

# JUST TRANSITION IN TRANSPORT: THE IMPACT OF A WEATHER PROTECTIVE BICYCLE TUBE

Terje Andreas Mathisen<sup>1</sup>, Thor-Erik Sandberg Hanssen<sup>1</sup>  
and Gisle Solvoll<sup>1</sup>

## ABSTRACT

*Cycling offers numerous benefits, positively impacting cyclists' health and having fewer harmful effects on the environment compared to most other forms of transport. However, adverse weather conditions can deter regular cycling. To mitigate these disadvantages, constructing a bicycle tube is a potential solution. We exemplify this with a planned bicycle tube in a Norwegian city known for harsh weather, discussing how it could promote cycling by reducing the negative impact of weather conditions. The number of cyclists is influenced by weather indicators such as temperature, wind, and precipitation, as well as variations between workdays and seasons. It is estimated that the construction of the bicycle tube would double the number of cyclists in the studied transport corridor due to improved weather protection. This increase would generate benefits related to travel time, health, and the environment. Additionally, the free-to-use bicycle tube could improve accessibility for people without access to a car, contributing to a just transition to sustainable transport. However, for the case studied, the benefits are not sufficient to cover the construction costs of the bicycle tube. Therefore, the project is not strictly profitable from a welfare perspective. Nonetheless, other non-monetary effects could be substantial for such a project.*

## KEYWORDS

*Bicycle tube, cycling, weather, welfare assessment*

---

<sup>1</sup> Nord University Business School, Bodø, Norway.

## 1. INTRODUCTION

It is a general political consensus that cycling is one of the most sustainable forms of transport, and that cycling, together with other forms of sustainable transport, is vital for achieving EU-objectives on climate, pollution and energy efficiency (e.g. European Commission, 2023). One of the major factors influencing the number of bicycle trips is the weather (Goldmann and Wessel, 2021; Zhao et al., 2018). Winters et al. (2011) applied econometric methods to quantify the relative impact of a wide-ranging set of motivators and deterrents that could influence cycling behavior. Poor weather such as ice and rain do, in line with the a-priori assumptions, reduce the likelihood of cycling and are generally considered difficult for policy makers to influence. Even though this study focuses on cold and wet weather, there are challenges in other parts of the world with high temperatures (Meng et al., 2016). Morton (2020) finds weather affects cycling conducted for both recreational and commuting purposes. The frequency of use of recreation areas depends not only on forecasted meteorological variables, such as air temperature and precipitation on the day of travel, but also on the weather conditions experienced over the preceding few days.

Hunt and Abraham (2007) focused on the influence of attitudes to non-recreational cycling and found that various individual attributes were related to cycling frequency. Characteristics having significant influence include the type of cycling facility, and the time spent on the cycle, the availability of showers and secure parking at the destination, cyclist age, levels of experience and cycle purchase price. In a later survey of cyclist commuters to the University of Calgary the weather conditions are identified as one of the major causes for accidents (Twaddle & Hall, 2009) and a broader review of the risk exposure for cyclists due to weather indicators was given by Pazdan (2020).

To address weather challenges, particularly for cycling in harsh climates, the construction of a protective bicycle tube with a transparent cover has been suggested. This bicycle tube would significantly improve cycling conditions by shielding cyclists from precipitation and wind. Reducing wind exposure would increase the effective temperature and lessen the effort required to ride against the wind. Additionally, the tube would deflect rain and snow, keeping the ground dry for cyclists. However, the benefits and costs of constructing such a bicycle tube are rarely studied in existing literature. Bicycle tubes can reduce travel costs and improve accessibility for people who do not own a car. In Norway, approximately 70% of the population has access to a bicycle, with even higher proportions among those without completed education and couples with children (Opinion, 2024). Therefore, bicycle tubes can contribute to a just transition towards sustainable transport by enhancing accessibility for these groups.

The aim of this article is to examine how the construction of a bicycle tube can affect cycling frequency by shielding cyclists from adverse weather conditions.

Additionally, it quantifies the costs and welfare economic benefits, discussing the project's profitability from a welfare perspective. The analysis and discussion focus on a proposed bicycle tube in Bodø, a Norwegian city located approximately 100 km north of the Arctic Circle.

The remainder of this article is structured as follows: Section 2 briefly discusses the concept of bicycle tubes and presents the case. Section 3 establishes a model for econometric analysis of cycling demand in relation to weather conditions, with the model estimated in Section 4. Section 5 discusses the results and societal consequences of establishing a bicycle tube. Section 6 compares costs and benefits, followed by concluding remarks and implications in Section 7.

