Report

Simplified approach to estimation of costs and material volumes in concrete road bridges

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Report EXCON

Simplified approach to estimation of costs and material volumes in concrete road bridges

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SUMMARY
The Excon project develops a decision-support model to manage large concrete structures by evaluating strategies that balance cost, environmental impact, and lifespan extension. It compares maintenance approaches with full replacement by integrating environmental and economic data. Since bridges are unique, estimating new construction impacts is complex. The work presented here uses technical drawings and cost data from existing bridges to create general estimates for material use and costs. The report details the methodology, case selection, and predictive parameters, offering a foundation for further model development. This study provides a first attempt at estimating bridge construction costs and environmental impacts using general data. The results are highly variable and uncertain—especially for material estimates due to differing ground conditions and design choices. The estimates provided here can offer rough guidance in the absence of more precise information and qualified estimates.

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Contents

1 Background/motivation

The main goal of the Excon project is to develop a generic and interactive model for decision support involving management strategies for large existing concrete structures. The model will be a techno-economic model extended to include environmental performance, thereby enabling evaluation of management alternatives on an equal level for both costs and environmental footprint. The development of the model and the work performed in the project are intended to contribute to knowledge and tools for extending the lifetime of existing concrete structures and thereby reduce both costs and emissions from maintaining and operating the structures.

Reductions in costs and emissions can be achieved in different ways and at different levels, such as:

- Reductions through optimized use of materials, energy and resources in current maintenance and repair activities.
- New methods for maintenance and repair activities with lower costs and/or environmental footprints from reduced use of materials and resources, or alternative materials with lower costs and/or environmental impacts.
- New methods for early damage detection and facilitation of preventive maintenance.
- Extended lifetime through improved management strategies resulting in postponed or avoided replacement of the structure.

For the decision support model to consider the economic and environmental implications of different management strategies, it requires information on the associated footprints of the maintenance and repair activities currently used. Furthermore, evaluation and comparison of alternative management strategies with lifetime extension as an alternative, need to include the costs, resource use and associated emissions from constructing a new structure. In this way, additional resources required in a management strategy for extending the lifetime can be compared to a scenario where the structure is allowed to degrade and be replaced by a new structure.

Comparing scenarios with extended lifetime and avoided construction is complicated for bridges because they can all be considered as unique and non-standardized structures. Estimating the costs and emissions from a new structure is therefore not straightforward since the design is usually not decided and detailed at the stage where the Excon model will be used.

Emissions from bridge construction are primarily related to the emissions occurring during production of the materials used in the bridge. Material quantities will vary according to a range of design and location specific parameters. This means that for the Excon tool to provide a meaningful basis for comparison between extended lifetime and new construction, it needs data to provide a reasonable estimate for the material use and costs of new bridges without specific information about it being known. However, the study and results presented here rest on the assumption that a replacement structure would have the same main characteristics and be similar in terms of structural system layout, main materials and components.

The analysis presented here represents a first attempt to provide the necessary basis for generic estimates of costs and quantities and discusses the relevance of different parameters to be used.

The work described in this report is based on empirical and existing information on bridge design from technical drawings of actual bridges to approximate the amount of reinforced concrete used. Furthermore, cost data from recent constructions are used to estimate unit costs for new bridges. The availability of cost data is limited, and the material use estimates and cost estimates used here are therefore not for the same sample selection of specific bridges. The report is structured with an introduction to the rationale for selection of case bridges used to quantify material use, description of the method for quantifying it and proposed parameters for predicting material use, description of data and parameters for cost estimation, and an example of use for prediction of both material use and costs. Finally, results and findings are discussed and suggestions for further work provided.

2 Estimation of concrete volumes

The estimation of concrete volumes begins by finding and selecting case bridges from which to collect quantitative data from. The selected bridges are detailed in Table 1 and the selection criteria described below.

	Description	Total Length	Max. SPAN	Byggverksnavn	Fylke	Kommune	Byggeår	Bruklast
SVV only > 100m length	beam & slab, 4 spans, max. span 31m, total length 100m	100	31	**Honingsbrui**	Vestland	Lærdal	2014	Bk 10/60
	beam & slab, 6 spans, max. span 22m, total length 125m	125	22	**Audna**	Agder	Lindesnes	1977	Bk 10/60
	arch, max. span 115.4m , total length 179m	179	115	**Trengsel**	Nordland	Sørfold	1964	Bk 10/60
	box girder, 3 spans, max span 171.5m, , total length 303m	303	171	**Kåkern Bru**	Nordland	Flakstad	2002	Bk 10/60
	box girder, 7 spans, max span 105m, total length 333m	333	105	**Nordsundbrua**	Møre og Romsdal	Kristiansund	1980	Bk 10/60
25-50 1-span - Trondelag	beam & slab, 1-span 27 m (total length)	28	28	**Elveråsbrua**	Trøndelag	Stjørdal	2004	Bk 10/60
10-20m 1-span - Trøndelag	solid slab, standard substructure, total length 17m	17	17	**Halsanbrua**	Trøndelag	Levanger	2012	Bk 10/60
	RC portal, long walls, total length18.5, span 6m	19	6	**Nyhus o/jernebane**	Trøndelag	Melhus	1985	Bk 10/60
	solid slab, standard substructure, total length 18m	18	18	**Songa**	Trøndelag	Orkdal	1977	Bk 10/60
	beam and slab deck, only abutment walls, total length 18m	19	18	**Tua bru**	Trøndelag	Stenkjer	1943	Bk 10/60
	precast beams deck, big foundation slab, total length 18m	19	18	**Hovsbakkan Bru**	Trøndelag	Orkland	1982	Bk 10/60
	Slab, standard substructure, total length 14m	13	14	**Skjøtskift**	Trøndelag	Orkland	2017	Bk 10/60
Plassproduserte platebruer SVV Bruhåndbok - 4	Standard bruplate - 8.5m wide	10	10	one-span 10m	SVV Bruhåndbok - 4			
	Standard bruplate - 8.5m wide	15	15	one-span 15m	SVV Bruhåndbok - 4			
	Standard bruplate - 8.5m wide	20	20	one-span 20m	SVV Bruhåndbok - 4			
	Standard bruplate - 8.5m wide	22	10	3-span 6,10,6m	SVV Bruhåndbok - 4			
	Standard bruplate - 8.5m wide	33	15	3-span 9,15,9m	SVV Bruhåndbok - 4			
	Standard bruplate - 8.5m wide	44	20	3-span 12,20,12m	SVV Bruhåndbok - 4			

Table 1: *Extract from the spreadsheet used, showing the list of bridges and description.*

2.1 Data and case bridges

BRUTUS is an IT solution developed by the Norwegian Public Roads Administration (SVV) to handle data on bridges, quays and other load-bearing structures on the national and county road network in Norway. The system contains information (SVV N-V441:2023) on all bridges, including inspections and condition assessments.

