Potential of the Bicycle as a Substitute for Other Modes of Transportation

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Without a doubt, the bicycle is the most ecologically acceptable mode of transportation. Nonetheless, for a long time, it had been almost ignored in transportation planning. Only very recently has this changed. However, some uncertainty still exists concerning the extent to which the bicycle can substitute for other modes of transportation in urban areas. This question is investigated by first observing the development of transportation in recent years in selected areas of the Federal Republic of Germany, in which use of the bicycle has been on the increase. This makes it possible to identify those changes in modal choice that have brought about this increase in the use of bicycles. The changes in modal split in favor of bicycles reflect individual reorientations that have led to substitution processes. Further potential of the bicycle as a substitute for other modes of transportation will depend on policymaking. Social scientific behavioral studies based on the concept of the situational approach make it possible to give reliable estimates of the order of magnitude of change to be expected and to predict the extent to which bicycles can become a substitute for private motor vehicles.

Since the 1950s, an increasing trend toward motorization has been observed in the Federal Republic of Germany. The use of private motor vehicles reached its peak in the mid-1970s. Use of nonmotorized modes of transportation was considered to be inconsequential, especially by transport planners, whose ideal it was to design cities suited to the needs of motorists.

Thus, it is not surprising that the first federal German survey on travel behavior (KONTIV) (1), in order to record all movements from one place to another place (including walking trips and trips made by bicycle), relied on methodological arguments and not arguments that had to do with content (2).

With regard to bicycle use, the results of the study were interesting for two reasons:

1. Bicycles were used to make 10 percent (3) of the total number of trips; thus, bicycle use turned out to be much more important than transport planners had generally assumed;
2. A number of arguments that had been used to determine whether the bicycle was a serious mode of transportation (e.g., a mode to be used only in good weather or by youngsters) were proved to be false.

These insights would not have had such a broad influence if car use had not been viewed with increasing scepticism, primarily due to the energy crisis and increasing awareness of the need to protect the environment, which had caused people to think more of the bicycle. This started a trend of increasing bicycle use in the Federal Republic of Germany, a trend that could be noticed "with the naked eye" (4).

These trends suggest new questions, which may easily tempt us to propose premature answers and evaluations, for instance, the following:

1. Is cycling a passing fad or is it an indication of a change in the behavior pattern?
2. Was one mode actually used to substitute for another mode or did changes occur only in such external factors as sociodemographic structures?
3. Is there a further potential for change to bicycle use?

Depending on their attitude, people may answer these questions differently--and often prematurely. Since the list of such questions, and of possible answers, can be extended indefinitely, it is especially difficult to design and implement policies intended to influence the use of bicycles.

It is the goal of this paper to present some findings on the current increase in bicycle use and to study the extent to which the bicycle has potential as a substitute for other modes of transportation.

CHANGES IN MODAL CHOICE

The considerations in this section are based on time-series data similar to the data reported in the national KONTIV study referred to above. Since then, numerous regional surveys that used a comparable design were performed in the early 1980s (5). The results were based on independent, representative random samples. The samples were large enough to make it possible to at least identify basic trends. Data were corrected when differences in the methodology (weighting) were present.

In order to show changes taking place as precisely as possible, an index was constructed, which starts from the 1980-1981 value as a base and permits calculation of the corresponding value for 1975-1976 (6):

Index of change = [(value for 1975-1976)/(comparable value for 1980-1981)] x 100.

When the calculated index exceeds 100, the 1975-1976 value is greater than the 1980-1981 value, which implies a retrogressive tendency; if it is less than 100, this value shows an ascending trend.

Transportation planners in the 1960s and 1970s frequently referred to increasing mobility because mobility was (incorrectly) equated with the use of motorized modes of transportation. However, when all possible ways of getting from one place to another are considered, there was never a very large increase in mobility (7,8) but only a change from the use of nonmotorized modes to motorized modes of transportation. In the communities discussed in this paper for which figures are available, mobility increased very slightly, as one might expect. Most increases in mobility were caused by the fact that those who were mobile increased the average number of trips they made by making complicated trip chains that resulted from a combination of various activities (see Table 1).

