reviewed paper

Social and Spatial Behaviour in Shared Spaces

Robert Schönauer, Martin Stubenschrott, Helmut Schrom-Feiertag, Karl Menšik

(DI (FH) Robert Schönauer, mobimera Fairkehrstechnologien, Taborstraße 11b/19, 1020 Wien, schoenauer@mobimera.at)
(DI Martin Stubenschrott, AIT Austrian Institute of Technology, Giefinggasse 2, 1210 Wien, martin.stubenschrott@ait.ac.at)
(DI Helmut Schrom-Feiertag, AIT Austrian Institute of Technology, Giefinggasse 2, 1210 Wien, helmut.schrom-feiertag@ait.ac.at)
(DI Dr. Karl Menšik, Rosinak & Partner ZT GmbH, Schloßgasse 11, 1050 Wien, mensik@rosinak.at)

1 ABSTRACT

Many European cities implement shared spaces or other mixed traffic concepts in order to revitalize city centers and provide alternatives to car-centric road designs. The main idea is to treat all modes of traffic equally and encourage social interaction between road users with the prospect of cooperation over egoism. Furthermore a higher attractiveness of a road for people requires a careful traffic behavior, increased safety and lower speeds and a more attractive urban environment overall. Little research has been done how and if the new road design can also help pedestrians and bicyclists to reclaim previously car-dominated spaces.

The analyses of existing implementations can support planners by objectively showing the effect on traffic behavior. In this paper the traffic situation at the Sonnenfelsplatz in Graz (Austria) is compared before and after it has been redesigned from a complex roundabout to a shared space. The traffic flow in the investigated area is about 1.000 motorized vehicles, up to 600 bicyclists and 3.000 pedestrians in the peak hour (before reconstruction). This location has been chosen because of the diversity of traffic modes and the high traffic volume in general. Therefore, the trajectories of pedestrians, bicyclists and cars have been recorded and analyzed. Among the compared characteristics are: The spatial distribution of road users, the consistency in speed and travel times, length of paths as well as safety aspects.

Given this extensive evaluation and the lack of an existing simulation model, we also describe the requirements for developing a simulation model. A trustworthy simulation could help architects and city planners to decide if and in which configuration a shared space zone could improve an urban area. A catalog of requirements from urban planners' perspective is created and discussed.

2 INTRODUCTION

The concept of designing public roads, junctions and spaces as so called Shared Spaces is increasingly popular in recent years and is seen as a chance to reduce the car-dominance in cities throughout Europe. In shared space designs, the segregation between motorized and non-motorized traffic is removed, creating an integrated space without traffic signs or signals, curbs and road markings. Instead, traffic flows are controlled by social interactions and supported by infrastructure measures like colored roadsurfaces and the thoughtful placement of road furniture. Due to this lack of legally binding elements like pedestrian crossings, people are said to be more safety-conscious and to pay more attention to the behavior of other people (Hamilton - Baillie, 2007).

There is ongoing debate about the merits and practicality of shared space: (Hamilton - Baillie, 2007) and (Clarke, 2006), mostly show the positive factors like reduced crash statistics or average speeds. Especially when it comes to opinion-based results, the situation is not as clear anymore. Especially the elderly and disabled people feel less safe in shared spaces (Gerlach et al., 2008). Given this discrepancy between hard facts like crash statistics and public opinion, this paper wants to research the missing link in between: How has people's actual behavior in a shared space changed after a reconstruction.

Therefore, a semi-automated annotation tool was developed (Schönauer et al., 2012a) which allows fast and accurate annotations of bicycles, cars and pedestrians in a highly frequented crossing. Video footage has been recorded at the Sonnenfelsplatz in Graz, Austria before and after a reconstruction using shared space principles from a complex roundabout (see Fig. 1).

ISBN: 978-3-9503110-2-0 (CD-ROM); ISBN: 978-3-9503110-3-7 (Print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI

