

Engaging virtual reality for transport planning

Applications in Singapore

Presentation

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Engaging Virtual Reality for Transport Planning Applications in Singapore

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ABOUT THE FUTURE CITIES LABORATORY

Singapore ETH Centre

- ETH Zurich's first major research centre outside Switzerland
- Part of CREATE Campus with many other international universities: MIT, Berkeley, Cambridge, TUM...

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- Through **science, technology** and **design**
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DISCIPLINARY EXPERTISE

A Architecture, Planning & Urban Design

B Mobility & Transportation Planning

C Sociology & Psychology

D Landscape & Ecosystems

E Energy Systems

F Materials & Engineering

G Information Technology

TRANSDISCIPLINARY SCENARIOS & RESEARCH MODULES

SCENARIO 1
HIGH-DENSITY MIXED-USE CITIES

- 1.1 *The Grand Projet*
- 1.2 Ecosystem Services
- 1.3 Energy Systems
- 1.4 Dense and Green

A B C D E F G

SCENARIO 2
RESPONSIVE CITIES

- 2.1 BigData-Informed Urban Design
- 2.2 Cyber Civil Infrastructure
- 2.3 Engaging Mobility
- 2.4 Cognition, Perception, and Behaviour

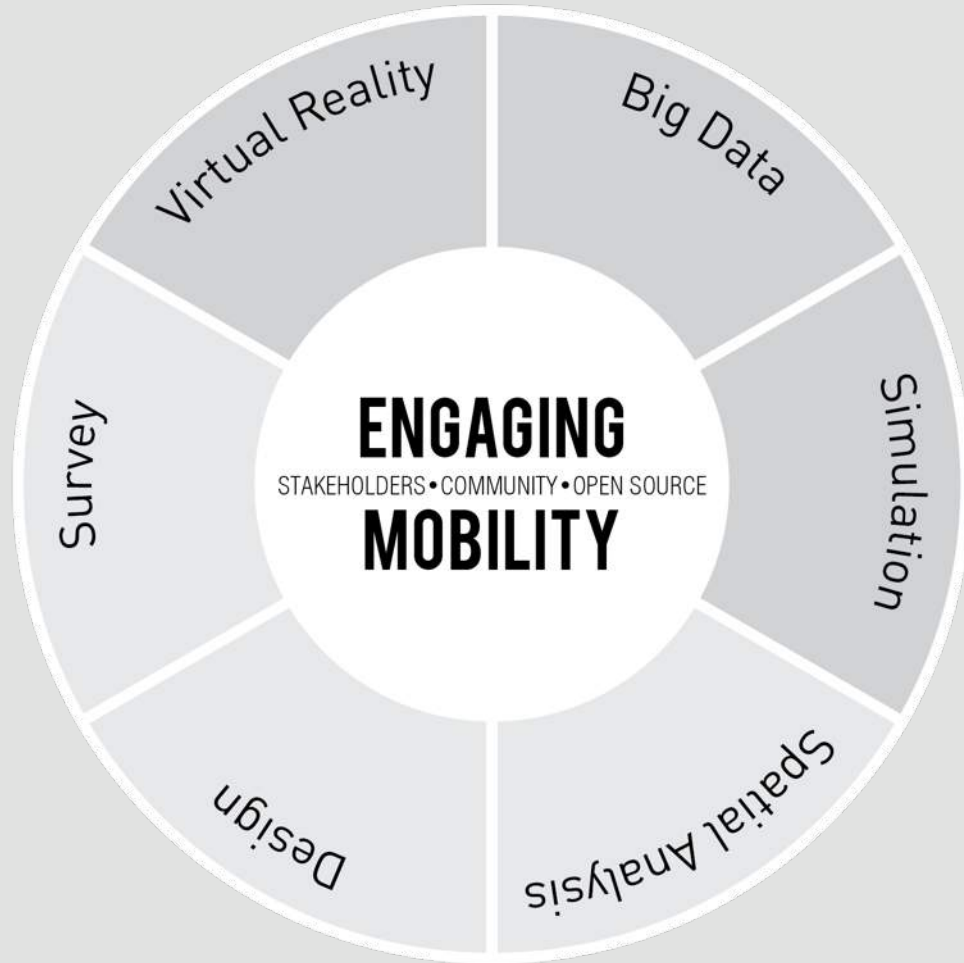
A B C D E F G

SCENARIO 3
ARCHIPELAGO CITIES

- 3.1 SIJORI and Extended Urbanisation
- 3.2 Urban-Rural Systems
- 3.3 Alternative Construction Materials
- 3.4 Tourism and Urbanisation

A B C D E F G

ENGAGING MOBILITY AS A RESEARCH PLATFORM



We can't address current and future urban mobility challenges alone and don't act in an ivory tower. Therefore, our core principles are Open Source and engaging with local stakeholders and communities.

Given today's highly specialised work and research environment, we believe in the power of working in an interdisciplinary manner.

Engaging Mobility combines cutting edge technologies with state-of-the art methods in innovative research projects.

CYCLING EXPERIENCE IN SINGAPORE: ON STREET

On Road Cycling (2016) Jonas Kupferschmid

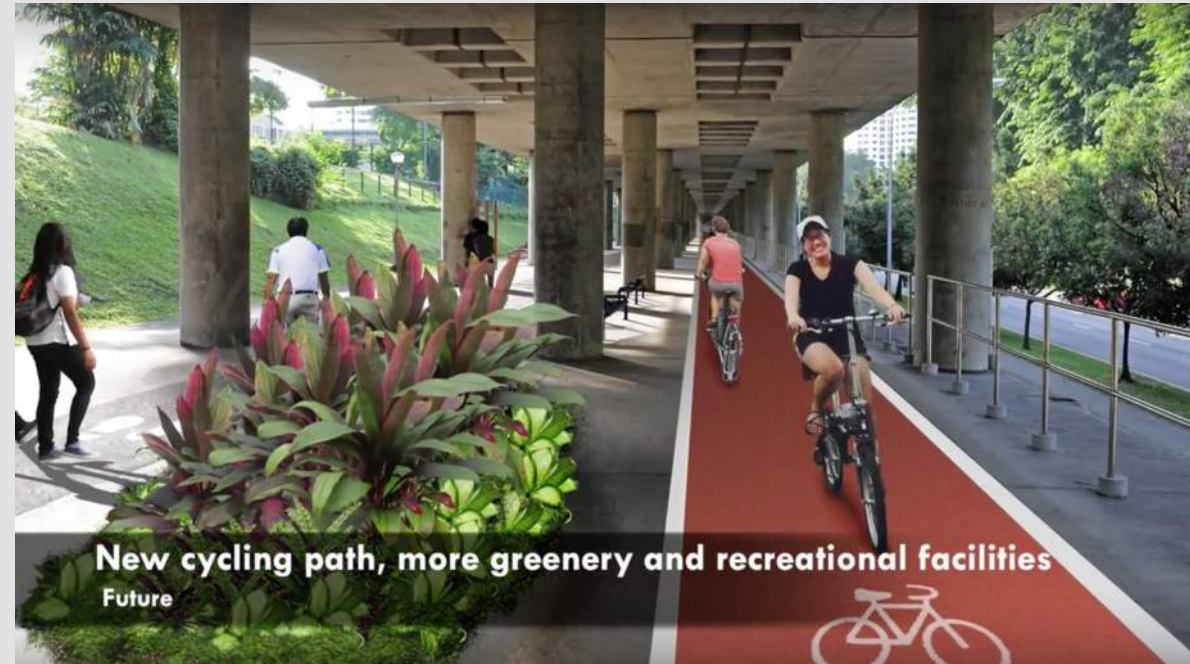


CYCLING EXPERIENCE IN SINGAPORE: OFF STREET

From Clementi to CBD in 62 minutes
(2016) The Straits Times. Available [here](#)



CYCLING IN SINGAPORE: FUTURE PLANS



ENGAGING VIRTUAL REALITY

Objective

To understand what is needed to make cycling viable modes of transport in Singapore