We used BRUTUS to access the SVV bridges database to obtain the data necessary for the calculation of the quantities.

Selection Criteria

Bridge data were extracted from the Brutus database using a structured filtering process to ensure relevance and representativeness. The selection proceeded in three steps:

1. **Initial filtering** – *190 bridges* were identified that met the following criteria:
    - Concrete road bridges
    - Load capacity classification: Bk 10/60
    - Ownership: Statens vegvesen (SVV) or county authority (fylkeskommune)
    - Span length between 100 and 1290 metres
2. **Refined selection** – *123 bridges* were retained by limiting the scope to those owned by **SVV only**, enabling more consistent documentation and design practices.
3. **Final selection** – From these 123 SVV bridges:
    - *5 of these 123 bridges* were selected as representative examples based on structural type and design characteristics.
    - To broaden the applicability of the results and ensure that the analysis captured the range of practices in Norway, additional bridges were included:
        - Bridges owned by **fylkeskommune,** to represent regional design and maintenance practices which may differ from **SVV's**
        - Bridges based on **SVV's Bruhåndbok** standard designs, to anchor the selection in typical, codified design solutions and enable comparison with current design templates.
        - The total number of bridges analysed is 18, whereof 12 are based on existing constructions and six from standard design in the 'Bruhåndbok', as presented in Table 1.

Across all categories, care was taken to exclude outliers or unique, atypical designs. The final set of bridges thus reflects common structural configurations and material usage across Norwegian concrete road bridges.

Bridge length was chosen as an important selection factor since it generally corresponds to the amount of concrete used in the structure, which is a major contributor to CO_2-emissions.

The focus on bridges with standard design elements, such as reinforced decks, usually either normally reinforced or prestressed, and typical foundation components, including reinforced retaining walls, columns, bases and wing walls, strengthens the generalizability of the results.

Construction type

The following type of deck construction (the main structural element of bridges) was chosen as the most representative:

- Solid or voided slabs
- Precast beams
- Beam-and-slab decks
- Box-girders
- Concrete arch
- Portal frame structure
- Standard bridges from 'SVV Bruhåndbok', 'bruplate' (one-span and three-span)

Construction period

The bridges selected for this study have a construction date spanning between 1943 and 2017.

Length

The maximum span length of the bridges included in the study ranges from 6 to 171 metres (see column 4 in Table 1).

2.2 Quantification

Construction drawings and estimation

To estimate material quantities in concrete road bridges, construction drawings were sourced from BRUTUS, the Statens vegvesen (SVV) database. The most relevant drawings for this purpose include 'oversikt-tegning', 'oversikt-rapport', 'formtegning', and 'ferdigbrutegning'.

For simple, single-span bridges, the 'oversikt-tegning' and 'oversikt-rapport' generally provide sufficient information to determine material quantities with good accuracy. However, for larger and more complex structures, such as Nordsundbrua, additional details are necessary, often requiring the examination of up to 20 different drawings to ensure a comprehensive assessment, as exemplified in Figure 1 and Figure 2.

15-1837 Nordsundbrua - Møre og Romsdal - ferdigbrutegning.pdf
15-1837 Nordsundbrua - Møre og Romsdal - Landkar Nord - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - Landkar Sør - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - Oversikt.pdf
15-1837 Nordsundbrua - Møre og Romsdal - pilar 1 - forskaling og armering.pdf
15-1837 Nordsundbrua - Møre og Romsdal - pilar 2 - forskaling og armering.pdf
15-1837 Nordsundbrua - Møre og Romsdal - pilar 3 - forskaling og armering.pdf
15-1837 Nordsundbrua - Møre og Romsdal - pilar 4 - forskaling og armering.pdf
15-1837 Nordsundbrua - Møre og Romsdal - pilar 5 og 6 - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 1 - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 1.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 2 - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 3 - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 4 - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 5 - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 5 6 7 - tverrsnitt forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 5-6 nivelleringsplan.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 6 - Nord - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 6 - Sør - forskaling.pdf
15-1837 Nordsundbrua - Møre og Romsdal - spenn 7 - forskaling.pdf