CHANGES IN MODE CHOICE

Modal split varied considerably in the different communities studied. In particular, the percentage of cyclists fluctuated radically, although topographical drawbacks to cycling were an important factor in only one instance. One should also note that the nonmotorized modes seem to strike a kind of balance with each other. Thus, changes in behavior are relatively insignificant when one analyzes the extended modal split. However, even here, certain trends can be observed (Table 2). Use of private motor vehicles decreased with only three exceptions; use of public transportation increased in urban areas (when the public transportation supply had noticeably improved) and decreased in smaller com-

Table 1. Mobility.

Variable	Index of Change					
					Hannover[a]	
	Detmold	Rosenheim	Landshut	Offenburg	Region	City
Out-of-house share	100	100	100	100	100	99
Trips per mobile person	98	98	98	97	100	98
Trips per person	98	99	98	98	100	97

[a]These figures are not available for the other survey in a German metropolitan area.

Table 2. Modal split and mode choice.

Item	Index of Change							
					Hannover		Large German City[a]	
	Detmold	Rosenheim	Landshut	Offenburg	Region	City	Region	City
Extended modal split:								
Nonmotorized mode	68	117	91	107	100	86	101	100
Motorized individual mode	117	83	112	91	106	135	100	108
Public transportation	171	87	108	131	85	80	97	85
Mode choice:								
Walk	82	180	135	134	117	94	102	103
Bicycle	41	50	45	73	81	68	99	63
Motorized one-axle vehicle	30	26	39	19	100	120	72	44
Car								
Driver	133	85	125	103	103	136	104	116
Passenger	75	93	95	82	119	132	93	91
Public transportation	171	87	108	131	85	80	97	85

[a]Survey results of a large German city. Since these results have not yet been published, the city remains anonymous.

munities beyond the range of the population centers. The use of nonmotorized modes of travel developed erratically.

The differences disappear if one considers all the modes usually used (Table 2). One can observe that bicycle use is increasing in all the areas studied, although at different rates. However, sometimes the increase in cycling occurs solely at the cost of pedestrian travel. This shows that one should view the increase in bicycle use, which is so frequently noted with joy, somewhat sceptically. Only rarely can one assume that a noteworthy change from motorized modes to cycling took place. Quite frequently, on the other hand, the bicycle is now used for trips that were previously made on foot. Nonetheless, this gets people used to riding bicycles, which might ultimately increase the potential for further, more effective changes in behavior.

When studying the changes in modal choice, one should not forget to take the initial situation into consideration. As Figure 1 shows, the bicycle share in 1975-1976 was above average in the four areas studied. In Offenburg and the region of Hannover, where the bicycle share in 1975-1976 was particularly high, the increase in the number of trips made by bicycle is less than in areas in which the bicycle share was smaller to begin with. One exception here is Hannover. Hannover shows a relatively small increase in the use of bicycles, although the share of cyclists in 1975-1976 was not particularly high.

It is possible to theorize that the bicycle fad progresses according to certain generally valid principles, i.e., independent of specific regional differences (communal "cycling climate," bicycle infrastructure, degree of motorization, topography, etc.), and that changes occur at different rates. This could mean that a development that took place in the region of Hannover and Offenburg in 1975-1976 took place at a later time in Rosenheim and Landshut. This would imply that the two latter cities will be able to maintain their existing very high bicycle share only with very great effort, although an increase in the bicycle share still seems to be possible in Detmold. In other words, bicycle planning should not only aim at increasing the percentage of trips made by bicycle but also try to stabilize those trips now made by bicycle.

Changes in modal choice also depend on local conditions. Thus, general behavioral trends do not always apply in specific areas. Since it is impossible to deal with the different areas studied here in depth, given the limitations of this paper, the variance in different communities will be shown by using the example of bicycle use according to different age groups. (We have figures for four different communities here.) Table 3 shows that the bicycle share according to age develops differently in different areas. In Offenburg, for example, younger persons, and in Detmold older persons, made relatively fewer trips by bicycle than they did in 1975. All in all, one can say that the increases for younger persons have been less than average, and indices showing changes for the middle age groups (30-49 years of age) more or less reflect the general trend.

