

TECHNISCHE UNIVERSITÄT BERLIN  
DEPARTMENT OF CIVIL SYSTEMS ENGINEERING



MODELING CIVIL ENGINEERED SYSTEMS

ASSIGNMENT 2 REPORT

PARAMETRIC MODELING

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# 1. INTRODUCTION

This project uses a parametric model made in Dynamo BIM to examine and optimize the design of a gravity sanitary sewer segment. The primary design problem addresses the engineering and financial requirements necessary to handle an expected future flow growth and models a population expansion from 10,000 to 20,000. The model links dynamic components like Pipe Diameter, Slope, and Material to high-performance criteria like Functional Capacity, Operational Velocity (self-cleaning/scouring checks), and Total Project Cost. The goal is to identify the best cost-effective design alternative that ensures long-term system viability and performance.

## 1.1 CORE DESIGN CHALLENGE

This research concentrates on a representative sewer section, which often serves as the primary functional unit for hydraulic analysis and optimization, due to the fundamental complexity of a full municipal network. Future-proofing a major sanitary sewer segment against flow increases brought on by anticipated population development (simulating 10,000 to 20,000) is the main design problem. The project focuses on optimizing this typical segment, which is initially set at 50 m in length, due to the complex structure of municipal networks. The design must minimize capital expenditure while accommodating an ultimate needed capacity of 80 L/s.

To derive the initial 40 L/s baseline and the required 80 L/s target, the methodology integrated the standard 120 LPCD (liters per capita per day) flow rate with a population-based Peaking Factor (PF). This ensures the design adequately handles peak hourly demand, establishing the necessary hydraulic constraints for the optimization phase.

## 1.2 HIGH PERFORMANCE CRITERIA

Three crucial, linked criteria are used to evaluate each alternative's viability and performance. The Functional Criterion of Flow Capacity is the main non-negotiable restriction: the pipe's true physical capacity ( $Q_{max}$ ) must equal or above the necessary 80 L/s design flow. The Operational Criterion of Flow Velocity, which guarantees pipe longevity by avoiding both system-clogging sedimentation ( $V \geq 0.6$  m/s) and destructive scouring ( $V \leq 3.0$  m/s), is equally significant. Lastly, the final design decision is guided by the Financial Criterion of Total Project Cost, which minimizes the combined cost of pipe materials and excavation volume while balancing technical needs against budget-efficient execution.

## 1.3 PARAMETERS AND INPUTS

The strict control of variables divided into fixed and flexible inputs is essential to design optimization. The three modifiable design parameters—the Pipe Diameter (D), the Pipe Slope (S), and the Manning's Roughness Coefficient (n) through material selection—are the fundamental levers of the project. The cost structure is determined by the Pipe Diameter (D), which also establishes the physical flow ceiling. The cost per linear meter ( $C_{Pipe, m}$ ) rises gradually with the diameter, reflecting manufacturing costs. The fundamental factor influencing both flow velocity and excavation volume is the Pipe Slope (S). The primary financial leverage element is the selection of Manning's n (PVC vs. Concrete), which establishes the shallowest slope necessary for hydraulic functionality.

Furthermore, to determine the Excavation Volume, the model depends on preset Trench Geometry Parameters. The total excavation volume and ultimate project cost are determined by these permanent limits, which include the Depth of Cover ( $H_{Cover}$ ), Trench Side Slope ( $S_{Side}$ ), and Trench Bottom Clearance ( $C_{Bottom}$ ).



Figure 1: Parametric Control Panel and Performance Criteria

## 2.Model Logic and Formulation

### 2.1 Model Architecture

Geometric inputs are turned into hydraulic and financial performance criteria by the parametric model, which is designed as a combined system. By combining three modules—Geometry, Hydraulics, and Cost, the system exhibits complexity. Manning's Equation, which is used to effectively calculate the flow capacity ( $Q$ ) and velocity ( $V$ ) for any combination of design factors, is the analytical foundation of the system:

$$Q = \frac{1}{n}AR^{2/3}S^{1/2}$$

### 2.2 Functional Module Integration

The dynamic coupling of the system's outputs establishes its integrity. The rate output is verified by the Hydraulic Module in relation to the Operational Constraints (self-cleaning and scouring restrictions). The precise Excavation Volume is produced by the Geometric Module using preset restrictions (Depth of Cover, Side Slope). The last phase of synthesis is carried out by the Financial Module, which uses an advanced interpolation function to determine the dynamic unit price for the pipe material based on its diameter and choice. The final budget criterion is then obtained by adding this cost to the total volumetric excavation cost.