Figure 1: *list of drawings used for Nordsundbrua quantities.*

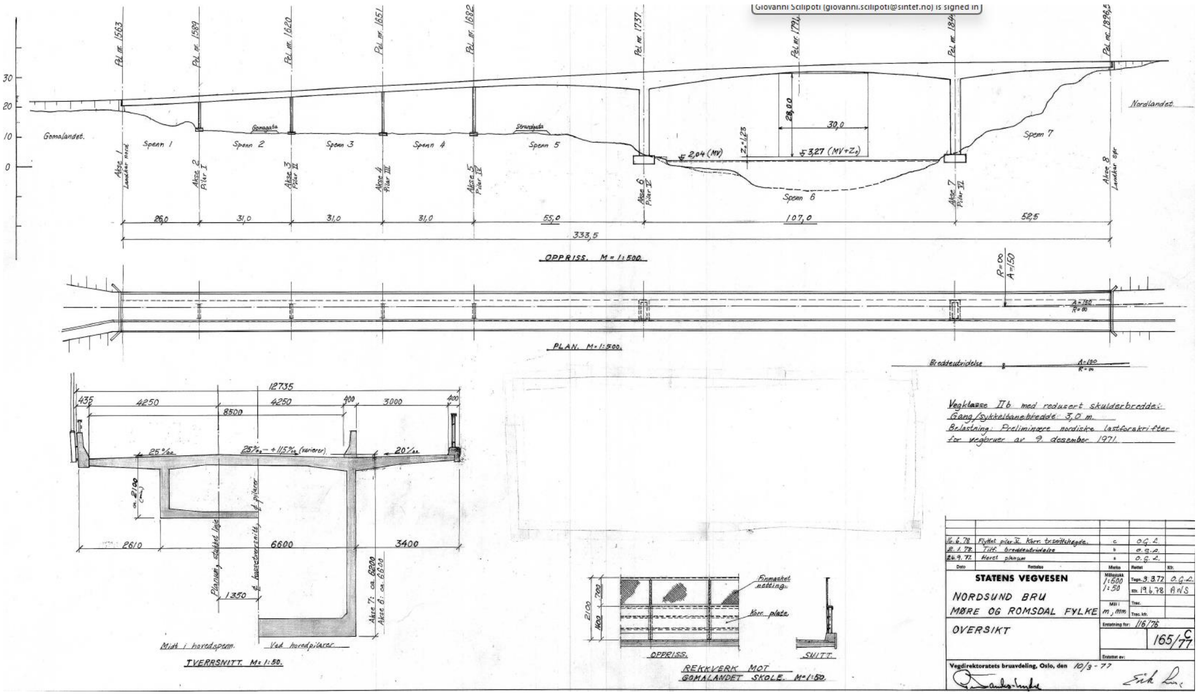

Figure 2: *'Nordsundbrua oversikt' drawing.*

The quantity estimation process is based on a geometric breakdown of the bridge components into simple shapes, such as rectangular, trapezoidal, and cylindrical elements. Concrete volume estimation for individual component dimensions are extracted, sub-volumes computed, and total volume aggregated. An example is shown in Figure 3. This method allows for a structured and replicable approach to material quantification, ensuring consistency and minimising estimation errors across different bridge types.

Total volume Superstructure		2889.71	[m3]
Total volume Substructure		1763.57	[m3]
Nordsundbrua			
superstructure spenn 1-4		985.93	[m3]
left cantilever:		0.96	[m2]
right cantilever:		1.14	[m2]
barrier		0.3	[m2]
main deck		5.24	[m2]
TOTAL AREA:		**7.64**	[m2]
Length spenn 1-4:		119	
diaphragm walls (5 nr)		76.77	[m3]
Pilar 1	**TOTAL**	77.14	[m3]
Stem:		32.02	[m3]
Base:		11.65	[m3]
Foundation:		33.48	[m3]
Pilar 2	**TOTAL**	97.92	[m3]
Stem:		42.87	[m3]
Base:		11.65	[m3]
Foundation:		43.40	[m3]
Pilar 3	**TOTAL**	115.56	[m3]
Stem:		55.48	[m3]
Base:		12.48	[m3]
Foundation:		47.60	[m3]
Pilar 4	**TOTAL**	134.99	[m3]
Stem:		62.51	[m3]
Base:		12.48	[m3]
Foundation:		60.00	[m3]

Figure 3: examples of calculations for Nordsundbrua quantities.

Superstructure/substructure as key separation

Construction quantities were categorised into superstructure and substructure (see Figure 4), reflecting the distinct structural and geotechnical factors influencing each.

The superstructure, which includes elements such as decks and girders, is primarily governed by span length, loading conditions, and structural design choices. It determines the bridge's ability to carry traffic and resist external forces, making it a key driver of material volume and cost.

The substructure, comprising abutments, piers, and foundations, provides support for the superstructure and transfers loads to the ground. Its design and material requirements are largely dependent on terrain geometry, soil conditions, and foundation type. Factors such as rock depth, groundwater levels, and soil bearing capacity influence both the volume of concrete needed and the complexity of construction.

This division allows for a more structured estimation process, ensuring that structural demands and geotechnical constraints are accounted for separately. It also improves comparability across different bridge designs by isolating the factors that influence material quantities in each category. Such factors vary depending on local variations and project-specific conditions, making precise quantification complex without more data.

Certain factors are expected to have a stronger influence, while others may introduce variability. For example:

- Superstructure volume is primarily influenced by span length, loading conditions, and structural type.
- Substructure volume is more dependent on foundation conditions (e.g., soil type, rock depth, groundwater levels).
- Total concrete volume is affected by both, but the relative contribution of each varies depending on site constraints and design choices.

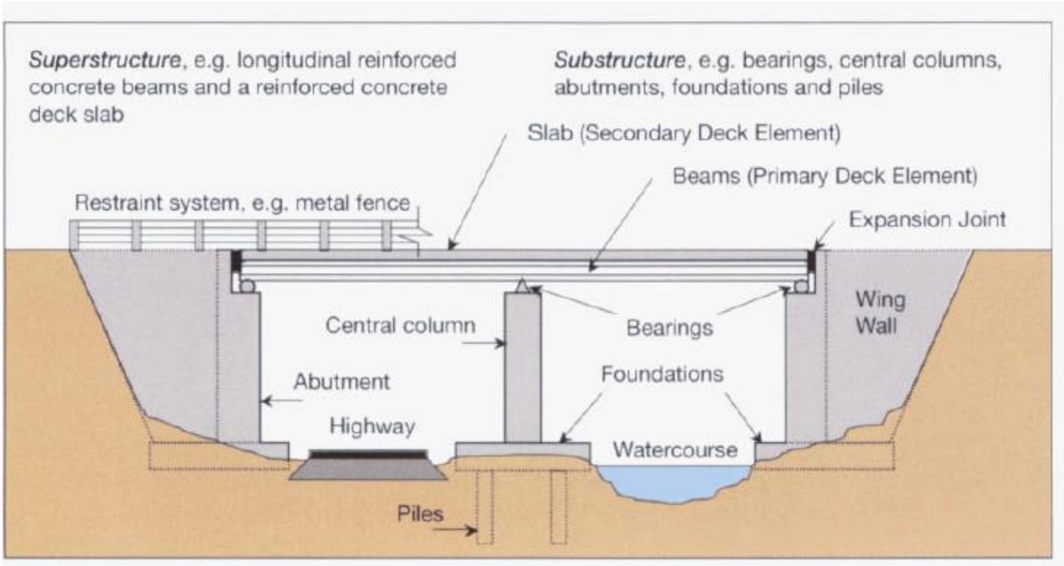

Figure 4: *Typical Bridge element (drawing from[1]).*

[1] *https://ukrlg.ciht.org.uk/media/16712/guidance-definition-of-asset-management-responsibilities-bridges-and-structures-version-18-february-2022.pdf*

