Wuhan Waterway Bureau in 2018, this paper compared and analyzed the width-depth ratio of the actual maintenance scale of each reach, and the ratio of the actual maintenance scale to the monthly planned maintenance scale. Then, the rationality of channel scale is further analyzed, and the rational analysis of channel maintenance scale is explored, which can provide support for the assistant decision-making of digital channel of Yangtze River.

1. Introduction

With the gradual improvement of the construction of digital waterway in the Yangtze River channel, higher standards for public welfare services are put forward [1-3]. Reasonable and effective improvement of channel scale is helpful to better to serve port enterprises and related units involved in water. Analyzing the rationality of the channel scale of the long river section is of great significance to guide channel maintenance and production, improve the scientific rationality of channel layout and navigation mark distribution, improve the accuracy of channel scale prediction, improve channel utilization and channel capacity, and improve channel service in an all-round way [4-7].

The logical framework of this paper is as follows: on the basis of obtaining the width-depth ratio of planned maintenance scale (RP) and the width-depth ratio of actual maintenance scale (RA), the ratio of the actual maintenance scale to the monthly planned maintenance scale (RR) is determined. The results of fitting analysis show that the frequency distribution histogram of RR is in accordance with the normal distribution. Furthermore, the normal distribution curve can be used to determine the cumulative probability corresponding to RR; In order to take into account both economy and practical maneuverability, the upper limit of 0.85 corresponding to RR of 1.465 and the lower limit of 0.15 corresponding to RR of 0.744. Furthermore, the upper and lower limit of RA can be obtained, so that the RP can be reasonably determined according to the actual channel conditions.

2. General situation of main channel of Yangtze River in Changjiang Wuhan Waterway Bureau

Changjiang Wuhan Waterway Bureau governs over 715.2 kilometers of main channel of Yangtze River from Dabu Street to Shangchaohu and 3.5km of Dongting Lake Estuary waterway [8-10], including 63 waterways, and about 1300 perennial navigation marks have been set up.

Most of the river sections in the area are sandy riverbeds, and there are many shoals reaches and bends, and the waterways change dramatically during the dry season, not only with flow disordered bends such as Diaoguan, Fanzui, Hanjin guan, Paizhou, and so on. There are also Taipingkou, Chibakou, ...
Wuqiao, DaiJiazhou and other famous shallow waterways, in addition to Jingzhou Yangtze River Bridge, Wuhan Yangtze River Bridge, Parrot Island Yangtze River Bridge and more than a dozen cross-river bridges that have been built and are under construction. Therefore, it is difficult to maintain these waterways.

3. Calculation of reasonable range of width-depth ratio of waterway scale

3.1. Width-depth ratio of planned maintenance scale

The monthly scale plan for channel maintenance of Changjiang Wuhan Waterway Bureau in 2018 is shown in Table 1. Because the widths of different waterways are usually fixed values, the maintenance scale data of different waterways can be normalized by calculating the ratio of monthly maintenance width to water depth. Furthermore, $RP$ of Changjiang Wuhan Waterway Bureau in 2018 can be obtained, as shown in Table 2.

| Reach | Dabu street-Jingzhou #4 Wharf | Jingzhou #4 Wharf-Chenglingji | Chenglingji-Wuqiao | Wuqiao-Shangchao Lake |
|-------|--------------------------------|-------------------------------|-------------------|-----------------------|
| January | 3.5                            | 3.8                           | 4.0               | 4.5                   |
| February | 3.5                            | 3.8                           | 4.0               | 4.5                   |
| March    | 3.5                            | 3.8                           | 4.0               | 4.5                   |
| April    | 3.8                            | 3.8                           | 4.5               | 4.5                   |
| May      | 4.5                            | 4.5                           | 4.5               | 5.0                   |
| June     | 5.0                            | 5.0                           | 5.0               | 6.0                   |
| July     | 5.0                            | 5.0                           | 5.0               | 6.0                   |
| August   | 5.0                            | 5.0                           | 5.0               | 6.0                   |
| September | 4.0                            | 4.0                           | 5.0               | 6.0                   |
| October  | 3.5                            | 3.8                           | 4.5               | 5.0                   |
| November | 3.5                            | 3.8                           | 4.0               | 4.5                   |
| December | 3.5                            | 3.8                           | 4.0               | 4.5                   |
| Width    | 100                            | 150                           | 150               | 200                   |
| Bending radius | 750                           | 1000                          | 1000              | 1050                  |