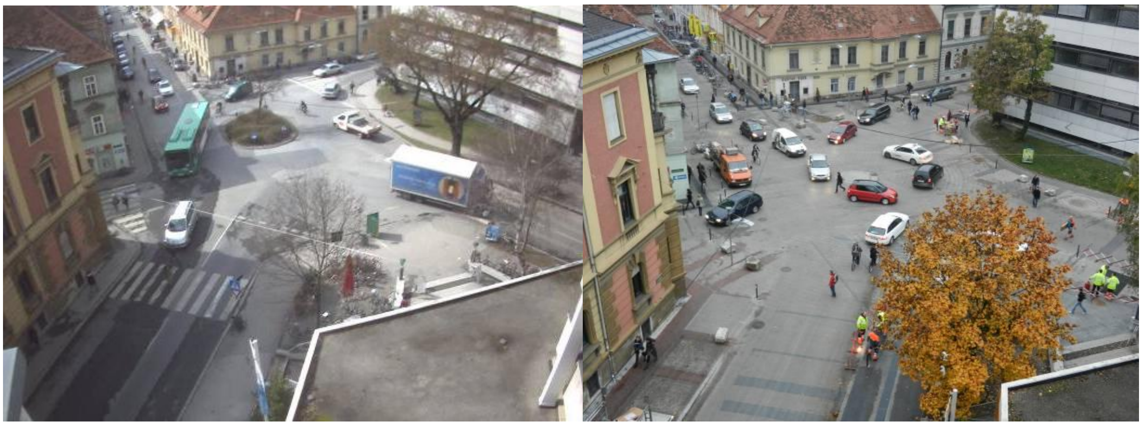

Fig. 1: Sonnenfelsplatz. LEFT: Before the reconstruction. RIGHT: After the reconstruction as a shared space.

The resulting movement trajectories of pedestrians and vehicles form the data base for further traffic flow analysis, spatial distribution of speed and interaction characteristics. The results of this analysis provide two fundamental benefits:

- The before and after comparison identifies potential benefits and drawbacks of the new road design.
- The analysis of the spatial distribution of the after data yields empirical information for civil engineers and is the basis for reliable traffic simulations.

The spatial distribution is especially interesting, as it builds the data base how the new space is actually used. The long-term goal is to link people's behavior directly to the influence of certain design elements like street furniture or trees. Therefore, after the spatial analysis, we conclude our work with discussing the requirements from urban planners' perspectives.

2.1 Related Works

With the growing number of already constructed and planned shared spaces, more research deals with the effects of the various design elements on the behavior of pedestrians and cars. Especially the UK has a wide range of reports on the design of shared spaces (Department for Transport, 2011) which act as guidelines for transportation planers and researchers the safety effects of a handful of converted shared spaces throughout Europe (Reid et al., 2009). The report summarizes the results of an appraisal stage in which available evidence on the performance of Shared Space has been collated and reviewed. It also includes a literature review by examining the most often characteristics of shared spaces. Among those are: Economic activity and property values, flows of users across the street, opinions of users, use of facilities such as seating and proportion of pedestrians moving freely. Especially the last property is a fundamental idea of shared space, but Reid acknowledges there is little data available. We try to fill this gap by analyzing the pedestrian paths using trajectories obtained from annotated video footage.

Many of the other properties are often examined by opinion polls. E.g. (Kaparias et al., 2011) describes a stated-preference study which queries specific elements of a shared space (like pedestrian density, vehicle density, speed of verhicles, …) which affect the willingness of drivers to actually share the space with pedestrians in a shared space.

Actual change in behavior by doing video analysis has been researched by (Bliek, 2010) by comparing the probability of cars stopping at intersections of conventional roads to the probability at redesigned shared spaces in Montreal. Two shared space crossings were compared to two reference crossings with similar properties of size and traffic volume. It was observed that drivers are more likely to give way to pedestrians on the shared spaces than on the conventional crossings.

(Karndacharuk et al., 2011) provides an extensive data aquisition and analysis of behavior in three streets in New Zealand which have been converted to shared spaces. Their performance indicators include: Dwell times, activities (eating, chatting, …), retail ocupancy rates in the area, speed reductions for cars and overall crash history. At the time of this writing, however, only the „before" period has been captured and analyzed, the data of the „after" period will only be fully analyzed in late 2012.

The conclusion of literature research indicates that there is not a well-defined set of optimization attributes which fits for every shared space. Depending on the surrounding and intention of the shared space, sometimes it could be beneficial to increase the dwell times of pedestrians, while in other situations the main objective could be the reduction of the travel times of pedestrians. The only recurring objective is, however, that shared spaces should encourage shared usage of the space instead of retaining the old behavior on a newly designed road. This is also the main research objective of this work.

3 BEHAVIOR ANALYSIS

As we have explained previously, Shared Space is rather a design guideline with multiple different ways of interpretation instead of a ready-to-use design which is implemented the same way in all projects. Thus we must acclaim that our findings are not necessarily transferable to any other Shared Space – it can, however, be used as the basis for verifying and refining existing guidelines.

3.1 Data Collection

Data has been collected at the Sonnenfelsplatz in Graz before and after the reconstruction to a Shared Space. In 2009 a classical traffic survey was conducted (Koop. Sonnenfelsplatz, 2009) counting the vehicular flow and the number of pedestrian crossings. It shows a pedestrians crossing count of about 3.000/h , a total daily traffic volume of up to 1.500 cars/h and a cycle rate of 12% (including a marginal part of motorbikes). Table 1 gives the number of counted traffic participants and the time of survey.