## 2. THE BICYCLE TUBE

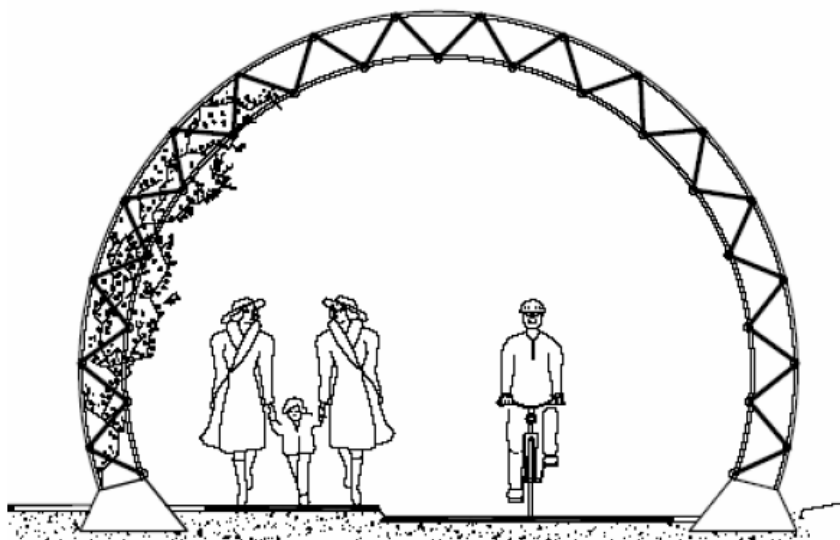
The construction of sheltered lanes, known as bicycle tubes, has been proposed to encourage cycling by reducing the discomfort caused by adverse weather. The primary argument for promoting cycling is environmental, as bicycles can replace car usage. Additionally, cycling can improve cyclists' health through physical activity and enhance traffic safety by separating cyclists from cars. Promoting cycling can also have political motivations, such as reducing dependency on authoritarian oil producers.

However, arguments against bicycle tubes mainly focus on the high construction and maintenance costs. Another concern is the safety of cyclists in the event of accidents or fires within the tube. It is also important to note that cyclists will still experience rough weather before and after using the tube. Therefore, while many cyclists will be sheltered for much of their journey, weather conditions will still pose a barrier to cycling to some extent.

Cyclist organizations and enthusiasts have promoted concepts to protect cyclists from adverse weather but, to our knowledge, no project has yet been realized. Such structures could come in the form of lightweight roofings (e.g. [www.bambutec.eu](http://www.bambutec.eu)). Alternatively, they could be designed as tubes that are assembled using modules and levitated above ground to exploit the areas in larger cities. Other designs include fans providing for downwind that will increase cycle speed. Still, even if the concepts of bicycle tubes are good, the costs for construction and maintenance have, to this date, not exceeded expected utility gains.

Unlike many concepts proposed globally, the bicycle tube in Bodø, a city in the middle part of Norway with 50 000 inhabitants, is designed for more rural conditions. Located at the tip of a peninsula facing the Atlantic Ocean, north of the 67th latitude, Bodø experiences a relatively harsh climate, particularly with respect to wind. As illustrated in Figure 1, the proposed tube is planned for ground-level construction with a transparent cover (either plate or plastic) and will include separate lanes for both cycling and walking. Interior lighting and frequent openings for security and ventilation will be necessary (Aas-Jakobsen, 2008).

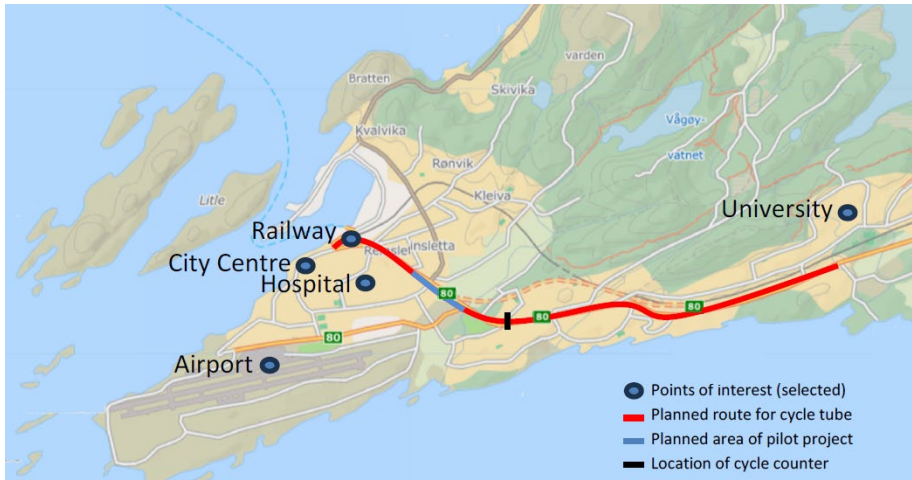
Figure 1: Possible outline of the bicycle tube. (Source: Aas-Jakobsen, 2008).