Explore VR as a research tool

Methods

Combine science, technology and design

Virtual Reality experiments

Stated preference surveys

Outcomes

Evidence-based street design recommendations

Virtual reality as a tool for transport planning



Engaging Active Mobility, Seng Poh Road (2016)

Introduction

Expert survey on cycling in Singapore

Generating and animating 3d streetscapes

Bike to to Future I

Bike to the Future II

Bike Pulse

Bike to the Future III

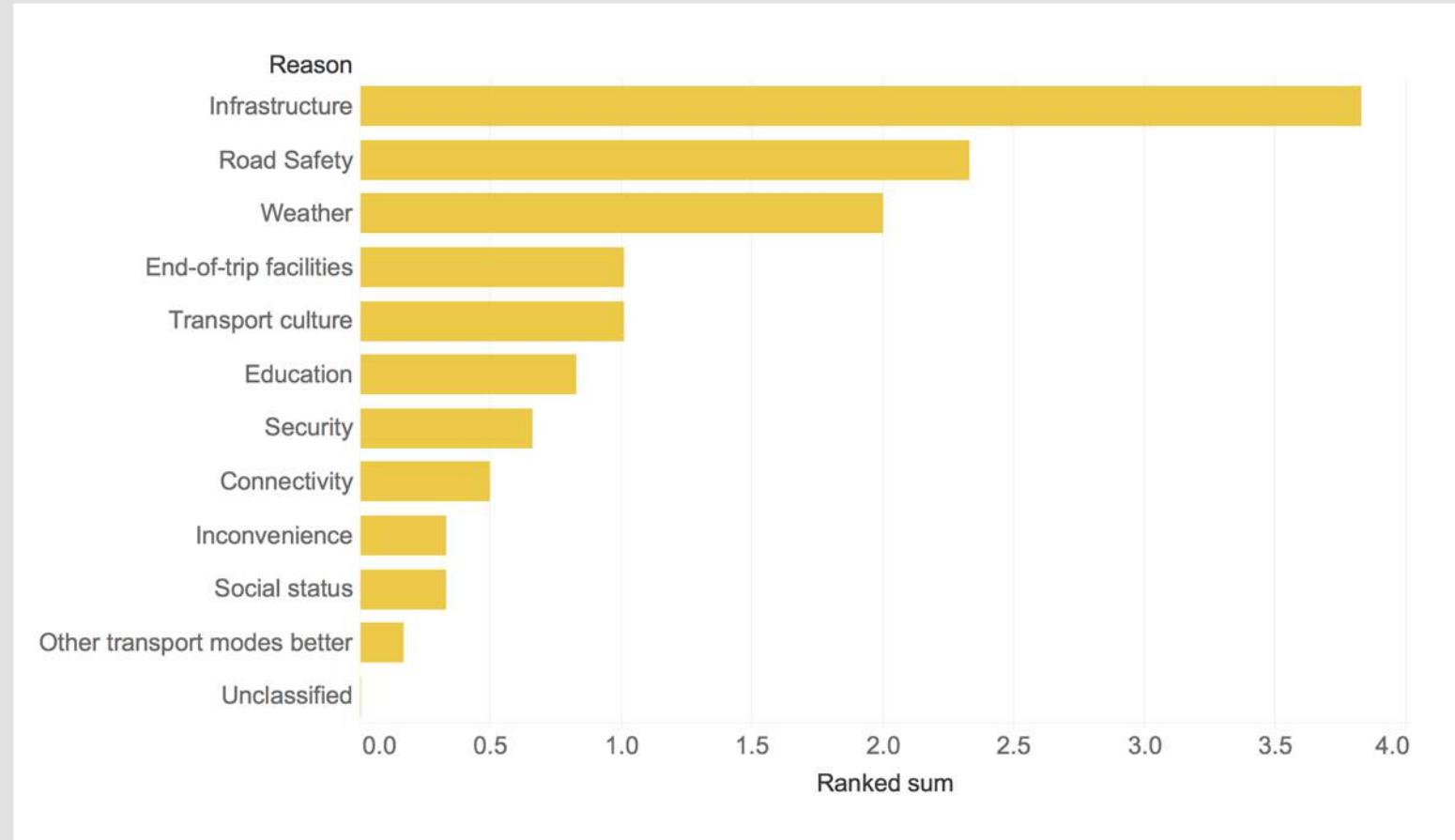
WHY ARE CYCLING ACTIVITIES SO LOW IN SINGAPORE?

Expert interviews (2016)
Source: Jonas Kupferschmid

Method

Expert interviews
Approx. 1 hour
Semi-structured
13 respondents from
government, research,
commuters & advocacy groups

Evaluation by ranked sum;
Experts were asked to state why
people are not cycling, first
mention received 0.5 points,
second mention 0.3 points, third
mention 0.2 points.



CYCLING IN THE NETHERLANDS

Michael van Eggermond (2016)
Kruisstraat, Eindhoven, the Netherlands



Introduction

Expert survey on cycling in Singapore

Generating Virtual Reality for cycling research

Bike to to Future I

Bike to the Future II

Bike Pulse

Bike to the Future III

WHY VIRTUAL REALITY?

Holistically understanding behaviour

Built environment influences perception of safety, comfort and pleasure

Challenges with cross-sectional and longitudinal surveys

Stated preference surveys for inexistent transport options, but limited reliability if people don't have any actual experience with it.

VR allows you to compose virtually any environment

How to create realistic experience?

- Eye Level Perspective
- Sense of place
- What can you see (sightlines), and who can see you (multiple agents)
- Speed, volume, proximity of moving traffic
- Idea of time? (slow spectator vs. fast spectator)
- Audio feedback
- *Temperature and humidity*
- *Effect of topography*

Rendering



Photo montage



Sketch



SURVEYS

YOUR VIRTUAL REALITY EXPERIENCE – PART 2

What did you *personally experience* in Virtual Reality?

	Not at all	1	2	3	4	5	6	7	Very much
Motion sickness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling comfortable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling excited	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Getting a realistic impression of the future situation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Given the *new design*, would you feel **SAFE** cycling along...?

	1 – not safe							7 – very safe						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Given the *new design*, would you **CONSIDER** cycling along...?

	Yourself		With a 10 year old child	
	Yes	No	Yes	No
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>


Bliss to the future survey Page 7/10

Traditional surveys

FCL Engaging Mobility, Survey conducted at Archifest (2016)

 sunny
  1:00 pm

ROUTE 1




major road, no shops, no cover, with trees

6 min walking | 2 min waiting


 overhead bridge

ROUTE 2



minor road, with shops, no cover, without trees

12 min walking

 no crossing required

Using images

Erath A, M.A.B. van Eggermond, S. Ordonez, K.W. Axhausen (Forthcoming) "Introducing the Pedestrian Accessibility Tool (PAT): Open Source GIS-Based Walkability Analysis.", Transportation Research Record

Introducing . . .

sensorama

The Revolutionary Motion Picture System that takes you into another world with

- 3-D
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- MOTION
- COLOR
- STEREO-SOUND
- AROMAS
- WIND
- VIBRATIONS



PATENTED

SENSORAMA, INC., 855 GALLOWAY ST., PACIFIC PALISADES, CALIF. 90272
TEL. (213) 459-2162

Using Virtual Reality

Heilig's Sensorama. Retrieved from [Theory and Research in HCI: Morton Heilig, Pioneer in Virtual Reality Research](#)