		Traffic survey 2009	Video analysis: Roundabout 2010	Video analysis: Shared Space 2011
DATE	**weekday, date**	Thursday, 15.10.2009	Tuesday, 23.03.2010	Thursday, 27.10.2011 / Friday, 28.10.2011
	time	06:00 - 20:00	12:53 - 12:57	10:38-12:42 (12:40 – 12:42)
COUNT	**pedestrians**	between **510** and **860** P./h at every crossing (12:00-13:00)	55	75(43)
	cycles (including motorbikes)	between **26** and **240** incoming single track vehicles at every bypass (12:00-13:00)	53	99(23)
	cars, busses, trucks	**941** between 12:00 - 13:00 (**15162** in 14h)	49	115(43)

Table 1: Road traffic survey and Data Collection Overview.

For this paper the movement trajectories of pedestrians and vehicles have been generated by tracking the objects in video footage and transforming the trajectories to world coordinates. Semi-automated tracking is used to obtain the data (Schönauer et al., 2012a). Fig. 2 shows an screenshot of the data annotation process in the video pictures.

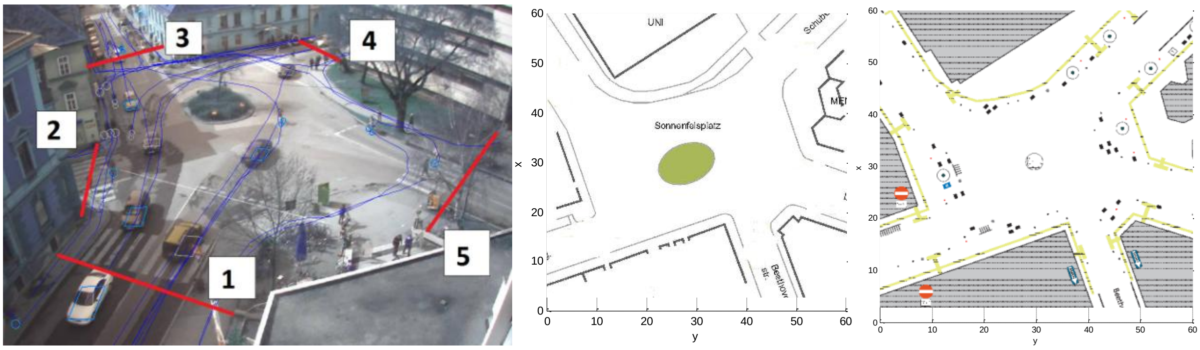

Fig. 2: LEFT: Screenshot of the pedestrian and vehicle tracking at the Sonnenfelsplatz in 2010, showing the measurement lines (red) and its numbers. MIDDLE: Scheme of the original design. RIGHT: Scheme of the new design

Road users are classified into pedestrians, bicycles and cars and tracked during their time inside the origin/destination measurement lines. The analysis focuses on two comparable scenes of a duration of several minutes in both the roundabout in 2010 and the Shared Space in 2011. The intersection of a trajectory with two of the five measurement lines (indicated with red lines in Fig.2) assigns the origin/destination to every track. In the further steps these trajectories are analyzed regarding spatial behavior, speeds and interaction properties.

3.2 Space usage

The willingness to share the available road space between traffic modes is a major aim of the Shared Space concept. This chapter qualitatively shows for each mode the spatial distribution change of the chosen paths. Before the reconstruction, the individual choice was narrowly constrained. On the left side of Fig.3 it is shown that pedestrians (red) cross the road in the area of the crosswalks. Bikes (green) and cars (black) follow the regulations to circle the central traffic island. Overtaking maneuvers of bicycles can be observed within the roundabout.