| Reach | Dabu street-Jingzhou #4 Wharf | Jingzhou #4 Wharf-Chenglingji | Chenglingji-Wuqiao | Wuqiao-Shangchao Lake |
|-------|--------------------------------|-------------------------------|-------------------|-----------------------|
| January | 28.6                           | 39.5                          | 37.5              | 44.4                  |
| February | 28.6                           | 39.5                          | 37.5              | 44.4                  |
| March    | 28.6                           | 39.5                          | 37.5              | 44.4                  |
| April    | 26.3                           | 39.5                          | 33.3              | 44.4                  |
| May      | 22.2                           | 33.3                          | 33.3              | 40.0                  |
| June     | 20.0                           | 30.0                          | 30.0              | 33.3                  |
| July     | 20.0                           | 30.0                          | 30.0              | 33.3                  |
| August   | 20.0                           | 30.0                          | 30.0              | 33.3                  |
| September | 25.0                           | 37.5                          | 30.0              | 33.3                  |
| October  | 28.6                           | 39.5                          | 33.3              | 40.0                  |
| November | 28.6                           | 39.5                          | 37.5              | 44.4                  |
| December | 28.6                           | 39.5                          | 37.5              | 44.4                  |
As can be seen from Table 1, Table 2 and Figure 1:

1) The planned width of each reach does not change with the month, that is, the RP is inversely proportional to the planned maintenance depth of the current month.

2) The general trend of RP in the same month is (Wuqiao-Shangchao Lake) ≥ (Jingzhou # 4 wharf-Chenglingji) ≥ (Chenglingji-Wuqiao) ≥ (Dabu Street-Jingzhou # 4 wharf).

3) In the same river section, RP is relatively large in the dry season (that is, the channel water depth is shallower, the channel should narrow the width to ensure depth), and the flood season is smaller (that is, the channel water depth is deeper, the channel must be widened).

4) In September, the unique phenomenon in which the upstream RP is larger than the downstream RP appears. The rationality of channel planning scale remains to be explored.

3.2. Ratio of the actual maintenance scale to the monthly planned maintenance scale

On the basis of RP and RA of Changjiang Wuhan Waterway Bureau in 2018, the RR can be determined, and its frequency distribution is shown in Table 3.

| Interval Range | Frequency | Proportion |
|----------------|-----------|------------|
| [0, 0.5)       | 9         | 0.04%      |
| [0.5, 1.0)     | 7340      | 33.52%     |
| [1.0, 1.5)     | 10827     | 49.44%     |
| [1.5, 2.0)     | 2443      | 11.16%     |
| [2.0, 2.5)     | 705       | 3.22%      |
| [2.5, 3.0)     | 349       | 1.59%      |
| [3.0, 3.5)     | 184       | 0.84%      |
| [3.5, 4.0)     | 43        | 0.20%      |

Table 3 shows that about 95% of RR is in the range of [0.5, 2.0), and the frequency in the interval of [1.0, 1.5) is the most, about 50%. On this basis, the frequency distribution histogram of RR is fitted by normal distribution, and the fitting result is as shown in Figure 2.
Figure 2. Normal fitting of RR

Figure 3 shows the residual distribution of normal fitting. The results show that the frequency distribution histogram of RR significantly conforms to the normal distribution, and its $R^2$ value is 0.992. Furthermore, the frequency distribution histogram of RR in 2018 is fitted normally. The frequency distribution is shown in Table 4 and the normal fitting is shown in Figure 4.

Figure 3. Normal fitting residual
Table 4. RR of Each Reach in 2018

| Interval Range | Dabu street-Jingzhou#4 Wharf | Jingzhou #4 Wharf-Chenglingji | Chenglingji-Wuqiao | Wuqiao-Shangchao Lake |
|----------------|-------------------------------|-------------------------------|-------------------|----------------------|
| [0, 0.5)       | 0                             | 7                             | 0                 | 2                    |
| [0.5, 1.0)     | 198                           | 2434                          | 1925              | 2783                 |
| [1.0, 1.5)     | 349                           | 4593                          | 3688              | 2197                 |
| [1.5, 2.0)     | 309                           | 1277                          | 729               | 128                  |
| [2.0, 2.5)     | 133                           | 84                            | 488               | 0                    |
| [2.5, 3.0)     | 96                            | 0                             | 253               | 0                    |
| [3.0, 3.5)     | 10                            | 0                             | 174               | 0                    |
| [3.5, 4.0)     | 0                             | 0                             | 43                | 0                    |