VIRTUAL REALITY AS A RESEARCH TOOL

Research questions

How to employ virtual reality for research

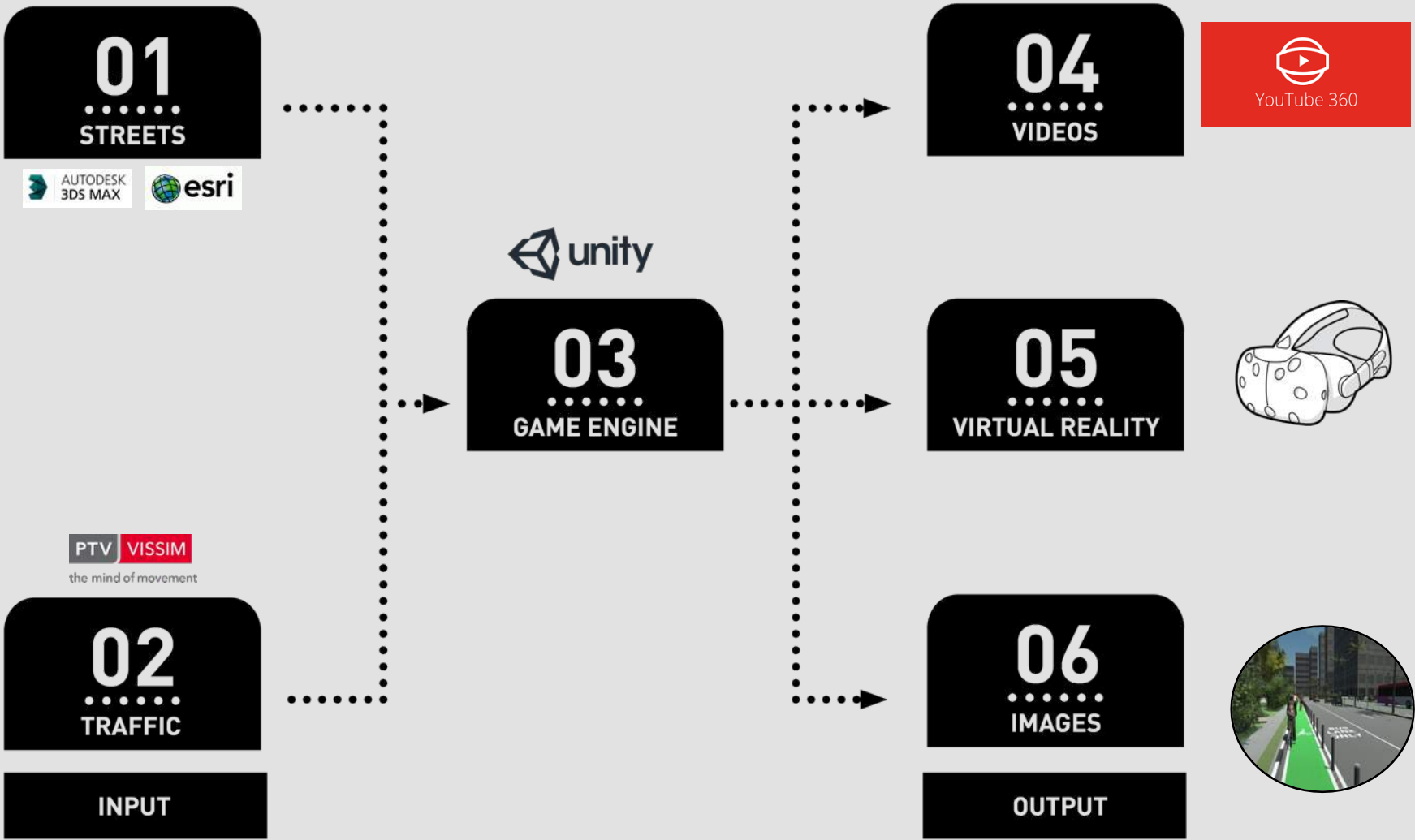
Reproducibility of real field observations

Limitations of VR in research

How can sensors of physical reactions enhance survey methods?



WORKFLOW



PROCEDURAL MODELLING OF STREETS

01

STREETS

Procedural modelling

- Computer graphics technique to create 3D models and texture from a set of rules
- Programmable visualisation saves a lot of modelling efforts
- Interactive rendering allows new applications

Complete streets rule

- Developed by ESRI Research
- Robust procedural street example that incorporates knowledge and ideas from various sources of transportation planning knowledge
- We further developed those rules to fit Singapore conditions and our modelling needs.



Code available at

https://github.com/fcl-engaging-mobility/Complete_Street_Rule

GENERATING IMAGINARY STREETS

The screenshot displays the CityEngine 2015.2 interface for a scene named "Parkour 1 high LOD.cej". The central viewport shows a perspective view of a multi-lane street with various vehicles (cars, a bus, a motorcycle), trees, and buildings. The interface includes a Navigator on the left, a Scene panel at the bottom left, and an Inspector on the right. A tooltip points to the "Type_3" attribute in the Inspector, explaining its function.

Inspector Panel:

- Name: Shape
- Shape Parameters:
 - Rules:
 - Rule File: Complete_Street.cga
 - Start Rule: Street
 - Complete_Street: Type_3
 - DISPLAY OPTL...:
 - Display_Text: true
 - Display_The...: Thematics Off
 - Solid_Color: #FFFFFF
 - Space_Mana...: Best Fit

ROAD LAYOUT Panel:

- Basic Comp...:
 - Lane_Distr: 0.54
 - Lane_Width: 2.9
 - Centerline: yellow
 - Traffic_Dir: left-hand
 - Speed_Li: 35
- Stop Markings:
 - Stop_Begin: line only
 - Stop_End: arrows on all ...
- Crosswalk M...:
 - Crosswalk: dashed
 - Begin_Cro: 3
 - End_Cross: 3
 - Crosswalk: white
 - Custom_C: Complete_Str...
 - Crosswalk: 3
 - Crosswalk: 3.73
- On-Street Pa...:
 - Right_Par: None
 - Right_Par: 0
 - Left_Parki: None
 - Left_Parki: 0
 - Parlet_Pe: -1
- CENTER SECTL...:
 - Basic Attribu...:
 - Center_Ty: Median
 - Center_Wi: 2
 - WalkWay: 0
 - Planting_a: WalkPlant
 - Boulevard: 7.1
 - Boulevard: Normal Lanes

Scene Panel:

- Search for layers, objects or attributes
- New Shapes [0 objects]
- Old Baselines [54 objects]
- Modified Baselines [246 objects]

System Information: SVY21 Singapore TM | Free Memory: 3906[MB] | 885[MB]

Vissim simulation 'Big Intersection' (2016)
Source: Jonas Kupferschmid



Challenges:

- Import of geometry
- Interaction of pedestrians and vehicles
- Modelling of cyclists
- Human (unpredictable) behaviour
- Rendering and video quality in 3D
- Shared space between pedestrians and cyclists
- Interface between Vissim and Unity3d