Selected parameters and justification for these

The concrete volumes (in m³) were determined from construction drawings by extracting and summing the dimensions of individual bridge components. These values were recorded in a spreadsheet for each bridge, ensuring a systematic approach to data collection. To provide a basis for comparison, the total deck area (m²) was also calculated using the bridge total length and bridge deck width.

Superstructure, m3/m2	Bridge, m3/m2	Ratio volumes - super. / substruct.

From these data, the following key ratios were computed and tabulated:

a) **Superstructure volume per deck area (m³/m²)** – This ratio provides an indicator of material efficiency in the superstructure, helping to compare different bridge designs in terms of their structural mass relative to deck area.

b) **Total bridge volume per deck area (m³/m**²) – By including both the superstructure and substructure, this ratio reflects the overall material intensity of the bridge, capturing variations in foundation and support structures.

c) **Superstructure volume to substructure volume ratio** – This ratio highlights the relative distribution of concrete between the superstructure and substructure, which can vary depending on span length, foundation type, and geotechnical conditions. Bridges with longer spans tend to have a higher superstructure-to-substructure ratio, whereas those with challenging ground conditions may require a more substantial substructure. For example, deep foundations in poor soil conditions may significantly increase substructure volume.

These parameters were selected to facilitate meaningful comparisons across different bridge types, providing insights into material distribution and potential cost drivers. By standardising the data in terms of ratios, trends could be identified, allowing for a better understanding of how structural and geotechnical factors influence concrete consumption.

Alternative indicators, such as substructure volume per metre of substructure height (m³/m), were considered in early discussions. While this approach could help illustrate the greater variability in substructure volumes, it was not applied in this study due to significant inconsistencies in how substructure height is defined and measured across different bridge types. For many bridges in the sample, especially those with embedded or stepped foundations, the height of the substructure does not correspond to a single, meaningful dimension. This limits the usefulness and comparability of a height-based metric. For this reason, volume-based ratios relative to deck area were preferred for their consistency and broader applicability.

2.3 Results

Figure 5 shows regression model results for material use in bridges (see selection in Table 2). We fitted four different models to our data: Power, Linear, Log, and Exponential. The regression analyses model the relationship between 'Bridge spans' and 'Bridge material use [m³/m²]'. The analysis also identifies outliers (one in this case at length 18.00, price 2.71) and for each model gives the R^2 value to measure the goodness of fit.

```
Regression Model Results:
       Model                  Equation        R²
 Power Model      y = 2.016 * x^-0.072 0.053114
Linear Model       y = -0.002x + 1.695 0.058395
   Log Model y = -0.117 log(x) + 1.975 0.054872
   Exp Model     y = 1.647 * e^-0.002x 0.070925

Outliers (Residuals > 2 std dev):
Length: 18.00, Price: 2.71
std res: 0.415
```

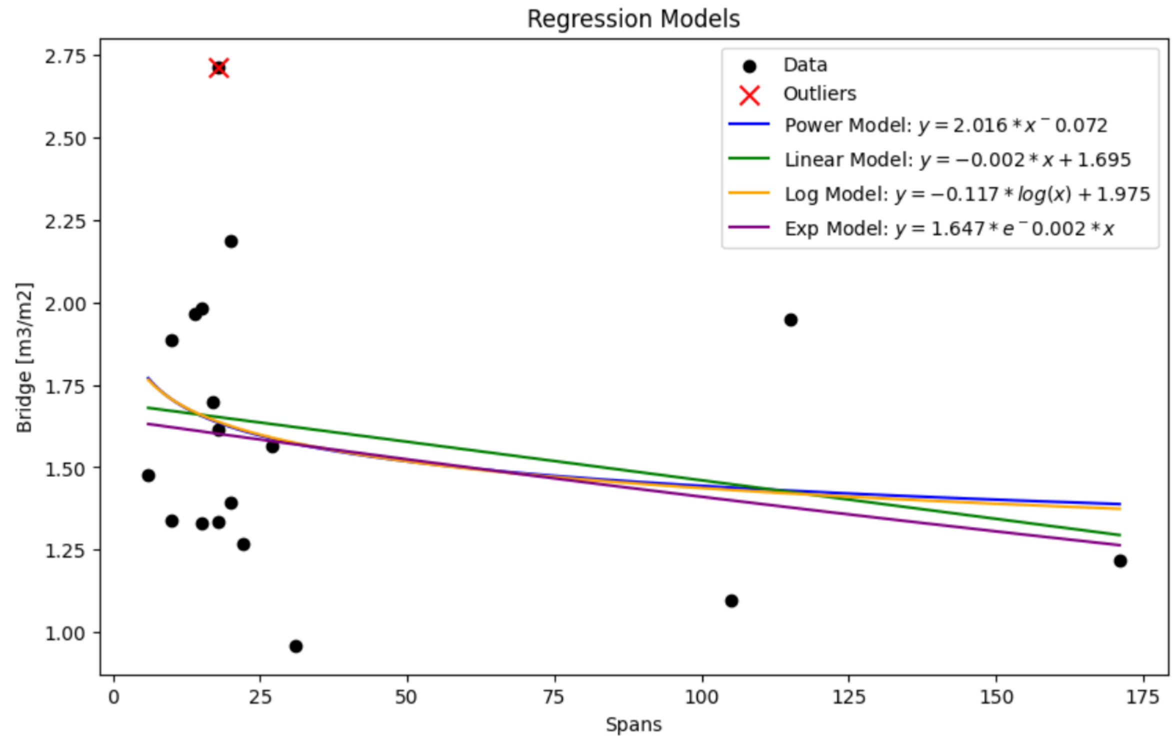

Figure 5: *Plot and regression model for material use in bridges; material use in bridges (Spans = length of longest span).*

The Exponential Model appears to be the best fit for our data, though with a modest R^2 value of 0.071. The Linear Model follows with R^2 = 0.058, while the Log Model (R^2 = 0.055) and Power Model (R^2 = 0.053) show slightly lower explanatory power. The R^2 values are quite low (all less than 0.08), indicating high variability in our dataset that cannot be well explained by maximum span length alone. This suggests that additional factors beyond span length likely influence bridge material usage.