The city of Bodø is characterized by traffic patterns and settlement areas that follow a single main road along an east-west corridor. According to Aarhaug et al. (2017), cyclists in Bodø differ somewhat from the national average in Norway, with a higher proportion of females and younger users. Additionally, cycling in Bodø accounts for a higher proportion of total trips compared to the national average, particularly for commuting to work. In the plan for developing transport in the city of Bodø (2024), it is argued that the proportion of cycling has been relatively stable the last few years.

The tube will be constructed along the main road, covering eight kilometres from the city center eastward. See Figure 2 for an illustration where selected points of interest are marked, along with the counter and the most likely location for a pilot tube. The planning for the bicycle tube began in 2007, but the project was not initiated at that time, and its status remains uncertain. At that time, the construction cost was estimated at approximately NOK 16,000 (EUR 2,000) per meter (Jensen & Risan, 2007). Considering inflation, as measured by the consumer price index, the total construction cost is expected to reach about NOK 188 million (EUR 16 million) in 2023 for the entire distance. Further maintenance costs were not estimated. As a pilot project aimed at providing a solution for sustainable urban transport, it was expected that the tube would be primarily financed by public bodies, both central and local authorities, rather than relying on user payments.

Figure 2: Planned route for bicycle tube in the city of Bodø.



### 3. THE MODEL

As previously mentioned, earlier studies have identified weather conditions as a significant factor influencing the demand for cycle trips. Let us assume a model presented in equation (1) where the number of cyclists can be explained by the weather variables temperature, precipitation and wind. According to Thomas et al. (2013), the weather explains as much as 80 % of fluctuations in cycling demand. Furthermore, it has been demonstrated that the demand for cycling trips is positively associated with working days (e.g. Mathisen et al., 2015) and, in many cases, negatively associated with the winter season (Hudde, 2023).

Earlier studies have noted that many of the same people ride bicycles each day. This means that the number of cyclists at time  $t$  depends on the number of cyclists at time  $t-1$ . Hence, error terms might be correlated in time and to correct for such autoregressive serial-correlation, a Prais-Winsten correction is applied. See e.g. Wooldridge (2019) for details on correcting for serial correlation by the use of Feasible Generalized Least Squares estimation.

$$(1) \quad \mathit{cycle}_t = e^{\beta_0 + \beta_1 \mathit{temp}_t + \beta_2 \mathit{wind}_t + \beta_3 \mathit{prec}_t + \beta_4 \mathit{workday}_t + \beta_5 \mathit{season}_t} + \varepsilon_t$$

In (1), the dependent variable,  $\mathit{cycle}$ , is a relative measure indicating the daily number of cyclists per 1000 inhabitants in the municipality in the specific transport corridor at time  $t$ . Temperature is represented by a midday variable measured in degrees Celsius and labeled  $\mathit{temp}$ . Wind speed is represented by a midday variable measured by meters per second and is labeled  $\mathit{wind}$ . More precisely, wind speed is

measured in 10-minute intervals, with the daily value calculated as an average of these intervals. Precipitation is represented by a day total measured in millimeter rain (snow in the winter) and is labeled *prec*.

The weather variables reflect the conditions on the same day the trip is made. According to the psychological effects identified by Brandenburg et al. (2007), it might be relevant to introduce lagged weather variables. However, lagged variables are not included for two reasons. First, due to the wide availability of weather forecasts with relatively high predictability for the next day, it is assumed that cyclists can adapt to the weather. Second, the lagged variables prove not to explain additional variation when running the model. The dependent variable *cyclists* as well as *temp*, *wind* and *prec* are all metric variables.

Additionally, the variables *workday* and *winter* are dummy variables. The value 1 represents Mondays through Fridays, excluding public holidays, for the *workday* variable. Although winter is technically defined as lasting three months, the winter variable is assigned a value of 1 for observations from October to March, when snow is often present on the ground in the region where construction of the tube is planned. Hence, an observation relating to an ordinary workday in the winter season will have value 1 on both dichotomous variables. In line with existing literature and empirical evidence it is assumed in (1) that parameters  $\beta_0$ ,  $\beta_1$ ,  $\beta_4$  are positive and  $\beta_2$ ,  $\beta_3$ ,  $\beta_5$  are negative. The error term,  $\varepsilon_t$ , is expected to fulfill the traditional requirements of regression analysis.