INTRAPERSONAL CHANGES IN MODAL CHOICE

The changes depicted above were based on the results of samples obtained at two different times. In order to attain further qualitative insights into the trends taking place, explorative in-depth interviews were done in the two cities of Detmold and Rosenheim. These were two of the cities included in the project city for cyclists (9). A sample of 50 households and 100 persons was selected for these explorative in-depth interviews. A special questionnaire was designed to deal with this difficult empirical task. The questionnaire included external factors such as neighborhood, place of work, and status as well as mode choice related to trip purpose; the average week was used as a basis. If

Figure 1. Development of bicycle traffic.

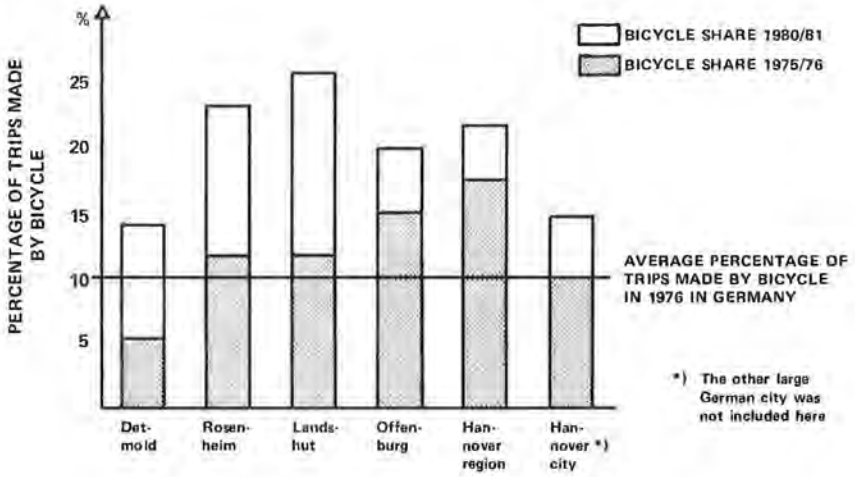

Table 3. Bicycle use by age.

Age Group	Index of Change of Bicycle Share[a]			
	Detmold	Rosenheim	Landshut	Offenburg
10-17	52	69	61	104
18-29	8	65	40	70
30-49	43	57	47	72
50-64	44	28	31	52
65+	117	37	55	24
All ages	41	50	45	73

[a] For the large cities these qualifications are not available.

changes in the behavior pattern occurred, reasons causing these changes were studied.

Changed travel behavior is rarely the result of external factors. With the exception of those who move to a new neighborhood, only 5 percent of the respondents or less were affected by changing external conditions. About 40 percent of the respondents moved within the period of observation; more than half of these moved to a new community. Although moves within the same community do not usually affect modal choice, it is different when people move to new communities. Since moves to new communities are usually accompanied by major changes in living conditions, changes in the entire personal activity pattern frequently occur. Other factors dealing with the social environment turned out to be relatively insignificant in a quantitative way. A major determining factor in modal choice is the availability of certain modes of transportation. In this paper, cars and bicycles are of central interest; other modes will not be dealt with further here.

Among the populations studied, the number of cars increased by 26 percent, whereas the number of bicycles increased by 55 percent between 1975 and 1981. Increased car ownership led to a greater percentage of households that had access to cars; in Rosenheim especially, the percentage of households with two cars and more doubled. The increase in bicycle ownership had a similar but more pronounced effect.

Increases in bicycle ownership correlated positively with the increased use of bicycles. This was not so for cars. The increase in car ownership (which was less than the increase in bicycle ownership) is paired with opposite trends in car use. Although the proportional increase in car ownership was similar in both areas studied, there was a noticeable decrease in car use in Detmold and a slight increase in Rosenheim. One possible explanation for this is the fact that in the last seven years in Rosenheim, cars were increasingly purchased by households that did not own a car previously. For the time being, we conclude that the availability of different vehicles is more closely related to changes in traffic patterns than to the external factors that had been considered first.

Most of the respondents in both areas perceive the changes in the general traffic situation to be the result of a general increase in the volume of traffic. As a second characteristic, however, we mention the increase in bicycle use. The differences in the two areas are interesting here. Although the rate of increase is comparable in both areas, this phenomenon is more noticeable in Rosenheim than in Detmold.

