The influence of surface roughness on cyclists' velocity choices

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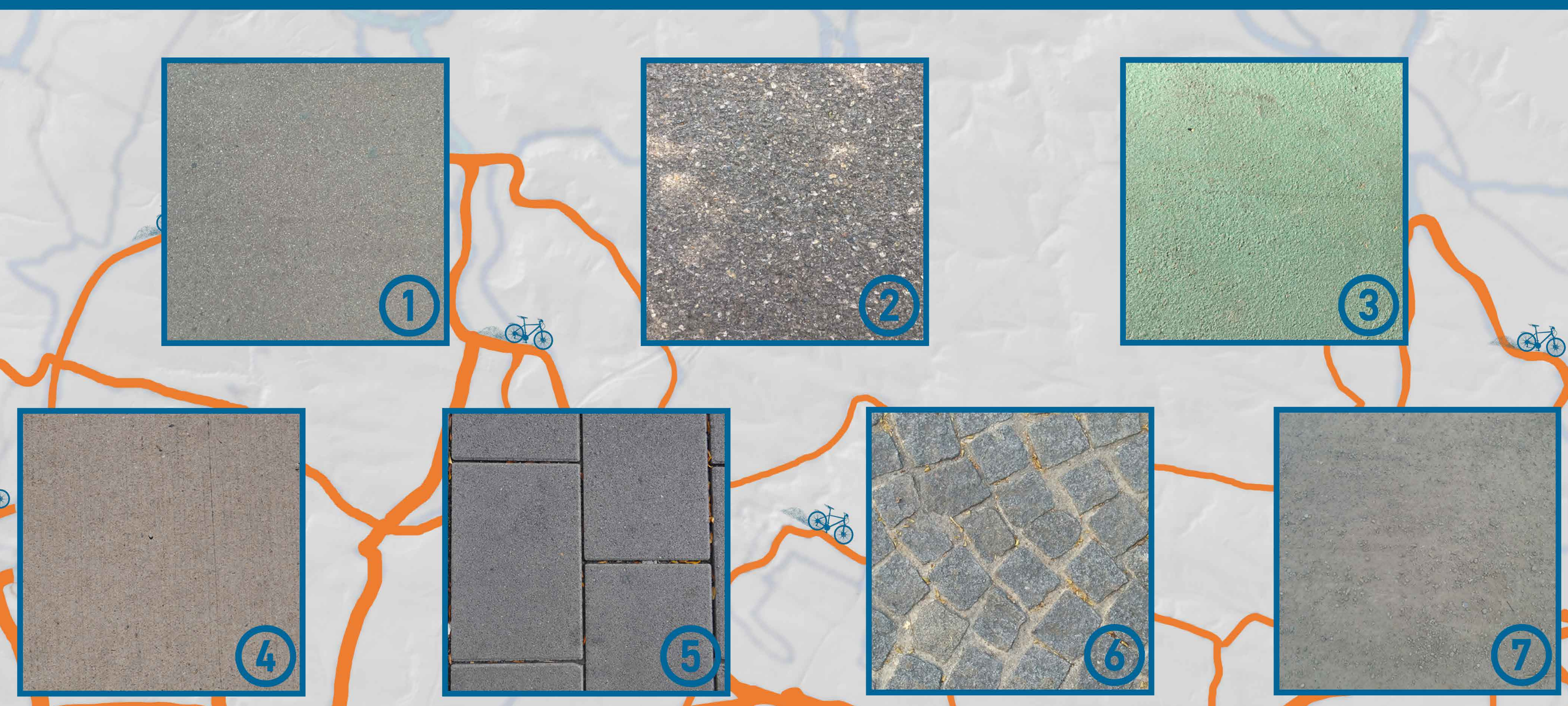


1) Abstract

What is the influence of the roughness of different roadway surface types on cyclists' velocity choices? Which environmental conditions have to be taken into account? And which of the identified factors have the biggest impact on the cyclists' velocity choice?