	Byggverksnavn	Largest Span [m]	Superstructure, m3/m2	Bridge, m3/m2	Ratio volumes - super. / substruct.
SVV only > 100m length	Honingsbrui	31	0.60	0.96	1.69
	Audna	22	0.69	1.27	1.19
	Trengsel	115	0.76	1.95	0.64
	Kåkern Bru	171	1.01	1.22	4.76
	Nordsundbrua	105	0.68	1.10	1.64
25-50 1 span trondelag	Elveråsbrua	27	0.75	1.56	1.19
10-20m span - Trøndelag	Halsanbrua	17	0.85	1.70	1.00
	Nyhus o/jernebane	6	0.40	1.48	0.37
	Songa	18	0.74	1.61	0.85
	Tua bru	18	0.45	1.33	0.50
	Hovsbakkan Bru	18	0.39	2.71	0.17
	Skjøtskift	14	0.77	1.97	0.65
Plassproduserte platebruer SVV Bruhåndbok - 4	one-span 10m	10	0.55	1.89	0.41
	one-span 15m	15	0.75	1.98	0.61
	one-span 20m	20	0.96	2.19	0.78
	3-span 6,10,6m	10	0.46	1.34	0.53
	3-span 9,15,9m	15	0.57	1.33	0.75
	3-span 12,20,12m	20	0.67	1.39	0.93
	Trimmed Mean (33%)		**0.66**	**1.57**	**0.83**
	AVERAGE		**0.67**	**1.61**	**1.04**
	Av. Dev.		0.14	0.35	0.59
	median		0.68	1.52	0.77
	st. dev		0.17	0.43	0.99
	confidence		0.08	0.20	0.46
	variance		0.03	0.18	0.97
	Coeff. of Variation		*0.26*	*0.26*	*0.95*
	upper boundary		0.81	1.96	1.62
	lower boundary		0.53	1.26	0.45
	upper boundary (95% conf.)		0.75	1.81	1.49
	lower boundary (95% conf.)		0.59	1.41	0.58

Table 2: *Extract from the spreadsheet (and Table 1), showing ratios used (Outliers (highlighted in yellow) are values outside the upper and lower boundaries). Blue shaded cells indicate 'SVV's Bruhåndbok' standard designs.*

Interpretation

The analysis of concrete quantities across the selected bridges inTable 2 provides key insights into material distribution between sub- and superstructure and total material use.

The three selected parameters—Superstructure Volume per Deck Area, Total Bridge Volume per Deck Area, and Superstructure-to-Substructure Volume Ratio—highlight variations in design strategies and structural demands. These will vary in function of the year of construction, designer's preferences and natural variation. Parameter values for all bridges are presented in Table 2.

a. Superstructure Volume per Deck Area (m^3/m^2)

Mean: 0.67,
Standard Deviation: 0.17,
Coefficient of Variation (CV): 0.259
95% Confidence Level (CL): (0.59 – 0.75)

Observation: The standard deviation (0.17) and coefficient of variation (0.26) indicate relatively low scatter, meaning most bridges cluster around the mean value. This parameter reflects consistent material use efficiency in the superstructure, although it does not capture substructure variations. It remains a useful measure for preliminary estimates where the superstructure dominates total volume.

b. Total Bridge Volume per Deck Area (m^3/m^2)

Mean: 1.61,
Standard Deviation: 0.43,
CV: 0.265
95% CL: (1.41 – 1.81)

Observation: Although the standard deviation is higher (0.43) than for the superstructure volume per deck area (0.17), the coefficient of variation is nearly identical (0.259 vs 0.265), indicating comparable relative variability around the mean. This parameter captures the total material usage, including substructures, and is therefore more comprehensive for estimating overall concrete quantities, though absolute scatter remains larger due to substructure influences.

c. Superstructure to Substructure Volume Ratio

Mean: 1.04,
Standard Deviation: 0.99,
CV: 0.95
95% CL: (0.58 – 1.49)

Observation: Very high standard deviation (0.99) → high variability across bridges.

This ratio is highly span-dependent (e.g., longer spans have higher ratios). Not a stable parameter for extrapolation, but useful for trend analysis.

Comments:

Best Fit Parameter

When considering both the mean and median values:

- **Superstructure Volume per Deck Area (m^3/m^2):**
  Mean: 0.67, Median: 0.685 → Minimal difference, indicating a symmetric distribution.
- **Total Bridge Volume per Deck Area (m^3/m^2):**
  Mean: 1.61, Median: 1.52 → Slight right skew, suggesting some higher values influence the mean.
- **Superstructure-to-Substructure Volume Ratio:**
  Mean: 1.04, Median: 0.77 → Strong right skew, meaning some bridges have much higher ratios than the majority.

Since the median is less affected by extreme values, the small difference between the mean and median for "**Superstructure Volume per Deck Area**" indicates a relatively symmetric distribution. Combined with its low coefficient of variation (0.26), this parameter can be considered the most consistent across bridges and thus the most suitable for comparative or extrapolative use.

Most Representative Parameter:

- **Superstructure Volume per Deck Area (m^3/m^2)** shows the lowest variability (st. dev = 0.17; CV = 0.26), indicating consistent material use across bridges.