This is perhaps due to the fact that the percentage of persons who use bicycles to travel is noticeably higher in Rosenheim and can therefore not be overlooked. A considerable number of respondents also claimed that it had become more dangerous to use bicycles. This is probably related to the fact that many respondents also observed that compared with seven years ago, car drivers have become less considerate. However, certain differences can be observed between Detmold and Rosenheim. The complaint that drivers are less considerate is one that can be heard more frequently in Rosenheim, where the volume of car traffic has actually increased, than in Detmold. However, the increasing danger of using bicycles in Detmold is emphasized somewhat more than in Rosenheim. Perhaps this shows that cyclists perceive danger as being inversely related to the proportion of bicycles in the total traffic volume, which is, as has been mentioned, higher in Rosenheim.

In a self-evaluation of changes in their personal choice of travel modes, more than half the respondents in each area claimed that nothing had changed. In both of the areas studied, 27 percent of the target persons claimed to use bicycles more frequently; this contributes to the fact that the share of bicycles in relation to the total traffic volume has doubled. A further noteworthy peculiarity, however, is that 4 percent of the respondents made fewer trips by bicycle than seven years ago. This can be explained by the fact that older persons use bicycles less, for safety reasons. The most striking fact here, however, is that 15 percent of the respondents in Detmold and 21 percent in Rosenheim claim to use their cars less. In Detmold, this agrees with the reduction in the car share, whereas in Rosenheim, one can assume that the increase in

car use is due to new car ownership by those who previously did not own their own cars.

There are many different reasons why changes in modal choice occur. In both towns, an increase in bicycle use is attributed primarily to cost consciousness and ecological awareness. In Detmold, health reasons were frequently quoted, and in Rosenheim, one frequently hears that the increase in traffic volume has resulted in parking problems but also that persons are using bicycles more than previously because they simply enjoy riding bicycles. The most important reason mentioned in Detmold for increasing car use is comfort, whereas this does not seem to play a role in Rosenheim. Reduced use of cars is generally a result of financial considerations, but this might also result from substitutions of walking trips or simply from not making certain trips at all.

Those persons who made fewer trips by bicycle than they used to claimed that it has become increasingly dangerous to use bicycles. Although this is sometimes simply related to the fact that older persons feel less safe using bicycles, it shows an aspect of bicycle use that could be relevant for planning. This brings us back to external reasons for not using bicycles. These external factors may also play a minor role in subjective reasons for changing modal choice.

To summarize the results of these explorative interviews, at least for the respondents (and we feel that these results can be generalized), the following statements can be made:

1. An increase in the number of trips made by bicycle is the result of a substitution process;
2. Increased use of bicycles reflects individuals' changes in behavior as the result of motivated reorientations;
3. An attractive bicycle infrastructure is not cited as being the reason for using bicycles;
4. Some persons show a tendency to use bicycles less frequently; this fact is easily hidden by the general increase in the use of bicycles; adequate planning of bicycle paths could serve to be a stabilizing influence here;
5. The fact that it is "in" to ride bicycles plays a certain role in influencing behavior; and
6. External factors, which take a macroscopic view of travel behavior, play only a minor role in behavioral changes.

It is important to emphasize the fact here that the greatest percentage of trips made by bicycle is to be found among younger persons; i.e., as the age structure of the population changes, this will be reflected in the number of trips made by bicycle. In the Federal Republic of Germany, this means that the drastic reduction in the birth rate in the 1970s will eventually be reflected in a considerably smaller contribution to bicycle use by the members of the bicycle-oriented younger generation.

BICYCLE AS SUBSTITUTE FOR OTHER MODES

It is generally agreed that the use of bicycles has considerably increased in recent years in the Federal Republic of Germany. Although this partly reflects permanent changes in behavior as regards modal choice, it is also partly the result of a currently friendly climate toward bicycle use. If one wishes to influence modal choice in favor of bicycle use, these findings mean that the current situation is favorable but that existing behavior patterns are deceptive. In other words, considerable planning is needed if the currently positive climate is to be used to influence long-range changes in behavior. It has already been shown elsewhere that besides those who have already changed to bicycle use, there is still a sufficient potential to be considered and a variety of integrated measures will be needed in order to attain this potential (10).