To find answers to these questions, first a survey is employed. After the identification and evaluation of the environmental conditions the main part of the paper then analyses the speed measurements of 3,750 cyclists, which were performed on seven different surface types using a radar gun:

smooth (SA) (1) and rough asphalt (RA) (2), painted bicycle lanes (PBL) (3), concrete (C) (4), large, regular (LRC) (5) and small, irregular cobblestones (SIC) (6) and gravel (G) (7) (see map).

Furthermore, by utilising the built-in accelerometer of an off-the-shelf smartphone and affixing it to a bicycle, the roughness of the surface types is determined by measuring three-dimensional accelerations over a fixed measuring distance on these sections. One aggregated value per surface type and fork stiffness remains to be used for comparison.

The combination of the gathered data is then used to find a correlation between the chosen velocity and surface roughness.

2) Methods

Online survey - Identification of all possible factors, which influence the cyclist's general behaviour and speed while riding a bicycle with subsequent assessment of the importance of each individual factor in comparison to the others. Thus the correct selection of test track locations, with non or only minimal distortions is assured.

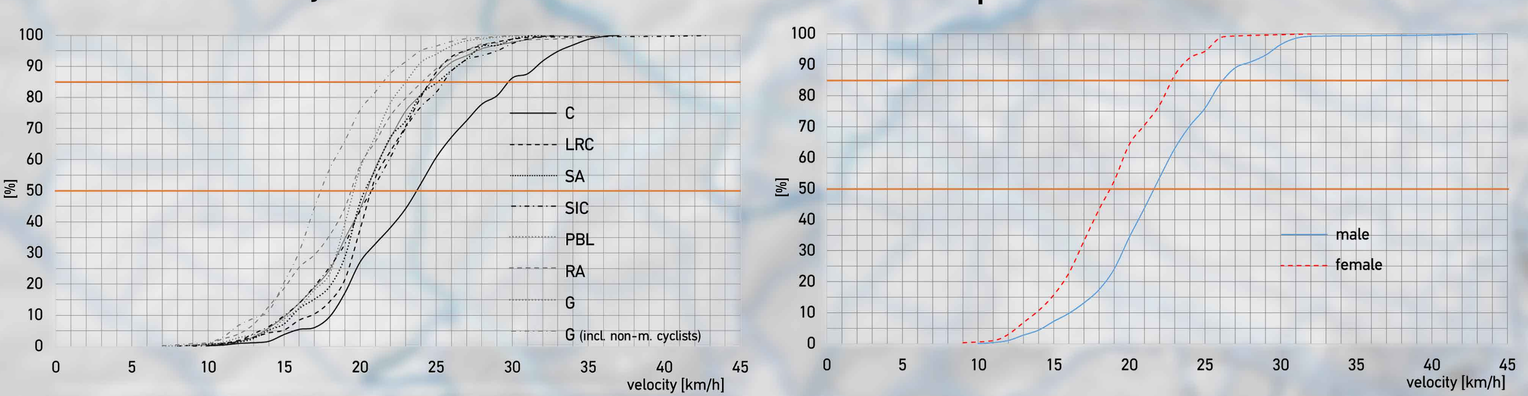
Preliminary speed measurements - Evaluation of assumptions regarding the expected differences in speed between sexes, daytimes and bicycle types.

Main speed measurements - Further speed measurements on the remaining, afore-mentioned test tracks. The data and experience gathered during the preliminary speed measurements allows the correct execution of the remaining speed measurements.

Surface roughness measurements - In order to asses the impact of the surface roughness, the roughness itself has to be evaluated first. This is done by measuring vibrations of the bicycle frame while riding across different surfaces. The accelerations caused by the vibrations are then cleansed from various interferences (e.g. from operating the phone) and are afterwards numericaly integrated. Hence one aggregated and comaprable value ($s_{z,60}$) remains for further analysis.