- **Total Bridge Volume per Deck Area (m³/m²)** has higher absolute scatter (st. dev = 0.43) but a similar relative variability (CV = 0.26), reflecting the influence of substructure design.
- **Superstructure-to-Substructure Ratio** shows the greatest variability (st. dev = 0.99; CV = 0.95), making it less reliable for generalised estimation.

In summary, while ***Superstructure Volume per Deck Area*** is statistically the most consistent parameter, ***Total Bridge Volume per Deck Area*** remains the most comprehensive measure for total material estimation since it accounts for both superstructure and substructure components.

We acknowledge that factors such as **year of construction**, **designer**, **location**, **budget constraints**, **geotechnical conditions** etc. likely influence the observed variation in material quantities. For example:

- Bridges designed in earlier decades may have different detailing standards or conservative assumptions.
- Local soil conditions and terrain strongly affect foundation design and therefore substructure volumes.
- Variability may also stem from individual design preferences or regional construction practices.

Why these were not included:
While potentially valuable, these explanatory variables were not included in the present analysis due to:

- Limited availability of structured metadata across all selected bridges (e.g., detailed geotechnical profiles or budget constraints);
- The added complexity of incorporating such parameters into a small, focused dataset;
- The scope of this study, which prioritised quantifiable, geometry-based comparisons suitable for early-stage estimation.

Nevertheless, further analysis using broader datasets and enriched metadata could provide valuable insights into how such contextual factors contribute to the observed variability. A broader dataset might also enable alternative and more refined modelling approaches.

3 Estimation of costs

3.1 Data selection

Availability and access to cost data for past construction projects is limited, and available data is in some cases aggregated and contain infrastructure objects that are not part of the bridge structure. This limits the number of cost examples that can be used as a basis for prediction of costs for new bridges. Table 3 presents an overview of the construction cost information for the projects reported for 2018.

4.18.2 Platebruer

Region	Fylke (kode)	Evt. bru nr.	Navn (prosjektnavn)	Hovedbyggverkstype	Total-lengde [m]	Total-bredde [m]	Lengde G bredde	Areal [m2]	Antall spenn	Største spenn [m]	Oppr. kostnad [mill kr]	Virkelig kostnad [mill. kr]	Herav Byggherre kostnader	Herav mva av Virkelig kostnad	Pris / m2 lengde * bredde
1. Øst	Hedmark	04-1805	Ny Melland bru	Platebru, massiv, m/vinger	21,0	7,5	157,5	157,5	1	16,0	10,45	10,54	2,03	1,70	67
3,Vest	Rogaland	11-2525	Primstad II	Platebru, massiv, skrå platekanter	15,9	12,0	190,2	190,2	2	14,0	7,50	7,88	1,00	1,38	41
3,Vest	Sogn og Fjordane	14-3242	Fardal vest	Platebru, massiv, skrå platekanter	24,0	4,5	108,0	108,0	1	19,6	3,40	3,50	0,20	0,80	32
4. Midt	Trøndelag	16-1817	Ekrabrua K32	Platebru, massiv, skrå platekanter	47,8	24,4	1 165,1	1 123,6	3	18,5	33,75	24,61	3,17	4,61	21
4. Midt	Trøndelag	16-1918	Hallbrua	Platebru, massiv, skrå platekanter	61,0	15,6	949,2	949,2	3	25,0		16,65	0,99	4,16	18
4. Midt	Trøndelag	16-1959	Skjøtskift	Platebru, massiv, rektangulært tverrsnitt	16,0	8,6	137,6	321,2		13,0	5,75	6,53		1,30	47
5. Nord	Nordland	18-2907	Sørdalen bru	Platebru, massiv, m/vinger	9,8	7,5	73,1	73,1		8,5	5,50	8,10			111
5. Nord	Nordland	18-3004	Selneselva bru	Platebru, massiv, skrå platekanter	17,0	13,0	221,0	221,0		12,0	15,00	15,80	1,20	3,16	71
5. Nord	Nordland	18-2960	Storelva bru	Ettspenns platebru	23,0	21,0	483,0	483,0	1	14,0	38,00	25,13	3,88	4,25	52
5. Nord	Troms	19-2960	Skårvikelv bru	Platebru	21,3	8,6	183,2	183,2	1	10,0	11,50	14,10	0,80	2,66	77
5. Nord	Troms	19-2939	Jernelva bru	Platebru, massiv medm/vinger	20,4	12,5	254,4	254,4	1	15,0	8,79	25,52	1,80	4,40	100

Table 3: *Extract from SVV report "Samledokumentasjon 2018" – Tabell 26.*

Data extracted from SVV reports[2] for 2015, 2017 and 2018 – extract above -; the report for 2016 is available but bridge data are not 'usable' because, for some reasons, the report doesn't give tables for the bridge categories but only for 'Broprosjekter' where the costs are given for both the bridge and the road.

The reports compile regional data to estimate project costs per linear metre for roads, bridges, and tunnels at a high level.

A section of the reports deals with bridges, for our purposes we extracted data from the 'platebruer' and 'bjelke platebruer'. The tables give the costs for "Pris / m2 (lengde x bredde)". The costs where all indexed to 2018, for consistency, using the "Byggekostnadsindekser" from "Statistics Norway"[3]. From these data we plotted the "Pris / m2versus the bridge 'total length'.

Limitations

The unit costs given in the tables are "all inclusive" and in some situations will also include approach road, ancillary structures, furnishing etc. rather than just concrete, as it is the case for the data used for "quantities" data analysis. This will impact structures with smaller spans more.

While in the 'quantities' data analysis, we ensured that all selected bridges were similar and that quantity take-offs were consistent, for the bridges in these table we have no visibility on the type of bridges.

A more refined dataset would require querying BRUTUS for each bridge, a resource-intensive process. It was therefore decided not to pursue this step at this stage, though it could be reconsidered if necessary.

3.2 Results

Bridge cost data (platebruer) from the 2015, 2017, and 2018 reports were aggregated and adjusted to 2018 values using Statistics Norway's 'Byggekostnadsindekser'. Price per m^2 is plotted against total bridge length in Figure 6.