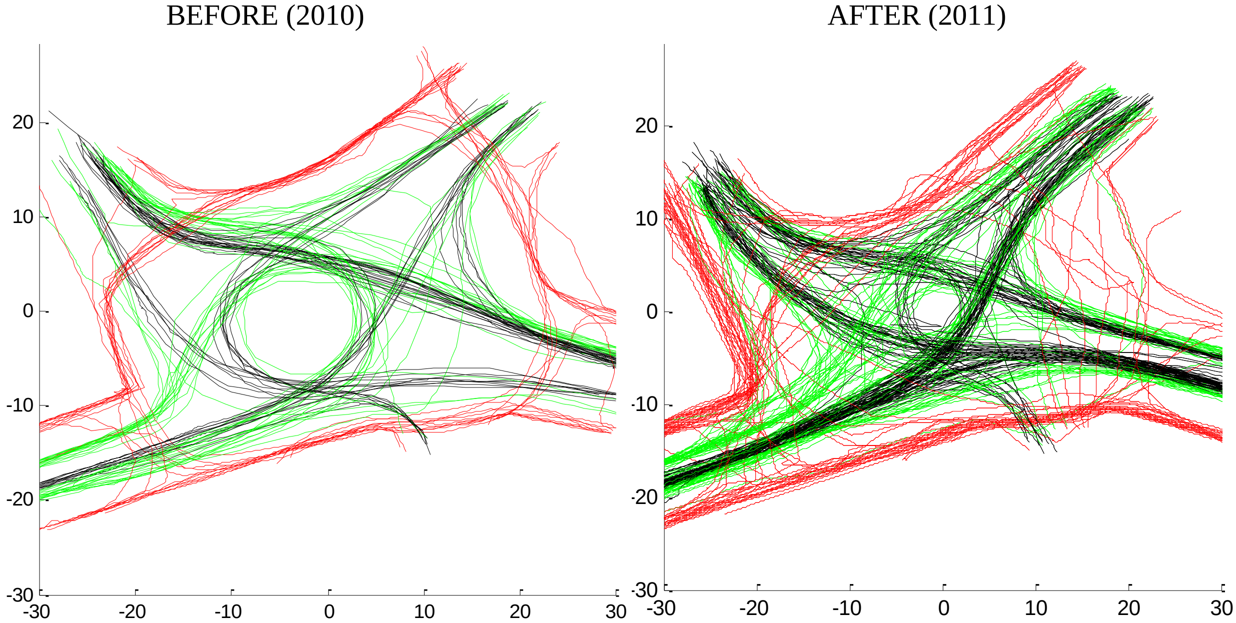

Fig. 3: Trajectories of pedestrians and vehicles. LEFT: Roundabout in 2010 (before). RIGHT: Shared Space in 2011 (after).

After the reconstruction several changes in the walking behavior can be observed. Pedestrians crossing the road are now using shorter paths closer to the squares center (Fig.3, right hand side). A higher variety in individual path choice can be observed, especially in crossing the road.

In the new design a slightly elevated island forms the center of the square, causing a white spot in the trajectories (Fig.3, right hand side). However, the islands' dimensions have been reduced from 8m x 11m to about 3m x 3m. Due to the smaller island the driving radii have also changed: At low turning angles (going "straight") the radii increased - at "U turns" the radii in cars and bikes trajectories decreased.

The trajectories in Fig.3 imply two phenomena in the redesign reducing path length and the travel time:

- A shift of the pedestrian crossings to the square's center.
- Changes in the driving radii of vehicles.

Travel time, average speeds and path length were calculated for each cell in the origin/destination (O/D) matrix. The empirical weight (number of samples in this mode and O/D relation) was considered in cumulating the results for each mode. The classification into O/D releation generates small groups of trajectories for most of the links and the statistical significance shows that the standard deviation error is refusing the tests. Higher sample sizes could provide a better statistical validity. To overcome the lack of data the next approaches do not split the trajectory sample into O/D relations.

3.3 Speed distribution

For the investigation of the speeds additionally to the path in world coordinate’s accurate timestamps for each single point are required. Therefore the camera encodes the timestamps in each single video frame in real time and errors caused by frame drops and deviating frame rates can be identified and taken into account. For a better comparison the whole trajectories were resampled to 0.1 second intervals which corresponds a frame rate of 10 frames per seconds using a linear interpolation algorithm.

The speeds are calculated for each segment in a trajectory using two neighbouring points and timestamps. For the computation of the speed distributions, the speed values are smoothed using moving average over the last two values. This was necessary to reduce jitter resulting from the annotation on discrete pixel positions in the video frames getting transformed to real world coordinates.

In Figure 4 the speed distributions for each mode separately are shown from left to right and for comparison between the roundabout with the Shared Space configuration one upon the other.