It has also been shown how much behavior varies if one views it on a local level. This variability characterizes not only the local traffic conditions but also the patterns of change or the ways in which they are influenced. This means, however, that only detailed knowledge of local traffic conditions gives one the prerequisites needed to plan effectively. The analysis of general behavior tendencies is insufficient for such planning. On the contrary, the danger that the bicycle is used only as an alternative to walking trips or trips made with public transportation is great.

Simultaneously, one should note here that not only does the traffic infrastructure serve to fulfill our traffic needs safely but it represents, in addition, a major element forming our environment. This becomes clear if one considers persons not only as tripmakers but also as the people who actually live in the environment; i.e., a person lives in a neighborhood that has a given infrastructure.

Since the early to mid-1970s, it has been found more and more important to better plan and design the areas in which we live. The most important factors here to improve the quality of life (11) are

1. Less traffic-generated noise and air pollution,
2. More green and recreational areas directly surrounding residential areas,
3. More room to move about on safer streets,
4. More consideration for disadvantaged groups (such as children, older persons, and the handicapped),
5. Appropriate consideration of nonmotorized modes of transportation, and
6. Rediscovery of streets as places of communication and living areas.

These factors have become increasingly important as criteria in the evaluation of different neighborhoods, but there has frequently been dissatisfaction with the degree to which these requirements have been fulfilled. On the other hand, as early as 1976, it was felt that a satisfactory traffic situation had been more than fulfilled [Table 4 (12)].

All these factors considered, one has to assume that there are other tendencies to reevaluate the use of private motor vehicles for daily travel than the definite trend to use bicycles more.

Table 4. Evaluation of characteristics pertaining to neighborhood in planning regions with urban structure.

Characteristic	Importance[a]	Contentment[b]	Degree to Which Fulfilled
Neighborhood, area surrounding residence	1.73	2.34	-
Residence (cost, size, furnishings)	2.10	2.49	-
Protection against pollution and noise caused by traffic	2.32	3.20	--
Shopping possibilities in area	2.33	2.40	0
Accessibility by			
Public transportation	3.16	2.63	+
Private motor vehicle	3.24	1.83	++

[a]The scale reaches from 1.00 = most important to 6.00 = least important (N = 2455).
[b]The scale reaches from 1.00 = very contented to 6.00 = very discontented (N = 2455).

Table 5. Possible increase in use of bicycles.

Dimension	Measure	Acceptance Index (A1)[a]: Per Dimension When Isolated Measures Used	Acceptance Index (A1)[a]: In Pro-Bicycle Community Climates per Measure in Other Dimensions	Acceptance Index (A1)[a]: In Pro-Bicycle Community Climates and Realistic Perception of Bicycle Use for Development of Bicycle Infrastructure
Current trend	None	1.03		
Subjective willingness	Community climate	1.20		
Perception of bicycle use	Public relations work	1.19	1.50	
Perception of route	Infrastructure planning	1.17	1.36	1.66
Constraints	Transporting baggage, weather protection	1.26	1.51	
Objective option	Bicycle rental	1.15	1.41	

[a]A1: 1.00 = current bicycle share remains same; 2.00 = current bicycle share doubled.

Table 6. Possible reduction in use of private motor vehicles.

Dimension	Measure	Reduction Index (R1)[a]: Per Dimension When Isolated Measures Used	Reduction Index (R1)[a]: In Pro-Bicycle Community Climates per Measure in Other Dimensions	Reduction Index (R1)[a]: In Pro-Bicycle Community Climates and Realistic Perception of Bicycle Use for Development of Bicycle Infrastructure
Current trend	None	0.99		
Subjective willingness	Community climate	0.98		
Perception of bicycle use	Public relations work	0.96	0.91	
Perception of route	Infrastructure planning	0.97	0.95	0.89
Constraints	Transporting baggage, weather protection	0.93	0.90	
Objective option	Bicycle rental	0.98	0.95	

[a]R1: 1.00 = current share of private motor vehicles remains same; 0.50 = current share of private motor vehicles reduced by one-half.

POTENTIAL OF BICYCLE AS SUBSTITUTE FOR TRIPS WITH PRIVATE MOTOR VEHICLES

To summarize these insights, one can say that although we have become more aware of the environment, other external conditions also appear to influence modal choice in favor of bicycles. A study must be done of the conditions under which those persons currently using private motor vehicles would be willing to use and would actually use bicycles.