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[2] SVV Reports links:

2015: https://vegvesen.brage.unit.no/vegvesen-xmlui/handle/11250/2670489

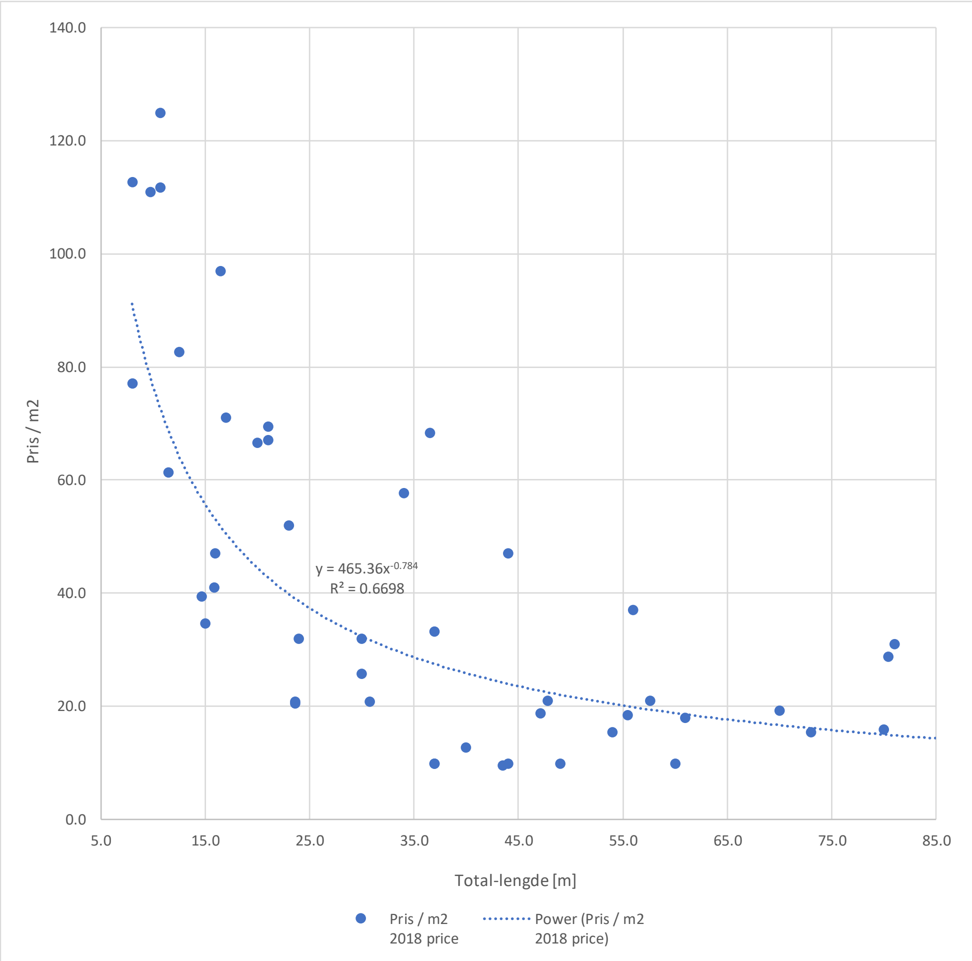
2017: https://vegvesen.brage.unit.no/vegvesen-xmlui/handle/11250/2614569

2018: https://vegvesen.brage.unit.no/vegvesen-xmlui/handle/11250/2633813

[3] https://www.ssb.no/priser-og-prisindekser/byggekostnadsindekser

Platebruer

Total-lengde [m]	Pris / m2 2018 price
44.0	47.1
131.8	15.9
55.5	18.4
30.0	25.7
30.8	20.8
23.6	20.6
23.6	20.8
95.0	20.9
47.1	18.8
15.0	34.6
14.7	39.4
34.0	57.7
81.0	30.9
80.4	28.7
16.5	97.0
12.5	82.7
56.0	37.0
8.0	112.7
8.0	77.2
11.5	61.3
70.0	19.3
54.0	15.5
37.0	9.9
37.0	9.9
43.5	9.4
60.0	9.8
44.0	9.9
49.0	9.8
73.0	15.4
37.0	33.2
57.6	20.9
90.0	18.7
30.0	31.9
40.0	12.8
36.5	68.4
80.0	15.9
10.7	111.7
10.7	125.0
21.0	69.4
20.0	66.6
21.0	67.0
15.9	41.0
24.0	32.0
47.8	21.0
61.0	18.0
16.0	47.0
9.8	111.0
17.0	71.0
23.0	52.0



MEAN WITHOUT OUTLIERS	**34.47**

upper boundary	104.21
MEAN	**41.06**
lower boundary	-22.10

median	30.93
st. dev	31.58
confidence	8.84
variance	997.14
upper boundary (95% conf.)	49.90
lower boundary (95% conf.)	32.22

Figure 6: *Plot of construction cost and total bridge length (Outliers (highlighted in yellow) are values outside the upper and lower boundaries).*

Interpretation

The data reveals significant variability. The large standard deviation and wide range indicate that unit costs vary significantly across projects.

The presence of outliers is a key factor to consider when interpreting the results. Outliers impact the mean: The mean price (41.06) is higher than the median (30.93), which suggests skewness due to high outliers.

'Trimmed' 'Mean value without outliers' is more representative: The 34.47 NOK/m² (after excluding values outside the boundaries) may provide a better estimate of a typical bridge cost.

Possible cost drivers: as expected, shorter bridges appear to have higher unit costs, likely due to economies of scale in larger structures. The unit cost per m² decreases as bridge length increases. Bridges shorter than 30 m show high-cost variability, with unit prices ranging from 30 to over 120 NOK/m². For longer bridges (>60 m), unit prices tend to stabilize around 10–20 NOK/m², indicating that the cost efficiency gains level off.

A regression analysis was performed to determine the best-fit model among power, logarithmic, and exponential functions. The power regression model provided the best fit, with an R^2 value of 0.6698, explaining approximately 67% of the cost variation.