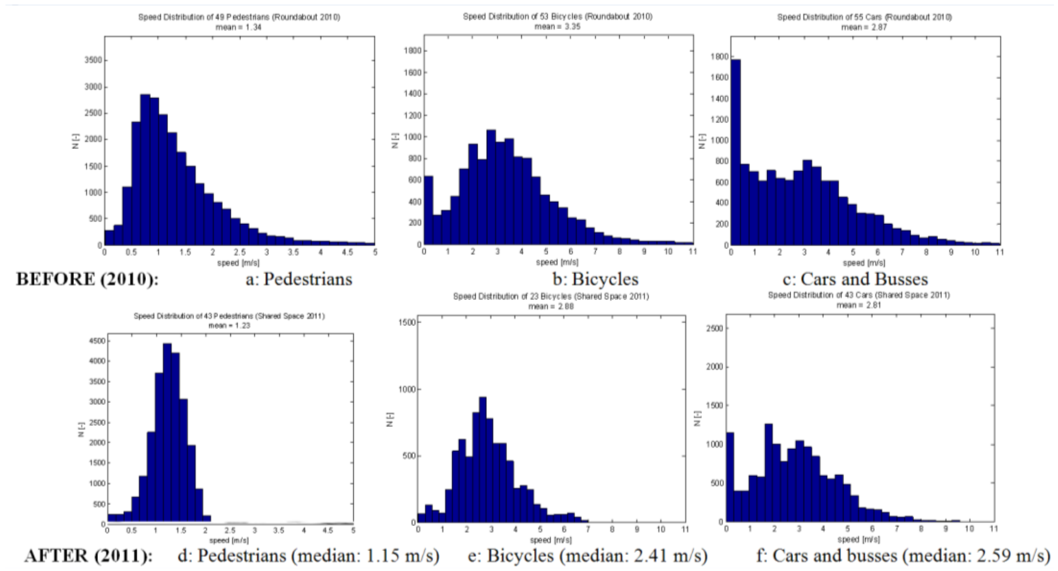

Fig. 4: Histograms of speeds before and after the reconstruction.

Inspecting the shape of the distributions in Shared Space for all modes they are narrower indicating a more constant speed and less stop and go behaviour compared to the roundabout. The mean speeds decrease in Shared Space as well as the speeds maximums. This could be an indication that people in the roundabout make short runs to pass the street before the vehicles arrive. The desired speeds within pedestrian crowds are Gaussian distributed with a mean value of approximately 1.34 m/s and a standard deviation of about 0.26 m/s (Henderson, 1971). The mean speed fits perfectly with the observed pedestrians in 2010, the distributions in the observations show standard deviations of 0.79 (before) and 0.37 (after).

The walking speeds in the Shared Space are lower but due to the shorter routes the total travel times decreases. For the cars the main difference is shown in much lower peaks in the Shared Space at lower speeds indicating less waiting times and a more continuous flow. In the following the spatial distribution of the speeds is investigated.

3.4 Speed maps

Driving and Walking speeds are major traffic performance and safety indicators. To show its spatial distribution the modal speeds are calculated for a cell grid of a grid size of 1m x 1m. Based on the generated grid speeds an estimator algorithm provides continous calculation of speeds in the map. The result is shown in Fig. 5.

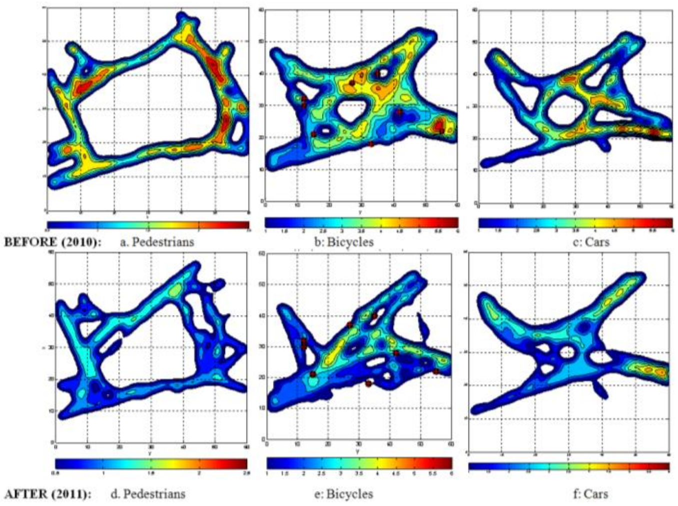

Fig. 5: Modal map of estimated speeds, based on cell grid speeds, all speeds in m/s. TOP: 2010. BOTTOM: 2011.

In the pedestrian class the main change is the shift to a more homogeneous speed level, especially the crossings of the roads are done in steady speed, which correlates with the findings in chapter 3.4. While bicycles' speed levels generally has dropped, their maximum speeds lie close to the center of the square. Reasons could be the higher awareness or the reduced space and a higher number of obstacles for bicyclists.

Car traffic speeds went down, especially in the area of interactions with all other modes the average speed level clearly sunk. In Fig.5b and Fig.5e the registered accidents in which bicyclists were injured between 2006 and 2008 (Koop. Sonnenfelsplatz, 2009) are marked by an red cross in a black filled circle (only in the central column). The comparison to 2011 shows that within all this spots the average speed sunk significantly. No accidents including pedestrian injuries have been recorded. At the time of submission no accidents in the redesigned scheme have been reported.

