

Automation of Bridge Scour Risk Assessment¹

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1 INTRODUCTION & SCOPE OF WORK

Bridge scour is the removal of sediment material from the bridge piers, abutments and foundations due to the actions of flowing water (e.g. Arneson et al. 2012, Kirby et al. 2012). Scour is one of the leading causes of bridge failure (e.g. Briaud et al. 2011, Prendergast & Gavin 2014, Dikanski et al. 2017). The estimation of scour risk has been a challenge for bridge managers and engineers as bridge scour is a complex challenge which combines hydraulic, geotechnical and structural processes (e.g. Melville & Chiew 1999, Arneson et al. 2012). The CS 469 manual is a well-established manual guiding engineers and bridge managers in estimating bridge scour risk for existing structures (Takano et al. 2021, National Highways 2024). The CS 469 was released in April 2024 by National Highways England to substitute an earlier version named BD 97/12 (National Highways, 2024). The CS 469 is the official manual utilized by national organizations within the United Kingdom and Ireland. The manual includes a series of empirical and semi-empirical equations which guide engineers and practitioners on the assessment of scour risk (National Highways, 2024). The current manual is a detailed procedure comprising multiple stages that must be carried out manually for each bridge. Whilst the scour risk assessment methodology followed by the manual is robust, applying the methodology to an entire bridge network is time intensive. Specifically, the user should thoroughly read the 276 pages outlined in the manual to first define the required data to be collected. After collecting the required inputs, the user must perform multiple calculations on a series of empirical and semi-empirical equations and priority plots to estimate secondary outputs such as the threshold velocity, U_{th} and the local pier scour depth, $D_{l, pier}$ to then calculate the relative scour depth, D_R and the priority factor, P_{FT-1} (Figure 1). The process is performed individually for each bridge. The aim of this work is to support bridge practitioners and engineers by automating the steps set out in the CS 469 manual, which will allow for efficient analysis, ranking, and comparison of many bridges within a network. Each step of automation will reduce the overall assessment time required for each bridge whilst maintaining consistency.

2 METHODOLOGY

The assessment of bridge scour risk within the CS 469 is structured in two levels, Level 1 and Level 2. Level 1 assessment is a simple screening level assessment which is utilized to determine whether a more detailed assessment is required (Level 2 assessment) (Takano et al. 2021, National Highways, 2024). Level 1 assessment includes looking at existing bridge data to determine whether there is potential scour risk (i.e. debris accumulation, scour history, constriction of the waterway) which direct the bridge practitioner to the Level 2 assessment (National Highways, 2024). Level 2 aims at estimating the Scour Risk Rating as High, Medium, Low and give a Scour Risk Score between 10 – 100, where 100 indicates maximum severity

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(National Highways, 2024). The Level 2 assessment is outlined by the flow chart in Figure 1. The Level 2 assessment requires the estimation of the relative scour depth, D_R and Priority Factor, P_{FT-1} which are then used as indicators to determine the scour risk score and rating with the assistance of priority plots (see Figure 5.52, p.122, National Highways, 2024). The estimation of the two parameters requires the collection of data from the examined bridge which are then processed to acquire the necessary inputs in order to estimate the local pier scour depth, $D_{l, pier}$ and constriction scour depth, D_c to then calculate the total scour depth, D_T .

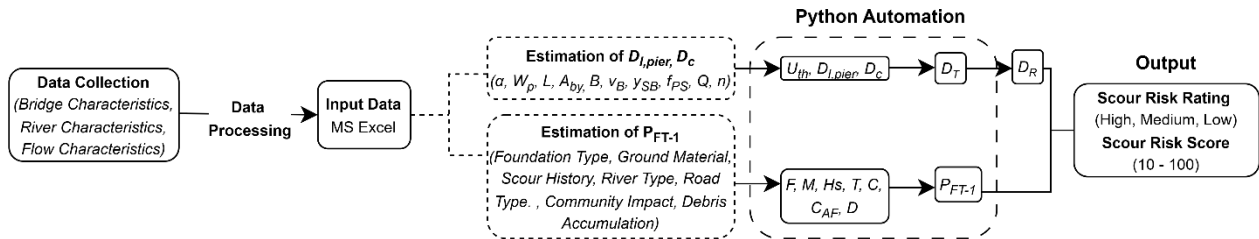


Figure 1. Flow Chart describing the steps within Level 2, scour risk rating assessment highlighting the automated steps within the process as 'Python Automation'.

Table 1. Input Parameters in MS Excel Spreadsheet based on information collected for **Masonry arch bridge in Northern Ireland** and Output Values estimated with the Python Script.

INPUT PARAMETER	ACRONYM	UNIT	INPUT VALUE	OUTPUT VALUE
PIER WIDTH	W_p	m	1.5	
PIER LENGTH	L	m	15	
SKEW ANGLE	a	°	0	
FLOW DEPTH	y_{SB}	m	1.53	
APPROACH VELOCITY	V_B	m/s	1.16	
PIER SHAPE FACTOR	F_{ps}	-	0.8	
SEDIMENT SIZE	D_{50}	mm	8	
DISCHARGE	Q	m ³ /s	38.2	
FLOW REA	A_{BY}	m ²	32.85	
CONstriction SCOUR DISTRIBUTION FACTOR	F_s	-	1.25	
DEBRIS FACTOR	f_d	-	1	
CHANNEL WIDTH	B	m	18	
MANNING'S COEFFICIENT	n	-	0.05	
FOUNDATION TYPE	-	-	Masonry	
GROUND MATERIAL	-	-	Unknown	
SCOUR HISTORY	-	-	Yes	
RIVER TYPE	-	-	Very Steep	
ROAD TYPE	-	-	Motorway	
COMMUNITY IMPACT	-	-	Severe	
DEBRIS RISK	-	-	High	
TOTAL SCOUR DEPTH	D_T	m		1.41
PRIORITY FACTOR	P_{FT-1}	-		4.75

The total scour depth, D_T , is then used to calculate the relative scour depth, D_R (Figure 1). The estimation of P_{FT-1} requires dimensionless inputs which are quantified as factor coefficients. Figure 1 marks the steps within the process which have been automated with the assistance of Python libraries, Pandas and NumPy, in Visual Studio Code Software. The Python script uses the inputs from Table 1 to return the constriction scour depth, D_c and the local pier scour depth, $D_{l,pier}$ to then calculate D_T . The script is also able to quantify words in terms of coefficients. For example, when the user provides 'masonry' as the foundation type, the script returns a foundation type factor, F , of 1.25. The script is able to return the factor coefficient for all parameters required to estimate P_{FT-1} as shown in Figure 1. Table 1 shows the input data that were collected from a masonry arch bridge in Northern Ireland to test the Python script. To validate the Python script, a one-input-at-a-time approach was followed where individual parameters were systematically changed one by one, whereas the rest of the inputs were kept constant to ensure that the Python script and the Excel spreadsheet returned the same D_T and P_{FT-1} .

3 RESEARCH OUTCOMES

This study has successfully put the foundations for a faster more efficient estimation of scour risk on bridges when using the CS 469 manual. The Python script outlined in the methodology is able to calculate D_T and P_{FT-1} for multiple bridges in less than a minute, considering that the necessary data are included in the script. In contrast, the excel spreadsheet requires at least 15 minutes to perform the same calculation for a single bridge. Future work aims in the automation of more steps within the Level 2 assessment, for example aiming at the code to directly indicate the level of scour risk assessment, at the application of the automated process to the entire National Irish Network as well as the creation of a more user-friendly version that will be directed to bridge managers and practitioners.

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