IMPROVING THE 3D ENVIRONMENT: FROM VISSIM TO UNITY

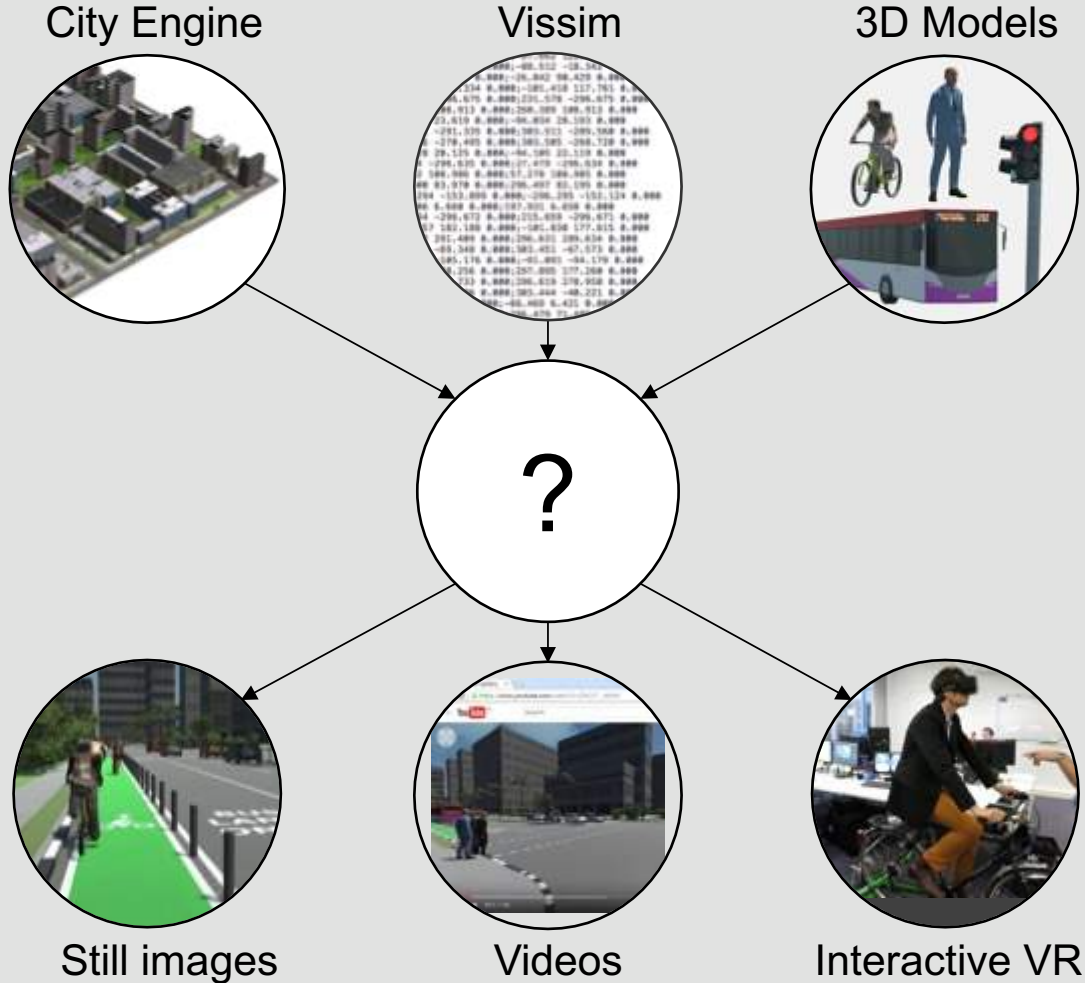
Output file with vehicle trajectories from Vissim (2016) Source: Jonas Kupferschmid

Prototype of virtual cycling environment Source: Michael Joos (2016)

```
S\VISION
* File: C:\Users\Jonas\Desktop\Vissim\Projects\SG_3D_Parkour\SG_3d_Parkour_v9.inpx
* Comment:
* Date: 27/4/2016 5:15:26 PM
* PTV Vissim: 8.00 [08]
*
* Table: Vehicles In Network
*
* SIMSEC: SimSec, Simulation second (Simulation time [s]) [s]
* NO: No, Number (Number of the vehicle)
* VEHTYPE: VehType, Vehicle type (Select Vehicle type from the list box)
* COORDFRONT: CoordFront, Coordinate front (Coordinate of front end of vehicle at the end of the time step)
* COORDREAR: CoordRear, Coordinate rear (Coordinate of rear end position of vehicle at the end of the time step)
*
* SimSec; No; VehType; CoordFront; CoordRear
*
$VEHICLE:SIMSEC:NO;VEHTYPE;COORDFRONT;COORDREAR
2000.25;589;10;-83.750 6.321 0.000;-85.494 6.650 0.000
2000.25;625;10;-86.769 6.963 0.000;-87.459 8.598 0.000
2000.25;686;10;-13.842 -296.626 0.000;-15.616 -296.626 0.000
2000.25;709;10;225.118 -296.673 0.000;223.343 -296.673 0.000
2000.25;748;10;303.509 -280.943 0.000;303.508 -279.168 0.000
2000.25;772;10;20.107 -296.633 0.000;18.332 -296.633 0.000
2000.25;789;10;-22.295 -296.624 0.000;-24.070 -296.624 0.000
2000.25;799;10;-88.512 -31.213 0.000;-88.512 -29.438 0.000
2000.25;806;10;10.151 -296.631 0.000;8.376 -296.631 0.000
2000.25;824;10;-88.512 -28.032 0.000;-88.512 -26.257 0.000
2000.25;830;10;-88.512 -13.380 0.000;-88.513 -11.605 0.000
2000.25;837;10;-87.666 124.795 0.000;-87.662 126.570 0.000
2000.25;869;10;-88.512 -20.117 0.000;-88.512 -18.342 0.000
2000.25;883;10;-28.616 90.429 0.000;-26.842 90.429 0.000
2000.25;884;21;-101.512 122.334 0.000;-101.418 117.761 0.000
2000.25;904;10;233.353 -296.675 0.000;231.578 -296.675 0.000
2000.25;908;10;262.164 108.913 0.000;260.389 108.913 0.000
2000.25;911;21;-94.087 23.619 0.000;-94.034 28.193 0.000
2000.25;924;10;303.511 -291.335 0.000;303.511 -289.560 0.000
2000.25;926;10;303.506 -270.495 0.000;303.505 -268.720 0.000
2000.25;930;22;-94.128 20.125 0.000;-94.105 22.119 0.000
2000.25;935;10;29.254 -296.635 0.000;27.479 -296.634 0.000
2000.25;946;10;59.052 108.986 0.000;57.278 108.985 0.000
2000.25;954;10;296.500 83.970 0.000;296.497 82.195 0.000
2000.25;962;10;-296.294 -153.899 0.000;-296.295 -152.124 0.000
2000.25;964;10;199.706 6.660 0.000;197.931 6.658 0.000
2000.25;968;10;217.434 -296.672 0.000;215.659 -296.671 0.000
2000.25;972;21;-101.857 182.188 0.000;-101.830 177.615 0.000
2000.25;978;10;296.633 291.409 0.000;296.631 289.634 0.000
2000.25;981;10;303.452 -69.348 0.000;303.451 -67.573 0.000
2000.25;984;33;-91.103 -105.176 0.000;-91.091 -94.179 0.000
2000.25;985;33;297.907 188.256 0.000;297.895 177.260 0.000
2000.25;992;10;296.621 280.733 0.000;296.619 278.958 0.000
2000.25;993;10;303.444 -41.996 0.000;303.444 -40.221 0.000
2000.25;994;10;-64.694 6.422 0.000;-66.469 6.421 0.000
2000.25;996;10;296.482 73.260 0.000;296.479 71.485 0.000
2000.25;998;10;296.595 256.977 0.000;296.594 255.202 0.000
2000.25;1000;33;-116.898 -5.790 0.000;-106.202 -3.238 0.000
2000.25;1001;10;-5.674 -296.628 0.000;-7.449 -296.627 0.000
2000.25;1002;22;-77.301 -5.266 0.000;-75.501 -5.266 0.000
2000.25;1005;10;-72.799 6.415 0.000;-74.574 6.414 0.000
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2000.25;1009;10;296.528 195.216 0.000;296.526 193.441 0.000
2000.25;1010;10;-206.204 -286.368 0.000;-206.206 -284.502 0.000
```



PUTTING ALL TOGETHER



Input

- City Engine: procedural city 3D models
- Vissim: vehicles, cyclists, pedestrians and lights simulation data
- Other 3D models: vehicles, pedestrians, street furniture, traffic lights, etc.