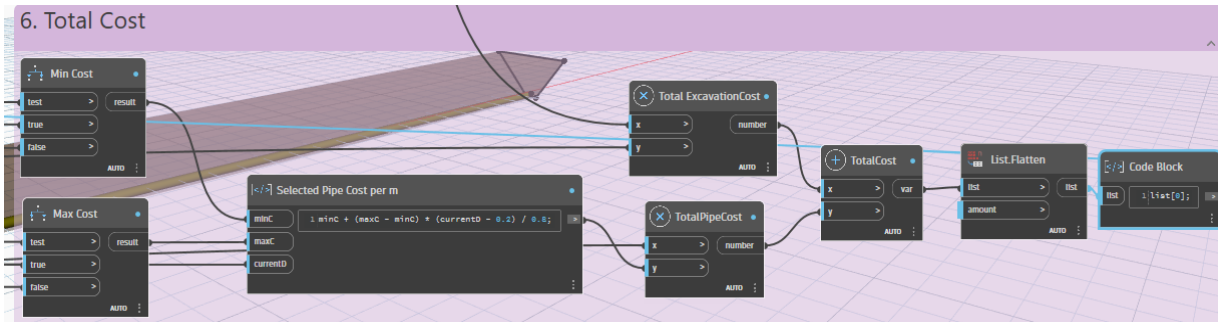


Figure 2: Dynamic Financial Module (Total Cost Logic)

### 3. Design Space Exploration and Results

The analysis obtained from the parametric model, which was crucial in defining the practical design space while determining the operational and financial constraints, is presented in the next part. The design space was severely limited by hydraulic needs. The 0.20 m pipe failed to meet its practical limit, which required a minimum diameter of 0.25 m. The Operational Limit was established by the 3.0 m/s scouring constraint. The highest cost limit was defined by the significantly steeper slope required by the high Manning's n of concrete, which resulted in an excessive excavation volume.

The model analyzed four configurations, summarized below, demonstrating the required upgrade investment and the financial leverage achieved through material and system configuration choices.

Alt.	Design Focus	Material	Length (m)	Diameter (m)	Slope (m/m)	Operational Pass?	Total Cost (€)
0	Baseline (40 L/s)	Concrete	50	0.2	0.016	No (Capacity FAIL)	14,432.50
1	System Trade-Off	PVC	25	0.3	0.005	Yes	6,659.00
2	Optimized Standard	PVC	50	0.25	0.009	Yes	13,515.00
3	Conventional Benchmark	Concrete	50	0.25	0.019	Yes	16,467.03

Table 1: Comparison of Optimized Alternatives (Flow Requirement: 80 L/s)

## 4. Conclusion and Engineering Rationale

### 4.1 Synthesis of Design Extremes and Limits

The analysis confirmed that a non-negotiable capacity improvement was necessary to future-proof the system because the 0.20 m baseline pipe did not meet the 80 L/s flow requirement. Hydraulic and financial limitations defined the design space: the Feasibility limit required a minimum diameter of 0.25 m, and the Economic Extremes demonstrated that the conventional Concrete pipe (Alternative 3) imposed a significant cost penalty (16,467.03 €) because of the

steep slope (0.019 m/m) necessary for operational compliance. High excavation volume was found to be the main cause of this cost impact.

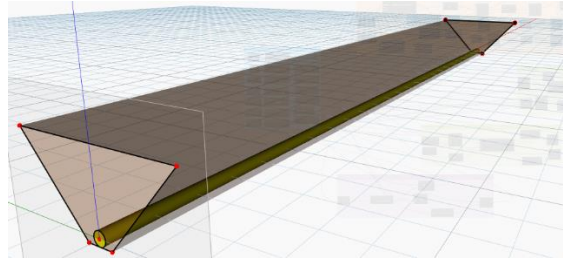


Figure 3: Visual Comparison of Slope Extremes

## 4.2 Final Recommendation

Alternative 1 (PVC, 25 m segment) is the suggested solution. Because it strategically optimizes the overall system design, this alternative is the most effective solution. The model showed that taking advantage of the cost-length relationship results in the greatest cost efficiency. Relative to the next cheapest 50 m option (Alternative 2), the solution produced significant capital savings of approximately 6,856 € in pipe material and excavation by lowering the segment length from 50 m to 25 m.

This saving is sufficient to offset the added cost of installing an extra manhole, which the shorter length requires. Alternative 1 meets all functional and operational criteria while achieving the lowest possible capital cost per segment (6,659.00 €). This confirms the core engineering rationale: optimal sewer design requires prioritizing system configuration and low-roughness materials (PVC) to minimize the high cost of earthwork, rather than accepting the costly constraints of conventional segment lengths.

## REFERENCES

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