One of the most important aspects of the chosen model specification is that it reflects how cyclists respond to change in weather indicators. A linear OLS-regression could be applied, but even though having the benefit of straightforward interpretations in such models the linear approximations are simplistic and not likely to fully account for variation in the explanatory variables. For the weather variables *temp*, *wind* and *prec*, it is not reasonable to assume a linear relationship on the cycling rate (see e.g. Böcker et al., 2013). Moreover, commonly applied models using log-transformations of the explanatory variables (e.g. Cobb-Douglas and Translog) cannot be applied due to the nature of the variables *temp*, having occasional negative values, and *prec*, having the value 0 frequently. See e.g. Baumol et al. (1988) for discussions of the properties of different multiproduct specifications. Consequently, similarly to Mathisen et al. (2015) an exponential specification with an untransformed dependent variable is applied (see equation (1)). Other non-linear specifications were also tested but did not give significantly better properties for the model. The applied function specification has the benefits of being flexible, following the principle of parsimony (e.g. Coelli et al., 2005) and it can handle negative and zero values.

#### 4. EMPIRICAL DATA AND RESULTS

As summarized in Table 1, the analysis is based on data from two sources in addition to the official calendar. First, weather data was obtained from the Norwegian Meteorological Institute (2015), with daily observations of temperature, wind, and precipitation. Second, the number of bicycles was recorded by an electronic counter managed by the Norwegian Public Roads Administration (NPRÅ). The inductive loop, located in the asphalt of the cycle path, provides objective and reliable information (Norwegian Public Roads Administration, 2011). Trips are counted continuously and reported hourly for both directions. Values are aggregated daily to match the meteorological data. However, despite the counter being situated in the main cycle corridor leading to the city center, some cyclists will use other routes, especially for shorter trips.

Table 1: Data sources.

<i>Variable</i>	<i>Unit</i>	<i>Frequency</i>	<i>Source</i>
<i>cycle</i>	Trips per 1000 inhabitants	Total per day	Norwegian Public Road Administration
<i>temp</i>	Degrees Celsius	Average per day	Meteorological institute
<i>wind</i>	Meters per second	Average per day	Meteorological institute
<i>prec</i>	Millimetre precipitation	Total per day	Meteorological institute
<i>workday</i>	Workdays = 0 else 1	Daily	Norwegian calendar
<i>season</i>	Winter = 0 else 1	Daily	Norwegian calendar

The period of registration spanned 7 years from 16th November 2007 to 15th November 2014 and produced 2557 observations. Of these, 524 observations lacked information on at least one variable. Since there were no apparent patterns in the missing data, these observations were omitted without further adjustments. Consequently, the daily registrations resulted in 2,033 valid observations. Table 2 presents the descriptive statistics for the data set.

Table 2: Descriptive statistics (N=2,033).

<i>Variable</i>	<i>Mean</i>	<i>Std. dev.</i>	<i>Min</i>	<i>Max</i>	<i>Median</i>
<i>cycle (trips/1000 inh.)</i>	7.03	5.89	0.02	33.36	5.31
<i>temp (° C)</i>	5.62	6.03	-14.00	22.90	5.60
<i>wind (m/s)</i>	6.45	2.81	1.30	17.4	6.10
<i>prec (mm)</i>	3.33	5.61	0	48.5	0.9
<i>workday (1 = yes)</i>	0.67	0.47	0	1	1
<i>season (1 = winter)</i>	0.50	0.50	0	1	1

It is shown in Table 2 that the average cycling rate is 7.03 per day in the studied time period (about 7 cyclists per 1000 inhabitants). The variation is considerable and by looking at the median value we find that a relatively low number of days with a high number of cyclists draws heavily the average value. This is also the case for the precipitation variable. The averages for temperature and wind have only minor deviations from median values. It is further shown that 67% of the observations are ordinary workdays and that 50% of the observations are made in the winter season. Mean values for weather indicators vary naturally between seasons. Mean values during summer (winter) are 9.8 (1.4), 5.1 (7.8) and 2.9 (3.8) for *temp*, *wind* and *prec*, respectively.