Output

- High visual quality renderings for presentations and surveys
- Videos of moving traffic in 3D environment.
- 360 videos for immersive VR experience
- Interactive VR application with real-time traffic reaction

PUTTING IT TOGETHER: SCRIPTS

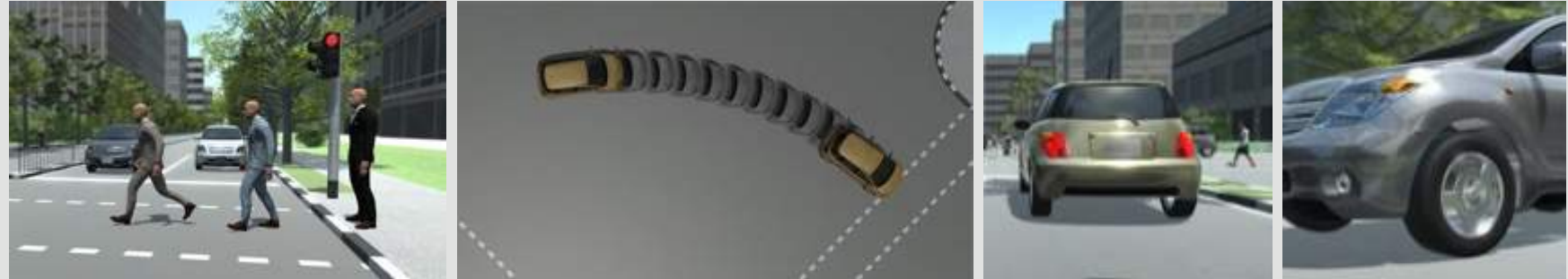
Traffic Data

- Interpret Vissim's traffic data
- Traffic lights system
- Traffic diversity generator



Animation

- Pedestrian adaptive movement
- Vehicle trajectory smoothing
- Vehicle brake lights
- Vehicle wheel rotation
- Animated cyclist



Code available at

<https://github.com/fcl-engaging-mobility/UnityScripts>

SOME PAPERS AND BLOG POSTS

Erath, Alexander, Tanvi Maheshwari, Michael Joos, Jonas Kupferschmid and Michael A. B. van Eggermond (2017). 'Visualizing Transport Futures: The Potential of Integrating Procedural 3d Modelling and Traffic Micro-Simulation in Virtual Reality Applications for Transport Planning', in *2017 Annual Meeting Compendium of Papers*, paper presented at 96th Annual Meeting of the Transportation Research Board, Washington D.C.

Maheshwari, Tanvi, Jonas Kupferschmid, Alexander Erath and Michael Joos (2016). 'Virtual Reality as a Tool to Assess Perception of Safety and Comfort for Cyclists in Singapore', paper presented at Great Asian Streets Symposium, Singapore.

Joos, Michael, Alexander Erath and Jonas Kupferschmid (2016). 'Gussy up Vissim with the Rendering Power of a Game Engine'. [Engaging Mobility Blog](#).

Kupferschmid, Jonas and Alexander Erath (2016). 'How to Model Pedestrians and Cyclists Interactions with out-of-the-Box Features of Vissim? [Engaging Mobility Blog](#).

VISUALIZING TRANSPORT FUTURES

THE POTENTIAL OF INTEGRATING PROCEDURAL 3D MODELLING AND TRAFFIC MICRO-SIMULATION IN VIRTUAL REALITY APPLICATIONS

Page No. 17-0452

Alexander Erath, Tanvi Maheshwari, Michael Joos, Jonas Kupferschmid, Michael van Eggermond
Future Cities Laboratory, Singapore ETH Centre
Corresponding author: erath@futurecl.ethz.ch

BACKGROUND
Visualization plays an important role in transportation planning to communicate plans and policies that support urban transport systems. These plans and policies should be based on a single reality: movement of people in the urban environment. However, visualization and simulation are often used in very vague or inconsistent ways. Each expert tends to work in their own way, usually in a 2D environment. This can lead to misunderstandings and errors in the design of the urban environment and in the way it is used. Visualization is a key tool to support the design of the urban environment and in the way it is used.

VR IN TRANSPORT PLANNING
The visualization of transportation future street designs (e.g. health, performance, phenomenology, usage or simulation value, future and ongoing use) is essential in the field of Virtual Reality (VR). VR offers new possibilities for general practitioners and scientific insights by allowing the user to immerse in the future environment. What are the potential use cases of Virtual Reality in transportation research and planning?

BEHAVIOURAL EXPERIMENTS
Modeling and testing is a multi-sensory experience which includes vision, auditory, somatosensory, olfactory and vestibular sensory information. Understanding how to understand the perception of each sense input design options based on specific processes can be interesting. Using Virtual Reality (VR) is a well-established methodology in the field of user experience design. Although there are several limitations in VR, such as lower resolution, low refresh rate and low latency, VR offers unique opportunities for user-centred design. VR experiments have successfully been conducted in various fields of user experience design.

STATED PREFERENCE SURVEY
The testing of new infrastructure plans and policies of transportation planning is essential to assess the impact of the urban environment on public choice. However, experimental variables is limited to the real world and the results of the findings is often restricted to features of the built environment that can be tested. Since the introduction of virtual reality and virtual worlds, the field of user experience design has opened new opportunities to generate realistic 3D scenarios that are suitable for behavior studies.

COMMUNICATION AND PUBLIC ENGAGEMENT
A common goal of transportation planning and policy is to improve the quality of the urban environment. This is often achieved by the visualization of the urban environment. The visualization of the urban environment is often achieved by the visualization of the urban environment. The visualization of the urban environment is often achieved by the visualization of the urban environment.

DRIVING SIMULATOR
Driving simulators have been used in transport research since the 1960s to study driver behavior and traffic interactions with other road users. Recently, there has been a growing interest in driving simulators for applications in the area of road safety and traffic planning. Using computer-generated environments allows for a high degree of control and flexibility in the design of the urban environment and allows for applications for research, for example to study the perception and mental physical models that influence driver design and traffic operation systems (e.g. traffic control).

INPUT
Modelling Streets
Procedural Modelling
The City Engine is a 3D modelling software application developed by ESR and ESR Zurich, that uses a procedural approach for this research. The ESR's Computer Science team has used it to generate various scenarios of transportation planning knowledge including MACTO, MACTO and MACTO scenarios. The goal of the tool is to represent a diversity of street configurations, to support multi-scale planning in urban areas.

Geometric Modelling
Procedural modelling offers a degree of generality that is not possible with traditional modelling. This method poses several limitations. Modelling urban street configurations procedurally is a challenging task as it requires a large amount of data. Therefore we implement procedural modelling with geometric modelling for unique cases.

Modelling Traffic
Traffic micro-simulation simulates the behavior of vehicles, bicycles and pedestrians. For this research project we use PTW Vissim as the main engine of the traffic simulation. The visualization of the urban environment is often achieved by the visualization of the urban environment. The visualization of the urban environment is often achieved by the visualization of the urban environment.

THE PIPELINE
Integration in Game Engine
To explore the potential of integrating virtual reality applications for transportation research and planning, we propose a software pipeline that integrates City Engine procedural 3D modelling, 3DS Max (geometric modelling) PTW Vissim traffic micro-simulation in Unity (game engine) supporting wearable output formats and applications.

We chose to use Unity to combine both, interact with the environment and present that experience in a VR head-mounted display (HMD) because of its visual capabilities. VR support, simple design of the interface and ease of use in the game engine data sets from Unity (game engine) in 2015. To combine a VR interface experiment we have to use the pipeline and use user testing in Unity back to the beginning of the pipeline. This structure leads to an experimental phase, and since both performance demand high levels of CPU usage.

OUTPUT
Virtual Environment
Videos
Images

CASE STUDY
Bike to the Future
In order to understand what would make Singapore more walkable and cycleable, and given the low popularity of cycling in Singapore, we used VR to make people understand better the impact of new design and planning interventions. On 10th October 2016, a parking lot in the Tanglin neighbourhood showcased what being a bike rider might be like in the future if it were implemented. The experience was a success.

Future Case Studies
Bike Pulse
Using the Computer Street Race we can automatically generate realistic 3D models of streets in different design configurations quickly. The learning of this capability we developed an experimental design for a stated preference survey enabling a set of variables with related attributes (e.g. based on the table below).