Due to the limits of most research methods (which has already been explained elsewhere) (13), it is relatively difficult to do such a study. However, the situational approach, which has been tested frequently in recent years (14), is very promising when used together with the new empirical survey techniques (15). This method is currently being used to study the general potential that exists for switching to bicycle use (16) (without taking specific private motor vehicles into consideration); the results are available for those who are interested (10).

In this study, the different factors (so-called dimensions) that influence modal choice were differentiated. It is possible to influence these dimensions by implementing certain types of policies. The dimensions are shown below:

Dimension	Description
Objective option of using bicycle	Bicycle available, trip < 15 km
Constraints against using bicycle or requiring use of specific mode	Baggage transport needed, weather conditions, health reasons, car needed at work
Perception of route	No bicycle paths, too many hills, dangerous intersections
Perception of bicycle use	Too slow, too tiring, clothes get dirty
Subjective willingness	Personally willing to use bicycle mode

To influence these dimensions, the following measures were considered:

1. Objective option: influence basic availability of bicycles (e.g., make it possible to rent bicycles),
2. Constraints: only constraints pertaining to the bicycle itself (baggage transport needed, weather conditions) are referred to here, since other constraints (e.g., passengers, car needed at work, complex trip chains) cannot be dealt with by the measures discussed in this paper,
3. Route: improve the bicycle infrastructure,
4. Bicycle use: do public relations work geared at clarifying misconceptions and incorrect perceptions, and
5. Subjective willingness: increase the number of persons willing to change to use of bicycle by creating a climate of opinion in the community favorably disposed to bicycles.

A so-called "acceptance index" was used to better describe the probable behavioral changes. This index indicated the extent to which current bicycle use could be increased maximally if measures pertaining to the different dimensions were to be im-

plemented. An index of 1.00 means that the current bicycle share remains the same, whereas an index of 2.00 means that the share of persons using bicycles doubled. This shows that if the bicycle infrastructure is improved but nothing else is done to encourage cycling, only relatively few persons can be expected to switch to bicycle use. However, if an integrated group of measures is used in which efforts are made to influence subjective areas, one can expect a considerable increase in the use of bicycles (Table 5).

If one wishes to determine the extent to which the increase in bicycle use is the result of persons who switch to bicycles from private motor vehicles, and thus the degree to which the use of private motor vehicles has declined, not only must one make a special evaluation of persons changing from one mode to another mode according to the type of transportation used, but one also needs another indication of the results. We have decided to use a reduction index per dimension and measure, which is similar to the acceptance index. A reduction index of 1.00 indicates that the use of private motor vehicles would stay the same if a certain policy were implemented, whereas a reduction index of 0.50 would indicate that it would be reduced by a maximum of 0.5.

The individual reduction indexes, which can be compared with those in Table 5, show that if bicycle use is encouraged by using the right policies, the use of private motor vehicles can be somewhat curtailed (Table 6). However, one should not forget that in the communities studied (population of 80 000 or less) in the Federal Republic of Germany, the percentage of trips made with private motor vehicles was 55 percent, or more than three times as high as the percentage of trips made by bicycle (16 percent). Therefore, a 1 percent reduction in the former results in a 3.5 percent increase in the latter. In order to reduce the number of trips made with private motor vehicles and to increase the number made by bicycle, it has been shown that measures dealing with both subjective attitudes (counteracting prejudices and negative opinions) and technical problems (transporting luggage and weather protection, etc.) play an important role, whereas (isolated) measures to improve the infrastructure are much less effective.

It should be emphasized that only the potential for changing to other modes has been studied here. If a person has started to use a bicycle and discovered that the bicycle infrastructure is inadequate, it is very likely that he or she will revert to the use of the former mode. Thus, a good infrastructure does not create an increased demand for bicycle use but ensures that the persons dependent on this infrastructure will continue to use bicycles. Thus, if one wishes to encourage bicycle use, it is not enough to simply build bicycle paths. If no other measures are taken, only a small additional incentive is created, especially to induce those persons who now use motor vehicles to change to bicycles. However, it is precisely this latter group that is of greatest interest to transport planners. Integrated groups of measures are needed in order to reinforce the currently positive trend to use bicycles.

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