The estimation results are presented in Table 3. All coefficients have signs according to the a-priori assumptions. The model explains about 61% of the variation in the number of cyclists and a highly significant F-test indicates good fit. The large sample size ensures that the results are consistent according to the central limit theorem. Due to the possible presence of serial correlation mentioned in section 2, the model is estimated using the Prais-Winsten correction. This was done using the «prais» command in the STATA software. This function assumes that errors follow a first-order autoregressive process. The corrected estimates have an acceptable level of serial correlation according to a Durbin Watson statistic of 1.75 and a rho-value of 0.52.

Table 3: Estimation results using the Prais-Winsten correction for serial correlation (R2 = 0.61, F-value = 628.45).

<i>Variable</i>	<i>Coefficient</i>	<i>Std.dev.</i>	<i>t-value</i>	<i>Sign.</i>
<i>constant</i>	1.287	0.059	21.8	0.00
<i>temp</i>	0.061	0.004	14.6	0.00
<i>wind</i>	-0.064	0.005	-12.4	0.00
<i>prec</i>	-0.012	0.002	-5.6	0.00
<i>workday</i>	0.963	0.026	37.7	0.00
<i>season</i>	-0.693	0.056	-12.3	0.00

The estimates in Table 3 indicate that the direct effect of an increase in *temp* is an increase in the cycle rate, while the effect is opposite for *wind* and *prec*. Based on mean values presented in Table 2 and coefficients in Table 3, the model estimates a cycle rate of 4.4 over an average day. The cycle rate shifts positively to 6 on work-days and negatively to about 3.1 in the winter.

## 5. ANALYSIS

### 5.1 CHANGES IN THE NUMBER OF CYCLISTS

The bicycle tube has the potential to mitigate issues related to wind and precipitation. Additionally, the temperature inside the tube will be slightly higher than the surroundings due to the transparent cover, which allows the sun to warm the air inside. For a most optimistic example, let *wind* and *prec* be 0 while temperature increases by 2°C. Furthermore, the tube is expected to eliminate winter-related cycling issues, effectively setting this parameter to zero.

As demonstrated in Table 4, the cycling rate would increase by 6.7 to 11.1 when using average values for all variables. However, cyclists would still need to travel to and from the tube, exposing them to external weather conditions. If winter-related issues are not fully addressed by the tube's construction, the number of daily trips would be lower. Therefore, the figures in Table 4 represent the most optimistic scenario and illustrate the maximum effect that can be expected from the tube.

Table 4: Effects on the number of daily trips by introducing a bicycle tube when assuming average values for all variables.

<i>Variable</i>	<i>Changes with tube</i>	<i>Isolated effect on cycle rate</i>
<i>temp</i>	Increase by 2 centigrade	0.88
<i>wind</i>	Removed 6.45 m/s	2.23
<i>Prec</i>	Removed 3.33 mm	0.18
<i>winter</i>	Removed	1.81
Estimated cycle rate without tube		4.37
Estimated cycle rate with tube		11.07
Estimated change in daily cycle rate		6.71

A further analysis of the change in the number of cyclists with the introduction of a tube is presented in Table 5. The assumptions remain the same: *temp* increases by 2 degrees from the mean value, *wind* and *prec* are both zero, and the presence of a tube eliminates the negative effects of *winter*. Additionally, average values are used for all variables. Table 5 demonstrates that the construction of a protective tube has the most significant impact on the number of cyclists during the winter season and on workdays.

Table 5: Sensitivity of daily cycle rate when introducing a bicycle tube.

<i>Day</i>	<i>Season</i>	<i>Tube</i>	<i>Cycle rate</i>	<i>Deviation from mean</i>
Workday	Summer	No	8.47	4.11
Workday	Summer	Yes	15.06	10.69
Workday	Winter	No	4.24	-0.13
Workday	Winter	Yes	15.06	10.69
Holiday	Summer	No	3.24	-1.12
Holiday	Summer	Yes	5.77	1.40
Holiday	Winter	No	1.62	-2.74
Holiday	Winter	Yes	5.77	1.40

The anticipated increase in demand raises concerns about potential capacity issues. In principle, crowding during peak times could increase the likelihood of accidents and the severity of any emergency situations. However, crowding is not expected to be a significant problem in the studied bicycle tube due to the initially low demand. The expected daily average of 250 trips each way is spread throughout the day, with peaks occurring between 7 and 9 am heading into the city and between 3 and 5 pm heading out of the city. Even if all trips occur during peak times, only a few cyclists would pass a given point in the tube per minute and problems related to que is not relevant.