Variable	Value
Street width	10m
Street width	12m
Street width	14m
Street width	16m
Street width	18m
Street width	20m
Street width	22m
Street width	24m
Street width	26m
Street width	28m
Street width	30m
Street width	32m
Street width	34m
Street width	36m
Street width	38m
Street width	40m
Street width	42m
Street width	44m
Street width	46m
Street width	48m
Street width	50m
Street width	52m
Street width	54m
Street width	56m
Street width	58m
Street width	60m
Street width	62m
Street width	64m
Street width	66m
Street width	68m
Street width	70m
Street width	72m
Street width	74m
Street width	76m
Street width	78m
Street width	80m
Street width	82m
Street width	84m
Street width	86m
Street width	88m
Street width	90m
Street width	92m
Street width	94m
Street width	96m
Street width	98m
Street width	100m

CONCLUSION AND OUTLOOK
In any field of application, it will be important to change development from VR applications into the existing methodological gaps or lead to more effective and efficient study designs. It will be important to conduct qualitative studies to understand the added value of VR and identify the research factors related to the perception and relative value of VR, as we prepared with the Parking Day case study.

We saw some potential for the use of VR to research based on procedural design models. However, VR-based interactive design models could help to understand the dynamics and dimensions of road infrastructure better. For example, users and customers to change in self-perception and the behavior of other road users could be studied in controlled experiments. Furthermore, with VR we can also experience the perspective of other road users.

An immersive virtual environment become a more accessible technology, the practical applications are fast regarding better traditional planning methods. Transportation planning, as we have discussed, is one such domain. While that experience can come to more qualitative and quantitative methods of transportation planning, VR is an additional tool, with unique advantages and particular limitations. These limitations are not to be overly concerned, but rather to be identified and addressed. The case studies presented in this paper help to further clarify the applications and potentials in this regard.

Acknowledgments
Research conducted in the Future Cities Laboratory is funded by the Singapore Government and the Swiss Government.

ETH zürich **CREATE** (FCL) FUTURE CITIES LABORATORY 未来城市实验室 (SIC) SINGAPORE ETH CENTRE 新加坡-ETH 研究中心

Introduction

Expert survey on cycling in Singapore

Generating Virtual Reality for cycling research

Bike to to Future I

Bike to the Future II

Bike Pulse

Bike to the Future III

BIKE TO THE FUTURE I

Explore how to use VR as a research tool

Redesign three streets around Tiong Bahru Market to accommodate cycling infrastructure.

Invite people to cycle on these three different streets designed for active mobility in Virtual Reality

Engage and get feedback on how **safe** and **comfortable** they feel cycling given the new design.

Leverage on existing 3D models and Park(ing) Day

3D Model



before



after

TIONG BAHRU: TRAFFIC CIRCULATION

Current



New design



DESIGN: STREETS

Current

3D rendering with traffic

New design with traffic

Lim Liak Street



Kim Cheng Street



Seng Poh Road



BIKE TO THE FUTURE I - EVENTS

1

16 Sep 2016
Park(ing) Day
Tiong Bahru

2

5 Oct 2016
Archifest
Raffles Place

3

19-21 Oct 2016
SITCE Conference
Suntec Convention Center

4

26 Mar 2017
Car-free Sunday
Telok Ayer Street



BIKE TO THE FUTURE I – UNEXPECTED MEDIA ATTENTION

Using virtual reality to get more people to cycle

Researchers Mohsen Nazami (left) and Jonas Kupferschmid will get feedback from participants. PHOTO: TIFTANY OOH FOR THE STRAITS TIMES

PUBLISHED: SEP 17, 2016, 5:00 AM SGT

Donning a pair of virtual reality (VR) goggles and pedalling a bicycle in Lim Liak Street, Ms Pamela Cheng, 19, "cycled" the perimeter of Tiong Bahru market.

But it was not the usual roads the university undergraduate was used to. Rather, in two minutes, she found herself "cruising" through a virtual path along Kim Cheng Street, and "riding" through a new area which was formerly Seng Poh Road - both in Tiong Bahru.

Ms Cheng was one of 150 people who yesterday tested out the virtual reality (VR) simulator put together by the Future Cities Laboratory (FCL), which is using VR to learn how street design can encourage more people to cycle in Singapore.

Using virtual reality to envision a car-lite future

By Olivia Song, Channel NewsAsia | Posted 05 Oct 2016 22:38 | Updated 05 Oct 2016 23:23

The virtual reality bicycle set up at Raffles Place to allow visitors to explore the streets of an alternative Tiong Bahru. (Photo: Olivia Song)

SINGAPORE: Visitors to this year's Archifest got a chance to explore the streets of an alternative Tiong Bahru, redesigned for cyclists and pedestrians, using virtual reality on Wednesday (Oct 5).

Bike to the Future, an exhibit by Future Cities Laboratory (FCL), was returning for its second run at the annual public architecture festival after its launch at PARK(ing) Day 2016 last month.

Using virtual reality goggles and a stationary bike, the set-up at Raffles Place gave participants a glimpse into an alternative future for the neighbourhood featuring bike-friendly features such as special road signs, dedicated cycling paths and a new town square closed off to cars.

Channel NewsAsia · 9 October 2016 · 4

BIKE TO THE FUTURE: A virtual reality exhibit that lets you cycle through the streets of an alternative, bike-friendly Tiong Bahru. More: <http://bit.ly/2dnpd7A> (Video: Olivia Song)

179 Likes · 4 Comments · 50 Shares

Kevin Sin, Kelvin Lee, Zae Min Oo and 176 others like this.

Emmeline Ong Anayah Mohd Nooh Jilyn Koh Claire Chin · 9 October 2016 at 03:58

Shahul Hameed Sharmuga Sundaram · 9 October 2016 at 03:14

Terence Wee Yung Koh Joey Ray · 1 · 8 October 2016 at 04:30

To see more from Channel NewsAsia on Facebook, log in or sign up.

Smart Cities 2.0 - EP4 Singapore

21 min

By Channel NewsAsia | Published: 25 Mar 2017 | Audio: English

Singapore has achieved stunning economic growth in just over 50 years, and now, the city-state is setting its sights on the next frontier - becoming a smart nation. Jason Pomeroy finds out how Singapore is turning to data and technology to tackle the persistent problems of city living.

Be The First To Comment

More From Channel NewsAsia

360 DEGREE VIDEO

You can watch the video [here](#)

Use Google Card Board for a VR experience



04
VIDEOS



(FCL) FUTURE
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未来
城市
实验室

SURVEY DESIGN

Would you **consider cycling along**

Segment 1: Lim Liak Street

Yourself
 Yes No

With a 10 year old child
 Yes No

Segment 2: Kim Cheng Street

Yourself
 Yes No

With a 10 year old child
 Yes No

Segment 3: Seng Poh Road

Yourself
 Yes No

With a 10 year old child
 Yes No

Bike to the future survey Page 3/10



YOUR VIRTUAL REALITY EXPERIENCE – PART 2

What did you **personally experience** in Virtual Reality?

	Not at all	1	2	3	4	5	6	7	Very much
Motion sickness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling comfortable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling excited	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Getting a realistic impression of the future situation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Given the **new design**, would you feel **SAFE** cycling along...?

	1 – not safe	2	3	4	5	6	7 – very safe
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Given the **new design**, would you **CONSIDER** cycling along...?

	Yourself		With a 10 year old child	
	Yes	No	Yes	No
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Bike to the future survey Page 7/10

Pre-survey

- Sociodemographics
- Habits and attitudes towards cycling
- Willingness to cycle with today's infrastructure

VR-Experiment

- Think aloud protocol (What do you see?)
- Physical reactions (pedalling, steering, turning head, braking)

Post-survey

- Willingness to cycle with new infrastructure
- VR Experience (realism, motion sickness, comfort, excitement)

SURVEYS

YOUR VIRTUAL REALITY EXPERIENCE – PART 2

What did you *personally experience* in Virtual Reality?

	Not at all	1	2	3	4	5	6	7	Very much
Motion sickness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling comfortable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling excited	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Getting a realistic impression of the future situation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Given the *new design*, would you feel **SAFE** cycling along...?

	1 – not safe							7 – very safe						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Given the *new design*, would you **CONSIDER** cycling along...?