3) Results - speed measurements

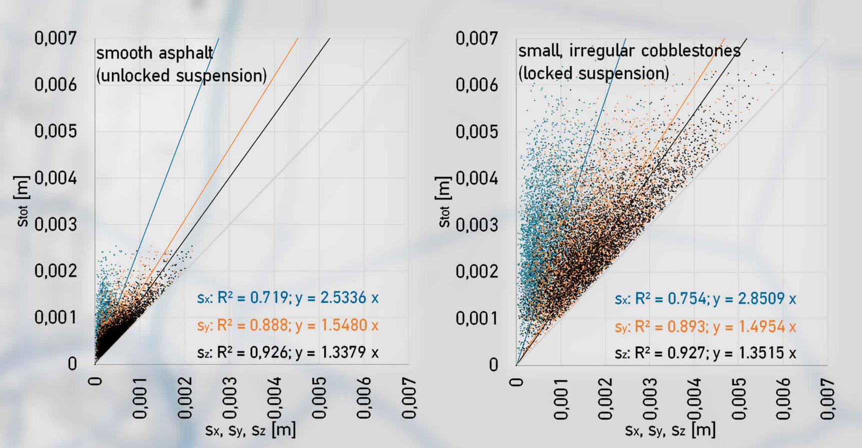
The preliminary results of the measurements taken on small, irregular cobblestones show that, men are riding singificantly (~14 %) faster than women. Additionally the results indicate that the chosen velocity also depends on the bicycle type as well as on the day time. Due to the similar ratio of male to female riders across Vienna (2:1), the small sample size of bicycle types (other than racing, mountain and city bikes) and the small speed differences between day times, it is either not necesarry or feasible to take these behavioral factors into account during the remaining speed measurements. The results of the main speed measurements show clearly that the chosen velocities are similar on nearly all road surfaces: $19.4 \leq v_{50} \leq 20.7$ km/h | $23 \leq v_{85} \leq 25.5$ km/h



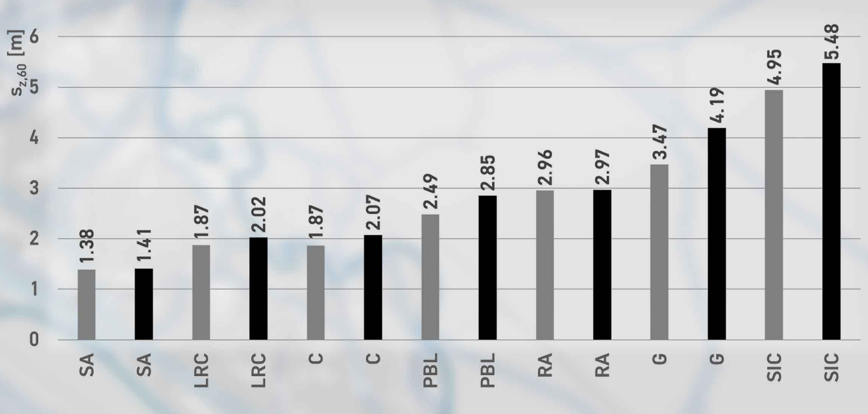
4) Results - roughness measurements

The analysis of all scatterplots suggests, that out of the three axes at disposal, the z-axis seems to be the relevant axis, due to the following reasons:

- The slope of the regression line is in 12 of 14 cases nearest to the slope of the first median.
- Contrary to both horizontal axes, the R^2 of the z-axis is always bigger then 0.9.