3.5 Safety aspects

Safety studies focuses often focus on the interaction between and within motorized and non-motorized traffic, as well as the conformity to traffic control regulations. Traffic safety analysis has traditionally relied on historical collision data. However, the shortcomings with this approach are the rare and random occurrence of collisions and its poor availability of data. Traffic conflicts are more frequent than traffic collisions. The first concept of road traffic conflict techniques (TCTs) was proposed by Perkins and Harris (1967) and involve observing and evaluating the frequency and severity of traffic conflicts at an intersection by a team of trained observers. Ismail et al. (2010) use indicators of time as objective and quantitative measure of the severity of conflicts.

This paper wants to outline the impact of speed and distance between traffic participants. We define a new indicator, including relative speed, and distance in time and space of a pair consisting of a non motorized road user and a car. It is calculated as the quotient of the squared relative speed and the distance between the object. Side constrains are the maximum distance of 5m and a time difference of maximum 3 seconds. To offer a spatial analysis we calculate for each 1m x 1m cell in the survey spot the median of the elements:

$$C_{xy} = \frac{1}{n*i*j} \sum_{\alpha=1}^{i} \sum_{\beta=1}^{j} \sum_{n=1}^{length(traj_i)} \frac{\left|(\vec{v}_\alpha - \vec{v}_\beta)\right|^2}{d_{\alpha\beta}}$$

,

where Cxy gives the relative squared speed by distance quotient for the cell at x,y. The vectors $v\alpha$, $v\beta$ are the speed vectors of the bike (respectively pedestrian) α and the car β which are at a distance $d\alpha,\beta$. A total number of i x j couples of i bikes (resp. pedestrians) and j cars are considered. The choice of data couples is constrained by distance in space (<1m) and time (<0.5s)

This indicator offers a simplistic approach to identify the spatial distribution of safety relevant variables. Fig. 6. shows the indicator Cxy calculated for 2010 and 2011, for pedestrians/cars and bikes/cars.

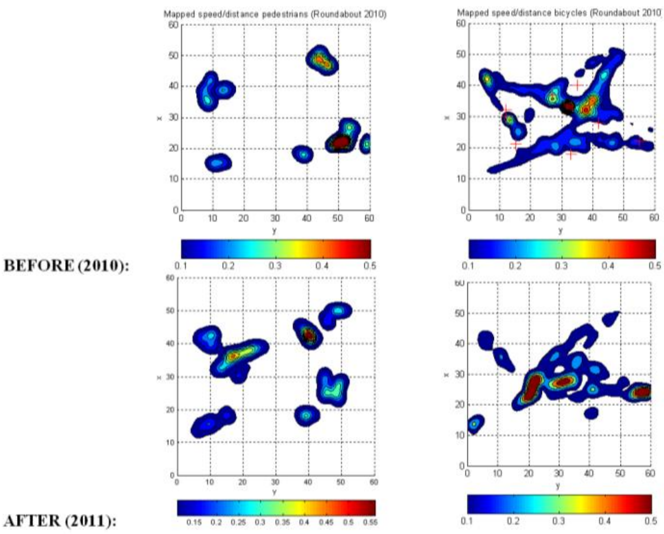

Fig. 5: Indicator Cxy based on cell grid speeds [m/s]. TOP LEFT: Pedestrian/Cars in 2010. TOP RIGTH: Bikes/Cars in 2010 (red markings for accidents during 2006-2008). BOTTOM LEFT: Pedestrian/Cars in 2011. BOTTOM RIGTH: Bikes/Cars in 2011.

The higher values represent spots where pairs of non-motorized road users and cars meet at higher speeds and lower distances. The comparison of BEFORE and AFTER shows that the hot spots moved and for bikes got even concentrated. Considering the lower driving speeds an explanation could be the smaller vehicle driving space and the smaller distances between vehicles. There is no scientific evidence to directly conclude to accident probabilities. Nevertheless hot spot areas are close to the occurred accidents in 2006 to 2008 (indicated in red crosses in the Fig.5, top right). Nevertheless the method has to improved including conflict classifications to generate prediction qualities. One major finding is that the total sum of all cells went down by about 10%.

4 APPLICABILITY IN THE PLANNING PHASE

Shared Space is a so far seldom implemented design concept that makes it difficult to point to existing examples. Furthermore, examples of Shared Space differ from each other because of the big variety of local conditions, design elements and traffic mixes. This makes it extremely difficult to show the effects of a planned Shared Space with the presently available tools. Different topography, complex traffic situations and a wide variety of design elements are a great challenge for planners.