	Yourself		With a 10 year old child	
	Yes	No	Yes	No
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Bliss to the future survey Page 7/10


Traditional surveys

FCL Engaging Mobility, Survey conducted at Archifest (2016)

sunny

1:00 pm

ROUTE 1



major road, no shops, no cover, with trees

6 min


walking

2 min

waiting

overhead bridge

ROUTE 2



minor road, with shops, no cover, without trees

12 min

walking

no crossing required

Using images


Erath A, M.A.B. van Eggermond, S. Ordonez, K.W. Axhausen (Forthcoming) "Introducing the Pedestrian Accessibility Tool (PAT): Open Source GIS-Based Walkability Analysis.", Transportation Research Record

Introducing . . .

sensorama

The Revolutionary Motion Picture System that takes you into another world with

- 3-D
- WIDE VISION
- MOTION
- COLOR
- STEREO-SOUND
- AROMAS
- WIND
- VIBRATIONS



PATENTED

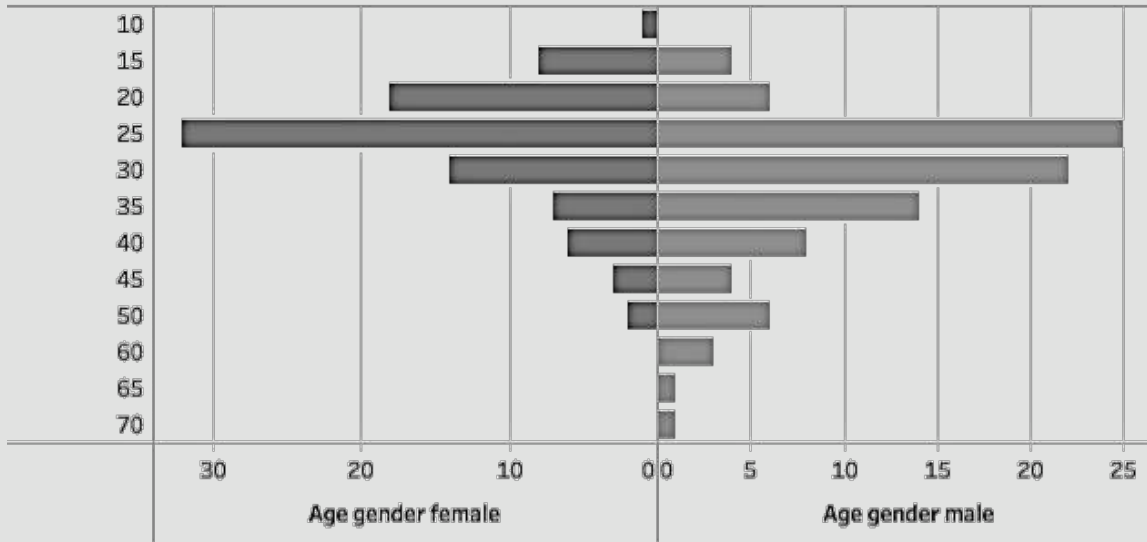
SENSORAMA, INC., 855 GALLOWAY ST., PACIFIC PALISADES, CALIF. 90272
TEL. (213) 459-2162

Using Virtual Reality

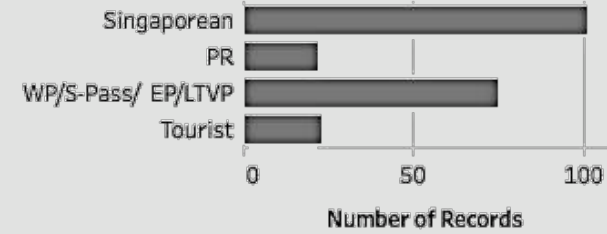
Heilig's Sensorama. Retrieved from [Theory and Research in HCI: Morton Heilig, Pioneer in Virtual Reality Research](#)

Descriptive statistics

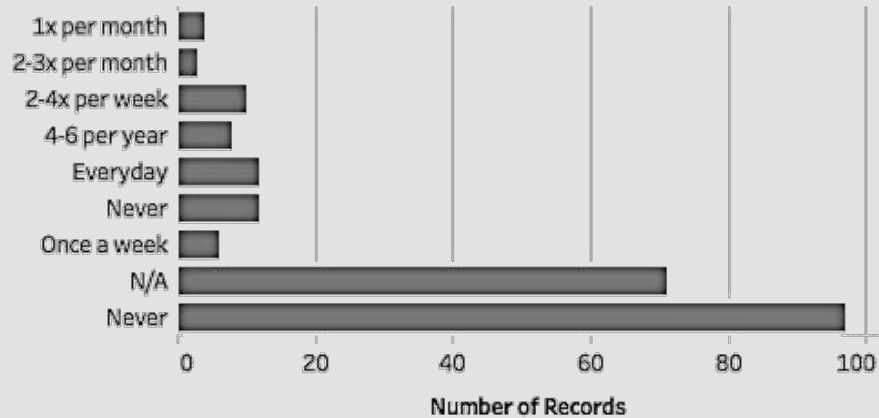
Age pyramid



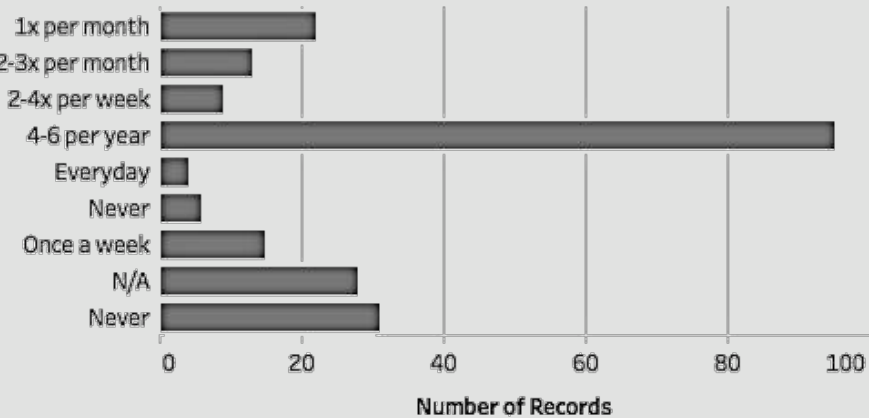
Residence status



Cycling commute



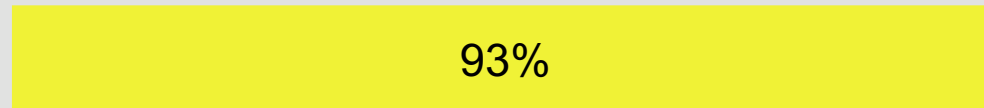
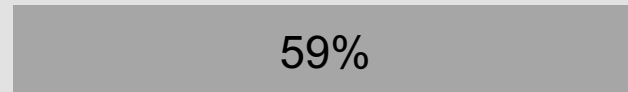
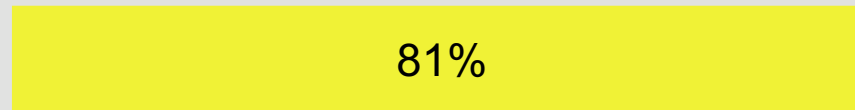
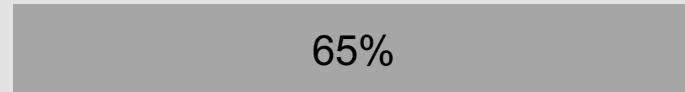
Cycling leisure