The remaining 33% variation is likely influenced by other factors, among them geotechnical conditions, foundation requirements, construction logistics etc.

Without further investigation it is not possible to fully understand the causes of this variability.

4 Examples of use

4.1 Climate emissions estimates

Different parameters were investigated for estimation of material quantities. When considering a complete bridge including both superstructure and substructure, the parameter *"Total Bridge Volume per Deck Area"* is the most relevant. This estimates the volume of concrete based on the deck surface area (m³/m²). A theoretical example of use is shown below.

Assumptions:

- Length: 80 m
- Width: 20 m
- Volume of steel reinforcement: 2% of total concrete volume.
- Density, steel: 7 800 ton/m³
- Climate emissions, concrete production: 245 kg CO_2-eq./m³
    - Assuming "Lavkarbon B", median value[4].
- Climate emissions, reinforcement steel: 339 kg CO_2-eq./ton
    - Assuming Norwegian production from Celsa[5].

Table 4 summarizes the results.

	Mean value [wo/outliers]	**-1 SD**	**+1 SD**	**Min**	**Max**
Bridge parameter value [m³/m²]	*1,54*	1,11	1,97	0,96	2,71
Reinforced concrete volume [m³]	*1232*	888	1576	768	2168
Reinforcement volume [m³]	*1207*	870	1544	753	2125
Concrete volume [m³]	*25*	18	32	15	43
Climate emissions [tons CO_2-eq.]	*361*	260	462	225	635
Difference, emissions [tons]	*0*	*-101*	*101*	*-136*	*274*
Difference, emissions [%]	*0*	*-28 %*	*28 %*	*-38 %*	*76 %*

Table 4: *Example of material use estimates for a full bridge construction.*

[4] Publikasjon nr. 37 – Lavkarbonbetong, Norsk Betongforening, 2024.

[5] Steel reinforcement products for concrete – Norwegian production from Celsa Steel Service AS, EPD no. S-P-00306.

The relatively wide range in estimated climate emissions following the assumption of a mean value, with standard deviation or min/max-value reflects the uncertainty associated with the bridge parameter.

4.2 Cost estimates

Cost data presented Figure 6 shows significant variation and will, like the material quantities, rely on more specific information to become more precise. However, assuming no specific knowledge, the trendline equation can be used to find a cost factor as a first estimate for costs.

$$Cost\ per\ m^2 = 465.36x^{-0.784},\ with\ x = total\ bridge\ length$$

Applying the equation to the example bridge used above for material use estimates gives an estimated cost per square meter of bridge of approx. 15 kNOK/m^2, and a resulting total cost of 12 MNOK. As pointed out in the cost analysis, the variation and uncertainty are significant, and for the example bridge used here, the cost per m^2 is significantly below both the mean and the median values for the bridges included in the study, with 41.1 and 30.9 per m^2, respectively. As can be seen from the plot in Figure 6, this is expected as the cost factor decreases with longer bridge lengths. For illustrative purposes, **Error! Reference source not found.** shows the variation in cost factor value and total costs for bridges of different lengths. For simplicity, the width is fixed for all bridges.

	Short bridge	**Medium bridge**	**Long bridge**	**Example bridge**
Length [m]	20	50	100	*80*
Width [m]	10	10	10	*10*
Cost factor [kNOK/m2]	44.4	21.7	12.6	*15.0*
Total cost, cost formula [MNOK]	8.9	10.8	12.6	12.0

Relying on an equation for the cost estimates might give an impression of higher precision than what is the case. Results should be interpreted as having considerable uncertainty in general and used accordingly.

5 Discussion and conclusions

The approach and results presented here represent a first attempt to develop generic estimates for costs and environmental impacts from bridge construction. By extracting information on material use and costs for bridge construction from existing constructions, a first impression of the variation and uncertainty has been provided. Different parameters were suggested for estimation of material use, and the variance and uncertainty vary. However, in addition to design and engineering choices, bridges are built under different local conditions which significantly affect the total material use due to the large variations in ground conditions and resulting need for materials for stabilization and support. This inherently leads to considerable variation in material use intensities for full bridge structures. If considering the superstructure only, the results are more uniform.

Cost estimates also vary considerably between different bridge projects. However, there is a relatively clear trend towards lower unit costs (NOK/m^2 deck area) for longer bridges, which can likely be attributed to economies of scale and costs related to design and engineering which are more similar regardless of bridge size than material costs. As for material use, ground conditions will influence costs, but the available cost information does not specify the share used for different parts of the bridge structure. For estimation of total costs when no further cost information is available, a simple trendline equation based on total bridge length has been suggested.

The suggested parameters should be regarded as first attempts to estimate material use, climate emissions and costs for new bridge structures where no specific information is available, and planning has not started. The estimates could be used to indicate the size of costs and emissions, but their variance and uncertainty imply that decisions should not be based on these for scenarios where the alternatives give results within the same range.

6 Further work

Further work should focus on increasing the number of bridges used as basis for the estimation parameters to improve the precision and representativeness of the estimations. Extending the number of projects could be used to possibly distinguish between classes of bridges. The analysis presented here does not provide sufficient basis for classification according to construction principle, age cohort or other parameters. However, the most important parameter to include and represent in a better way is likely to be related to local ground conditions and the implications on substructures. If a meaningful classification could be developed for ground conditions and substructures, this could be a separate parameter to combine with the superstructure parameter presented here. The result would likely be improved precision and a more robust way of predicting both costs and emissions and reduce the most extreme variations.

The limitations outlined above highlight a clear opportunity to extend this research. Incorporating data from a larger and more diverse set of bridges would help refine estimation parameters, potentially enabling classification by bridge type or ground conditions. A larger dataset might also enable more refined modelling approaches. This, in turn, could improve the accuracy and robustness of lifecycle cost and emission predictions, thereby increasing the practical value of the developed models.

EXCON

https://www.sintef.no/prosjekter/2023/excon-gronn-forvaltning-av-konstruksjoner-for-infrastruktur/

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