The behavior analysis from Chapter 3 gives the confirmation that the intended goal of remixing the traffic at the Sonnenfelsplatz did happen. However, it is still hard to conclude which specific elements helped to achieve the effects – making it difficult to assess the impact of potential future Shared Space projects. Therefore, we suggest creating a realistic Shared Space simulation which could help in the planning phase for future projects. A simulation model allows the planners to test the effects of different design elements before they are built. It could help during the concept phase by

- addressing capacity concerns,
- determining potential bottlenecks and
- improving safety and comfort

It also would be suitable to illustrate the traffic flow in a planned Shared Space to citizens, politicians and stakeholders. The persons concerned should get a clear view, how the new design would work.

4.1 Planning requirements for the simulation

The difficulty lies in the identification and proper modeling of various design elements. Several design elements and traffic characteristics must be taken into account for an appropriate simulation. Also different road users have various characteristics and differ in traffic behavior and must therefore be simulated separately. The final important requirement is modeling the correct origin-destination relations as the space usage might change completely with additional offers like benches or other places to stay.

4.1.1 Types of road users

The foremost question is to decide which type of road users must be present in any Shared Space simulation to be helpful at all:

- Motorized vehicles, pedestrians and bicyclists are widespread in Shared Space. Private motorized vehicles should be treated separately in three classes: passenger cars, motor-bikes and heavy vehicles.
- Public transport occurs not in every Shared Space area. But if it does, it is very important, that it can be simulated, especially when the stations are located close to the investigated area and congestions caused by i.e. bus stops reach back in the shared space area.
- Persons in wheel-chairs and blind people are not wide spread, but call for a special approach not only in the simulation but in planning generally.
- Other road users were found to be not so important for the simulation. Such as emergency vehicles are so seldom, that their priority for the simulation is lowest.

4.1.2 Design elements

Different design elements affect traffic behavior in different ways. Road users stay away from poles, hedges and trees. Seats are obstacles as well, but also points of interest. Curbs, grassed areas and trees have a separating and a guiding effect on traffic behavior. Different colors of the sidewalk influence traffic behavior in a softer way. The structure of the surface influences the chosen route through an area or to a destination. Points of interest like shops and seats attract the road users.

Given the vast number of different design elements outlined above, these determining factors call for an accurate analysis of effects of design elements on the traffic behavior and the interaction between the road users.

4.1.3 Origin and destination points

The most common origin and destination points for all road users are at the borders of the planning area where they enter or exit the shared space. Within the area different road users have different points of interest, which attract them. Important points for vehicles in general are parking facilities. Cyclists do not use cycle stands only but also poles for parking. Stations of public transport are origin and destination for vehicles and for passengers as well. Entrances are the primary origins and destination of residents. Shops and restaurants are origin and destination points for pedestrians and cyclists. Some elements as shop windows attract people. They are origin and destination and invite people to stay for a while.

4.1.4 Prioritization

The great number of design elements and the various traffic mixes makes it necessary to identify the most relevant factors, which should be included in the simulation. The criterions for the assortment are occurrence, relevance and the data availability. These criterions are applied to the road users, to the design elements and to the origin-destination relations:

- The occurrence describes the frequency of different road users and design elements in existing Shared Space areas. If a certain type appears often, it is important that it is represented in the simulation. The absence of seldom types is acceptable.
- The relevance takes the effects of a certain element into account. Some different elements influence the traffic flow in a similar way. Such elements can be simulated as one.
- The data availability was treated for a pragmatic reason. Even if an element occurs often and affects the traffic flow it cannot be simulated if there is not enough information about it available.

These criterions are categorized in three classes for every type of road user, for design elements and for different origin-destination relations. The single criterions are aggregated to the criterion priority. The priority stands for the importance of an element to be represented in the simulation model and often depends on cultural peculiarities. For the analyzed area in Austria, following the above criteria the priorities of road users are cars, bicycles and pedestrians. The most important design elements at the Sonnenfelsplatz are obstacles like pollards, benches, greens and side areas where pedestrians feel safe.

4.2 Outlook

Given the extensive behavior analysis and analysis of planning requirements, the first steps towards a generic simulation framework suited for Shared Space planners have been done in (Schönauer & Schrom-Feiertag, 2010), (Schönauer et al., 2012b) and applied to two fundamentally different locations in Austria. Future research work deals with the effects of more design elements like benches or different road surface materials.

5 CONCLUSION

We have shown an approach to validate the effectiveness of a shared space implementation in an environment with highly diverse traffic modes. Especially at times of little traffic, the usage of the available space has changed and not only pedestrians but also cars use more abbreviations, leading to shorter paths and lowered travel time. Against our expectations, the travel times of bicycles did increase slightly though. Possible causal explanations could offer the lower turning radii and the higher conflict potential in the centre of the square. Statistical shortcomings in the analyze can't be excluded completely and further investigation is needed.