## 5.2 BENEFITS FOR SOCIETY

How the cycling rate might change if a tube is constructed is demonstrated in Tables 4 and 5. This development will benefit several groups: current cyclists, new cyclists, other travellers using different modes of transport, and society as a whole. It is expected that new cyclists will have previously used other means of transport, such as buses or private cars. Switching to cycling provides personal health benefits and affects time and monetary costs. Other travellers will benefit from reduced queues and waiting times due to decreased demand for bus and car trips. Queues are external costs that travellers rarely consider. Societal benefits of people choosing to cycle instead of using private cars include reduced health costs and environ-

mental gains from less noise and pollution. Most of these benefits can be assessed in monetary terms using recommended values from previous studies and within the framework of cost-benefit analysis (CBA).

One example of applying cost-benefit analysis (CBA) to assess walking and cycling projects is the PROMISING project (2001), which identified considerable variation in methodologies between countries. In Norway, several studies have provided recommendations for assessing the costs and benefits of projects aimed at improving walking and cycling conditions. In addition to the general recommendations for CBA by the NPRA (2018), assessments of risk and accidents are addressed by Veisten et al. (2005), while non-market benefits such as the health benefits of cycling are covered by Elvik et al. (2006) and Veisten et al. (2010). The recommended valuations of changes in health, crowding, and CO<sub>2</sub> reductions form the basis for calculating the utility of the tube. Accidents will not be assessed for two reasons: the current cycle lane is already separated from the main road, and the road intersections (crossings) will not be changed (no elevation of cycle lanes above the road). The estimated monetary valuations of these effects are summarized in Table 6 and discussed in the following paragraphs.<sup>1</sup>

Table 6: Estimated valuations of benefits (change per year in NOK).

<i>Type of effect</i>		<i>Monetary effect</i>
Cyclists		
Time cost	For existing cyclists	2.480.000
	Transferred from car	-1.080.000
	Transferred from bus	540.000
Total change in time cost		1.940.000
Health	Short term illness	340.000
	Severe illness	590.000
Total change in health		930.000
Total change in benefits for cyclists		2.870.000
Society		
External costs	External cost car use	120.000
	External cost bus use	160.000
	Change in CO <sub>2</sub> emissions	40.000
Total for society		310.000
Total change in welfare effects		3.180.000

<sup>1</sup> All monetary values in this section are adjusted for inflation to 2023 prices, based on the consumer price index provided by Statistics Norway ([www.ssb.no](http://www.ssb.no)).

For this study, it is assumed that most trips are work-related and evenly distributed between bus and car. We also suppose that the average distance travelled in the tube is 5 km, which is less than the total trip length. Reduced annual costs amount to approximately NOK 770,000 for car use and NOK 1,930,000 for bus tickets. However, these are distributional effects transferred to the cyclists and should not be considered benefits in a welfare analysis.

The tube will reduce time costs for current cyclists and those transferred from buses, but time costs could increase for passengers transferred from private cars. Based on the suggested time values in Norway by Flügel et al. (2020), the monetary value of the overall reduced time consumption amounts to about NOK 1.94 million per year.

Veisten et al. (2010) suggest that each new cyclist generates a health benefit of NOK 4.23 per kilometre. This valuation includes welfare effects and real economic costs due to reduced illness-related absences, both in the short term and for serious diseases. The reduced health costs following the construction of the bicycle tube amount to approximately NOK 930,000 per year. On the margin, an additional car driver inflicts negative externalities such as congestion, noise, and pollution on other drivers and travellers, none of which are internalized in the car driver's behaviour (e.g., Button, 2022). Pollution from emissions can be compensated by converting them to CO<sub>2</sub> equivalents, which in 2023 are traded at NOK 1,046 per tonne. Other external costs, as suggested by Veisten et al. (2005), equate to NOK 0.53 and NOK 0.72 per kilometre for passengers transferred from cars and buses, respectively. This valuation includes emissions, noise, congestion, and accidents. The monetary assessment of the environmental effects amounts to approximately NOK 310,000 per year.

## 6. COMPARISON BETWEEN COSTS AND BENEFITS

Let's now consider the costs in relation to the expected benefits. The total annual benefits for the bicycle tube amount to approximately NOK 3.2 million. Following the recommendation for CBA for transport projects in Norway by DFØ (2013), using a 40-year time horizon and a 4% interest rate, this annual benefit results in a net present value of about NOK 63 million. Given that the investment costs alone are estimated at NOK 188 million, the project generates a negative net present value of NOK 125 million. In other words, the bicycle tube is highly unprofitable in socio-economic terms. Even if we halve the investment costs and reduce the interest rate to 2%, the project still has a negative net present value of NOK 7 million.