Figure 4. RR of Each Reach in 2018

Table 5 shows the accuracy of the normal fitting of RR. The results show that the frequency distribution histogram of RR is also significantly consistent with the normal distribution.
Table 5. Check of Normal Fitting Accuracy

| Reach                                | Dabu street-Jingzhou #4 Wharf | Jingzhou #4 Wharf-Chenglingji | Chenglingji-Wuqiao | Wuqiao-Shangchao Lake | All  |
|--------------------------------------|-------------------------------|-------------------------------|--------------------|------------------------|------|
|                                      | R² value                      | 0.992                         | 0.998              | 0.985                  | 0.998| 0.992 |

4. Determination of Reasonable Width-Depth Ratio of Actual Maintenance Scale

The RR is determined by using 95% confidence interval, so that the RA does not need to be adjusted, which has no guiding significance for the actual channel maintenance work. In this paper, the RR corresponding to the upper limit of 0.85 and the lower limit of 0.15 is used to determine the reasonable RA, which is economical and operable for adjusting the RA at the present stage.

The normal fitting formula in Figure 2 is as shown in Equation 1, in which the mean value of the parameter μ is 1.10454, and the standard deviation is 0.34761. When the upper limit is 0.85, the RR is 1.465. When the lower limit is 0.15, the RR is 0.744.

\[
 f(x) = \frac{1}{\sqrt{2\pi \sigma}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{1}
\]

According to the upper and lower limits of RR, and the known RP, the upper and lower limits of RA can be calculated, as shown in Table 6 and Table 7, respectively.

Table 6. The upper limit of RA

| Reach                                | Dabu street-Jingzhou #4 Wharf | Jingzhou #4 Wharf-Chenglingji | Chenglingji-Wuqiao | Wuqiao-Shangchao Lake |
|--------------------------------------|-------------------------------|-------------------------------|--------------------|------------------------|
| January                              | 41.9                          | 57.9                          | 54.9               | 65.0                   |
| February                             | 41.9                          | 57.9                          | 54.9               | 65.0                   |
| March                                | 41.9                          | 57.9                          | 54.9               | 65.0                   |
| April                                | 38.5                          | 57.9                          | 48.8               | 65.0                   |
| May                                  | 32.5                          | 48.8                          | 48.8               | 58.6                   |
| June                                 | 29.3                          | 44.0                          | 44.0               | 48.8                   |
| July                                 | 29.3                          | 44.0                          | 44.0               | 48.8                   |
| August                               | 29.3                          | 44.0                          | 44.0               | 48.8                   |
| September                            | 36.6                          | 54.9                          | 44.0               | 48.8                   |
| October                              | 41.9                          | 57.9                          | 48.8               | 58.6                   |
| November                             | 41.9                          | 57.9                          | 54.9               | 65.0                   |
| December                             | 41.9                          | 57.9                          | 54.9               | 65.0                   |
Table 7. The Lower Limit of RA

| Reach                        | January  | February | March   | April   | May      | June    | July    | August  | September | October  | November | December |
|------------------------------|----------|----------|---------|---------|----------|---------|---------|---------|-----------|----------|----------|----------|
| Dabu street-Jingzhou #4 Wharf | 21.3     | 21.3     | 21.3    | 19.6    | 16.5     | 14.9    | 14.9    | 14.9    | 18.6      | 21.3     | 21.3     | 21.3     |
| Jingzhou #4 Wharf-Chenglingji | 29.4     | 29.4     | 29.4    | 29.4    | 24.8     | 22.3    | 22.3    | 22.3    | 27.9      | 29.4     | 29.4     | 29.4     |
| Chenglingji-Wuqiao           | 27.9     | 27.9     | 27.9    | 24.8    | 24.8     | 22.3    | 22.3    | 22.3    | 27.9      | 29.4     | 27.9     | 27.9     |
| Wuqiao-Shangchao Lake        | 33.0     | 33.0     | 33.0    | 33.0    | 29.8     | 24.8    | 24.8    | 24.8    | 33.0      | 33.0     | 33.0     | 33.0     |

5. Conclusion and Prospect

Based on the actual maintenance scale of the waterway under the jurisdiction of Changjiang Wuhan Waterway Bureau in 2018, this paper analyzes the distribution law of the RR, so as to reasonably determine its upper and lower limits. Furthermore, the actual monthly maintenance scale of the channel can be determined. It is of great significance to guide channel maintenance and production, improve the scientific rationality of channel layout and navigation mark distribution, improve the accuracy of channel scale prediction, improve channel utilization and channel capacity, and improve channel service in an all-round way.

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