The paper shows the spatial distribution of path choice, resulting in a clearly wider variety in walking and driving positions. The distribution of speeds shows a lower mean and a higher homogeneity for all modes. Finally a new approach is applied to show the spatial distribution of quotients of relative speeds and distance of pairs of non motorized road users and a cars. The result shows shifts in location and intensity of the "hot spots". The comparison with locations of historical accident is done. To conduct valid correlations or even do accident predictions more research is needed.

Furthermore, we have given an overview of the requirements of transport planners in Shared Space projects. This helps towards creating reusable design guidelines and later even a simulation model. However, there is still a missing piece in linking specific design elements to the behavior of people. This paper gives specific guidelines for the analysis of people’s behavior in shared spaces. Using these analysis techniques the effects of placing certain design elements can be validated by comparing the trajectories in an before and after study.

6 ACKNOWLEDGEMENTS

The authors thankfully acknowledge Christian Rudloff and Dietmar Bauer for their continuous valuable contribution and support on this research topic. Further, the authors thankfully acknowledge Stefan Schrom and Clemens Vierthaler for video annotation, Christopher Lindmayer for providing a road design scheme and the planning team Kooperation Sonnenfelsplatz for providing traffic survey and accident data.

The work on that paper is part of the project MixME. The authors gratefully acknowledge the support of the Austrian Ministry for traffic, innovation and technology (BMVIT) by funding the project within the national funding framework IV2Splus.

7 REFERENCES

BLIEK, Desmond: Impacts of Shared Space Design on Pedestrian and Motorist Behaviour. In: . Vancouver, 2010.

CLARKE, E: Shared Space - the alternative approach to calming traffic. In: Traffic Engineering Control, vol. 47, no. 8, pp. 290–292, 2006.

DEPARTMENT FOR TRANSPORT, Great Minster House: Shared space. URL http://www.dft.gov.uk/publications/ltn-01-11/. - retrieved 2012-02-28. — Shared space is a design approach that seeks to change the way streets operate by reducing the dominance of motor vehicles, primarily through lower speeds and encouraging drivers to behave more accommodatingly towards pedestrians.

GERLACH, J. , Boenke, D. , Leven, J. , Methorst, R.: Sinn und Unsinn von Shared Space 1. In: Straßenverkehrstechnik, vol. 2/2008, 2008.

HAMILTON - Baillie, B.: Shared Space: Reconciling People, Places and Traffic. In: BUILT ENVIRONMENT, vol. 34, no. 2, pp. 161–181, 2007.

HENDERSON, L. F.: The Statistics of Crowd Fluids. In: Published online: 05 February 1971; | doi:10.1038/229381a0, vol. 229, no. 5284, pp. 381–383, 1971.

ISMAIL, Karim , Sayed, Tarek , Saunier, Nicolas: Automated Analysis of Pedestrian-Vehicle. In: Transportation Research Record: Journal of the Transportation Research Board, vol. 2198, no. -1, pp. 52–64, 2010.

KAPARIAS, I , Bell, M , Chan, C , Biagioli, T , Kennedy, J: Investigating The Willingness of Drivers to Share Space With Pedestrians. In: . Washington DC, 2011.

KARNDACHARUK, A. , WILSON, D J , Tse, M.: Shared space performance evaluation: quantitative analysis of pre-implementation data. In: . Auckland, 2011.

KOOP. SONNENFELSPLATZ: Sonnenfelsplatz. Innovative civic participation at the first shared space project in Graz, 2009.

PERKINS, S. , Harris, J.: Criteria for Traffic Conflict Characteristics (no. Report GMR 632) : General Motors Corporation, 1967.

REID, M. , Kocak, Nazan , Hunt, Laura: DfT Shared Space Project Stage 1 □: Appraisal of Shared Space, Report for Department for Transport : MVA Consultancy, 2009.

SCHÖNAUER, R. , Lipetski, Y. , Schrom-Feiertag, H.: Vehicle tracking data for calibrating microscopic traffic simulation models. In: Proceedings of SPIE, vol. 8301, no. 1, p. 83010F–83010F–9, 2012a.

SCHÖNAUER, Robert , Schrom-Feiertag, Helmut: Mikrosimulation von Mischverkehr – Konzept MiMiSim und Ausblick auf MixME. In: Schrenk, M. ; Popovich, V. V. ; Zeile, P. (eds.): 15th International Conference on Urban Planning and Regional Development in the Information Society. Vienna, pp. 1157–1161, 2010.

SCHÖNAUER, Robert , Stubenschrott, Martin , Huang, Weinan , Rudloff, Christian , Fellendorf, Martin: Modeling concepts for mixed traffic: Steps towards a microscopic simulation tool for shared space zones. In: . Washington, 2012b.