The measured accelerations of the z-axis are in turn numerically integrated, which leads to covered distances per minute $s_{z,60}$. This value is subsequently used for the comparison of surface roughnesses. As expected, smooth asphalt turns out to be the smoothest surface, whereas gravelled surfaces and small, irregular cobblestones represent the roughest

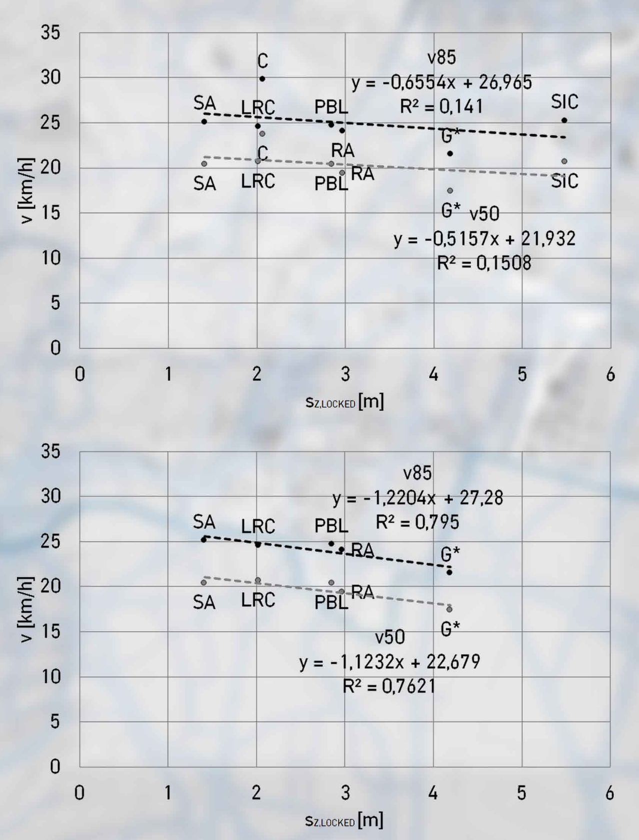


5) Comparison of results

To investigate the correlation between the two variables - namely the chosen velocity and surface roughness - the gained results are finally compaired.

At first glance, it seems to be clear that a higher roughness causes a decreased velocity, but on a closer look, it becomes evident that this result must be viewed very critical due to the low R^2, small sample size and the fact that two out of the sample of seven (concrete and small, irregular cobblestones) appear to be outliers or erroneous.

Therefore the two outliers are omitted from the sample, which increases R^2 up to at least 0.70 and decreases the slope of the regression line by a factor of about two.



6) Conclusion

Since the final result of the comparison of speed and surface roughness data needs an omission of likely outlying or erroneous values, the proposed method's suitability is difficult to assess. However, the gathered data suggest that the impact of the surface roughness in comparison to other factors is not dominating. Environmental, personal and possibly other, still unknown factors, like other traffic participants and the motivation of each individual person, appear to have a strong influence. As the initial data collection shows no strong evidence supporting the theory, it is also quite possible that the main question of this paper simply cannot be answered by pure observation alone.

Hence, further research would ask for creating an experimental setup, which includes groups of cyclists with different ages and bicycle types, who are then measured while passing different test tracks. The challenge of such a setup would be to prevent the cyclists from being biased.
This would also allow to simultaneously research the influence of different tire types

Ultimately the achieved results show that there is still extensive work to be done in this area of research.

7) Take-Home Messages

- Assessment of vertical accelerations sufficient for roughness evaluation
- Smoothest surface: smooth asphalt
- Roughest surface: small, irregular cobblestones
- Average bicycle velocity: $19.4 \leq v_{50} \leq 20.7$ km/h
- Results suggest correlation between surface roughness and chosen velocity

References

Background - https://www.wien.gv.at/ma41datenviewer/public/start.aspx
Background - http://labs.strava.com/heatmap/#12/16.39469/48.19333/blue/bike
Background - https://www.data.gv.at/katalog/dataset/dgm/resource/b347b029-3fd5-448a-8c2c-07f483c2c56e
Bike silhouette - https://herviscdn.azureedge.net/medias/sys_master/images/images/h19/hf5/9700450861086/KTM-Fun-Spirit-1987594-01-74484.jpg

Link to complete paper as PDF (GER):