However, this is a rough assessment of the monetary aspects of the utility of changed travel patterns related solely to improved weather conditions. There could be "non-weather" benefits that are not considered, such as wider economic (ripple) effects, benefits for non-cyclists, and other effects that cannot be expressed in monetary terms. On the other hand, some cyclists may prefer the open-air experience

and therefore choose to cycle outdoors, which could reduce the benefit of the bicycle tube. Examples of effects that cannot be fully included in a CBA are aesthetics and political considerations, such as distributional effects and environmental issues. One way to evaluate such consequences for projects aimed at vulnerable road users suggested by the PROMISING project (2001), involves clearly stating the policy objectives and assigning monetary values to them.

## 7. CONCLUDING REMARKS

Weather conditions are a key factor in explaining the demand for cycle trips. The introduction of a bicycle tube will mitigate the disadvantages of bad weather by providing shelter from wind and precipitation. Such a tube was planned for the city of Bodø, located in the harsh climate north of the Arctic Circle in Norway, but the project has not yet been completed. The planned tube would stretch 8 km along the city's main transport corridor and be constructed at ground level with a transparent cover. Investment costs are estimated at approximately NOK 188 million (about EUR 16 million, depending on currency rates), with additional maintenance costs over the project's lifetime.

An econometric model is established to explain how weather conditions influence the demand for cycle trips. An exponential specification was chosen due to its flexibility combined with the ability to handle negative values (temperature) and zero values (precipitation), as well as the straightforward interpretations of the estimated coefficients.

By applying the model results with mean values from the data set it is demonstrated that the tube will lead to a doubling of the number of cyclists per day. The relative effect will be highest on workdays in the winter season. This effect assumes a best-case scenario where weather conditions become irrelevant. Hence, the results should be considered the most optimistic case since cyclists must ride in the open air to and from the tube and thereby be exposed to the weather conditions to some extent.

The benefits related to reduced time costs, improved health, and environmental issues are estimated at NOK 3.2 million per year, corresponding to a discounted value of approximately NOK 63 million. Therefore, the project is not profitable from a welfare perspective. However, as with all applications of the CBA framework, these estimations have weaknesses related to the assumptions made. Additionally, there may be further benefits, such as ripple effects for non-cyclists and non-weather-related advantages associated with this project. Impacts that cannot be measured in monetary terms, such as aesthetics and distributional effects, should also be considered.

Improved cycling facilities can have positive distributional effects, especially for individuals who do not own a car or possess a driver's license. This group includes

young people, those on disability benefits, individuals in low-income jobs, and people with disabilities that prevent them from driving but not from using a bicycle or electric scooter. These individuals could experience significant welfare gains from infrastructure improvements such as the proposed bicycle tube.

The benefits of a bicycle tube are closely tied to the number of cyclists. Therefore, developing such a project in more densely populated regions than the studied area could yield higher benefits and potentially be profitable from a welfare perspective. However, to draw more general conclusions about the effects of a bicycle tube, it would be useful to study other projects located in regions with similar weather challenges related to cold and harsh climates. Additionally, a bicycle tube might also be beneficial in regions with other weather challenges, such as heat and sun, which could be a topic for further study.

## ACKNOWLEDGEMENTS

The project was funded by the municipality of Bodø, and the authors are grateful to the Norwegian Public Roads Administration for providing data.

## REFERENCES

- Baumol, W. J., Panzar, J. C. & Willig, R. D. (1988). Contestable markets and the theory of industry structure. Harcourt Brace Jovanovich.
- Bodø municipality (2024). Bypakke Bodø. Handlingsprogram 2024-2027. (Bypakke Bodø, action plan 2024-2027). Bodø, Norway. (In Norwegian). Accessed 10<sup>th</sup> January 2025 at <https://bypakkebodo.no/>.
- Brandenburg, C., Matzarakis, A. & Arnberger, A. (2007). Weather and cycling - A first approach to the effects of weather conditions on cycling. *Meteorological Applications*, 14(1), 61-67.
- Button, K. (2022). Transport Economics (4th ed.). Edward Elgar Publishing.
- Böcker, L., Dijst, M. & Prillwitz, J. (2013). Impact of Everyday Weather on Individual Daily Travel Behaviours in Perspective: A Literature Review. *Transport Reviews*, 33(1), 71-91.
- Coelli, T., Prasada Rao, D. S., O'Donnell, C. J. & Battese, G. E. (2005). An introduction to efficiency and productivity analysis (2nd ed.). Springer.
- Direktoratet for økonomistyring (2023). Veileder i samfunnsøkonomiske analyser. (Recommendations for welfare economic analyses). Oslo, Norway. (In Norwegian). Accessed 20<sup>th</sup> January 2025 at [www.dfo.no](http://www.dfo.no).
- Elvik, R., Eriksen, K. S., Sælensminde, K. & Veisten, K. (2006). Økonomisk verdsetting av ikke-markedsgoder i transport: behovet for nye verdsetningsstudier og drøfting av metoder. TØI rapport 835/2006. Oslo, Norway

- European Commission. (2023). Annex to the Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions. Proposing a European Declaration on Cycling. Brussels.
- Flügel, S., Halse, A. H., Hulleberg, N., Jordbakke, G. N., Veisten, K., Sundfør, H. B. & Kouwenhoven, M. (2020). Value of travel time and related factors. Technical report, the Norwegian valuation study 2018-2020. TØI report 1762/2020. Oslo, Norway.
- Goldmann, K. & Wessel, J. (2021). Some people feel the rain, others just get wet: An analysis of regional differences in the effects of weather on cycling. *Research in Transportation Business & Management*. 40(100541).
- Hudde, A. (2023). It's the mobility culture, stupid! Winter conditions strongly reduce bicycle usage in German cities, but not in Dutch ones. *Journal of Transport Geography*, 106(103503).
- Hunt, J. D. & Abraham, J. E. (2007). Influences on bicycle use. *Transportation*, 34(4), 453-470.
- Jensen, G. & Risan, T. C. (2007). Planning for "Bicycle tube". *Nordic Road and Transport research*, (2), 23.
- Mathisen, T. A., Annema, J. A. & Kroesen, M. (2015). The effects of weather and climate change on cycling in Northern Norway. *European Journal of Transport and Infrastructure Research*, 15(2), 261-273.
- Meng, M., Zhang, J., Wong, Y. D. & Au, P. H. (2016). Effect of weather conditions and weather forecast on cycling travel behavior in Singapore. *International Journal of Sustainable Transportation*, 10(9), 773-780.
- Morton, C. (2020). The demand for cycle sharing: Examining the links between weather conditions, air quality levels, and cycling demand for regular and casual users. *Journal of Transport Geography*, 88(102854).
- Norwegian Public Roads Administration. (2018). Konsekvensanalyser. Handbook V712.
- Norwegian Public Roads Administration. (2011). Veileder i trafikkkdata. Handbook V714.
- Opinion (2024). Nøkkeltallsrapport 2023. Nasjonal reisevaneundersøkelse (Key figures report 2023. National travel habits survey). Oslo.
- Pazdan, S. (2020). The impact of weather on bicycle risk exposure. *Archives of transport*, 56(4), 89-105.
- PROMISING (2001). Cost-benefit analysis of measures for vulnerable road users. Final report of Workpackage 5 of the European research project PROMISING, Deliverable D5.
- The Norwegian Meteorological Institute (2015). eKlima. Free access to weather- and climate data from Norwegian Meteorological Institute from historical data to real time observations. <http://eklima.met.no>
- Thomas, T., Jaarsma, R. & Tutert, B. (2013). Exploring temporal fluctuations of daily cycling demand on Dutch cycle paths: The influence of weather on cycling. *Transportation*, 40(1), 1-22.

- Twaddle, H. & Hall, F. (2009). University of Calgary Commuter Cyclist Survey Report.
- Veisten, K., Flügel, S. & Ramjerdi, F. (2010). Value of time, safety and environment in passenger transport. Positive health effects. TØI report 1053/2010. Oslo, Norway.
- Veisten, K., Hagen, K.-E. & Sælensminde, K. (2005). Bicycle injuries, risk of cycling and the tool for cost-benefit analysis of measures towards cycling. TØI report 816/2005. Oslo, Norway.
- Winters, M., Davidson, G., Kao, D. & Teschke, K. (2011). Motivators and deterrents of bicycling: Comparing influences on decisions to ride. *Transportation*, 38(1), 153-168.
- Wooldridge, J. M. (2019). Introductory econometrics: a modern approach (7th ed.). Cengage Learning.
- Zhao, J., Wang, J., Xing, Z., Luan, X. & Jiang, Y. (2018). Weather and cycling: Mining big data to have an in-depth understanding of the association of weather variability with cycling on an off-road trail and an on-road bike lane. *Transportation Research Part A: Policy and Practice*, 111, 19-135.
- Aarhaug, J., Hulleberg, N. & Lunke, E. B. (2017). On two wheels in Bodø – Possibilities for cycling in Bodø. TØI report 1586/202017. Oslo, Norway.
- Aas-Jakobsen (2008). Sykkelrøret i Bodø. R&D-report. Oslo, Norway. (In Norwegian).