RESULTS – WILLINGNESS TO CYCLE

YES, I would consider cycling on this road

Before



After



RESULTS – WILLINGNESS TO CYCLE

YES, I would consider cycling on this road with a 10 year old

Before



10%

44 %



11%

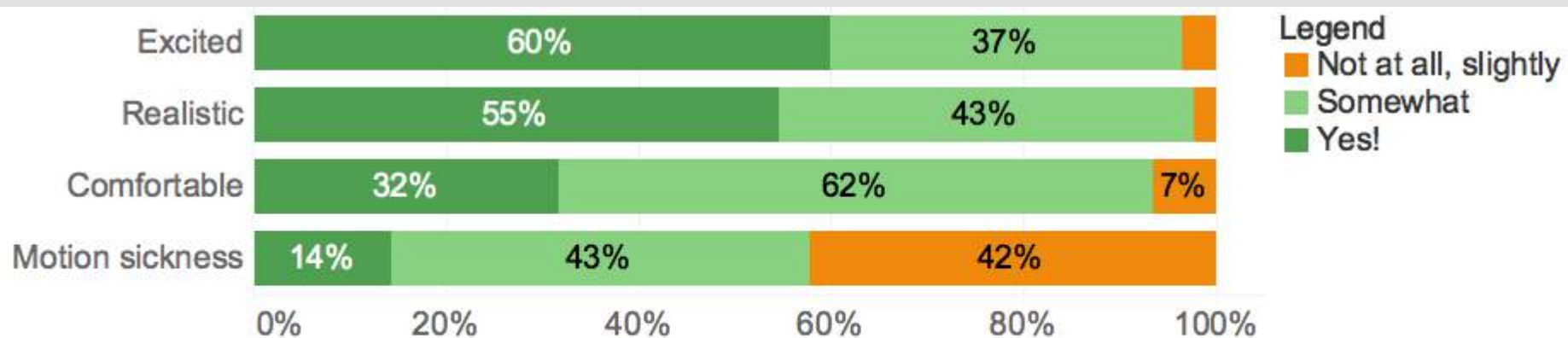
74%

After



RESULTS – VIRTUAL REALITY EXPERIENCE

Did you experience the following?



MOST MEMORABLE EXPERIENCE

'Pedestrians interacting with bicyclists'

'Realistic feeling that pedestrians were about to walk in my way'

Simulation

'Good design of surroundings in 3D. Pedestrians are not paying attention to me'

'That the brakes didn't work was very irritating.'

'Steering was hard'

Hardware

'Brakes not working'

Design

'That I was not competing with cars for road space'

'The new bicycle lane is very good for cyclists. I like it very much. It reduces conflict between types of commuters.'

'Three different designs give us different ideas and impressions. Good experience. Thank you. Personally I prefer segment 2.'

'Pleasant experience to see a car free area that will ultimately be greener, less polluted and more kids/people friendly.'

FINDINGS

VR really helps to communicate the experience of future street designs

- Better sense of place
- Respondents naturally look around
- Plenty of physical reactions
- Creates excitement and a lot of media attention

Limits of VR

- Tremendous amount of work
- People get motion sick
- Tremendous amount of work
- Time intensive
- 360 video is not enough for immersive experience

On which level you try to understand cycling behaviour?

- Willingness to cycle
 - > stated preference probably better suited
- Perception of safety, comfort and pleasure
 - > Behavioral reactions rather than survey

Introduction

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Bike to to Future I

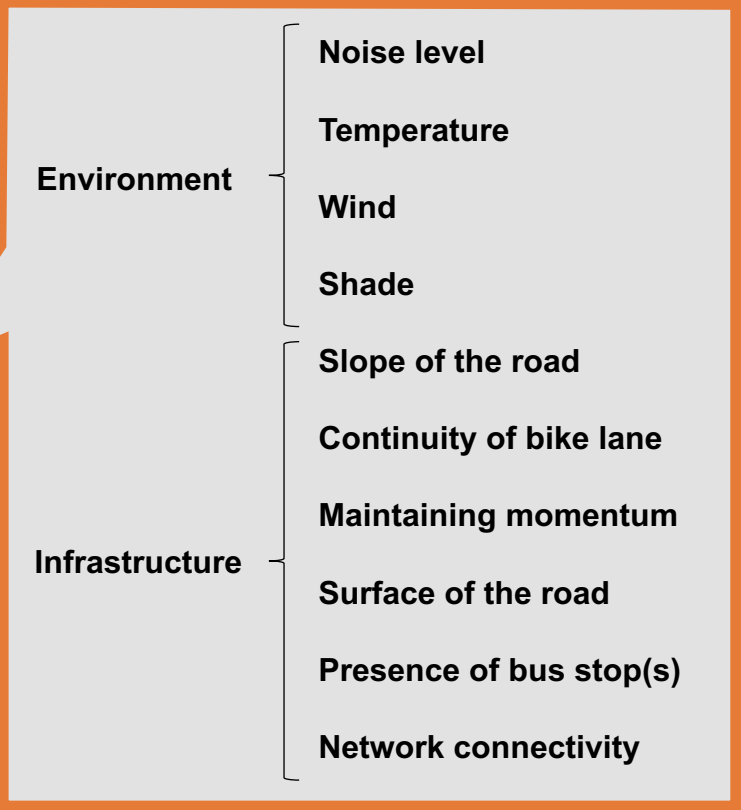
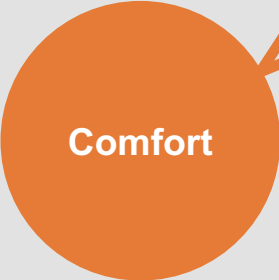
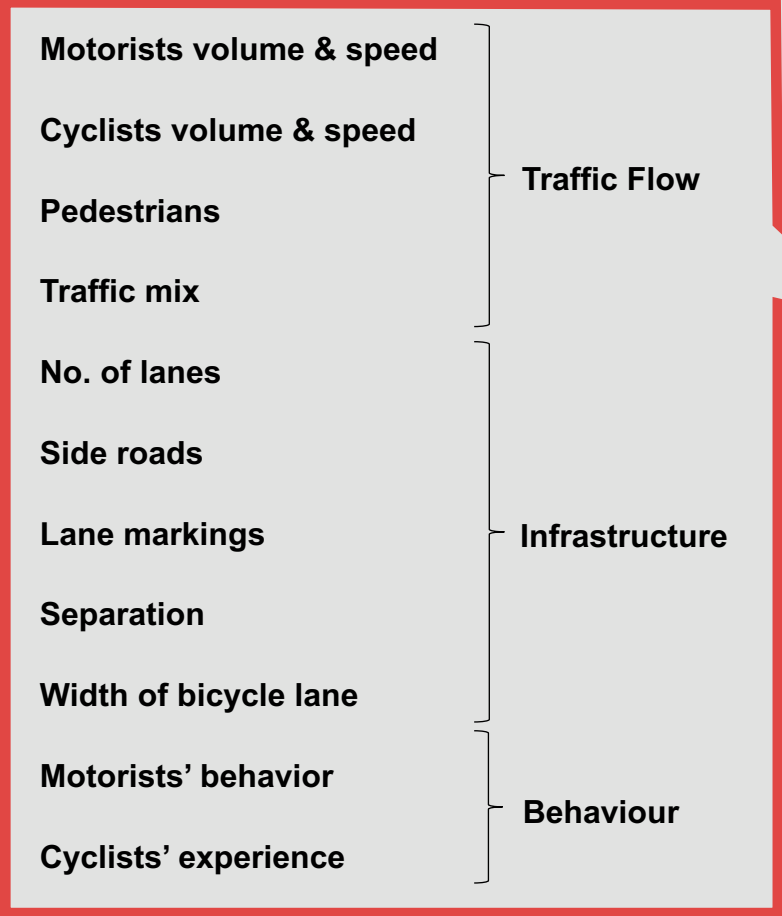
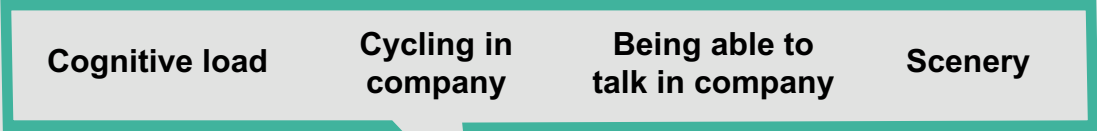
Bike to the Future II

Bike Pulse

Bike to the Future III

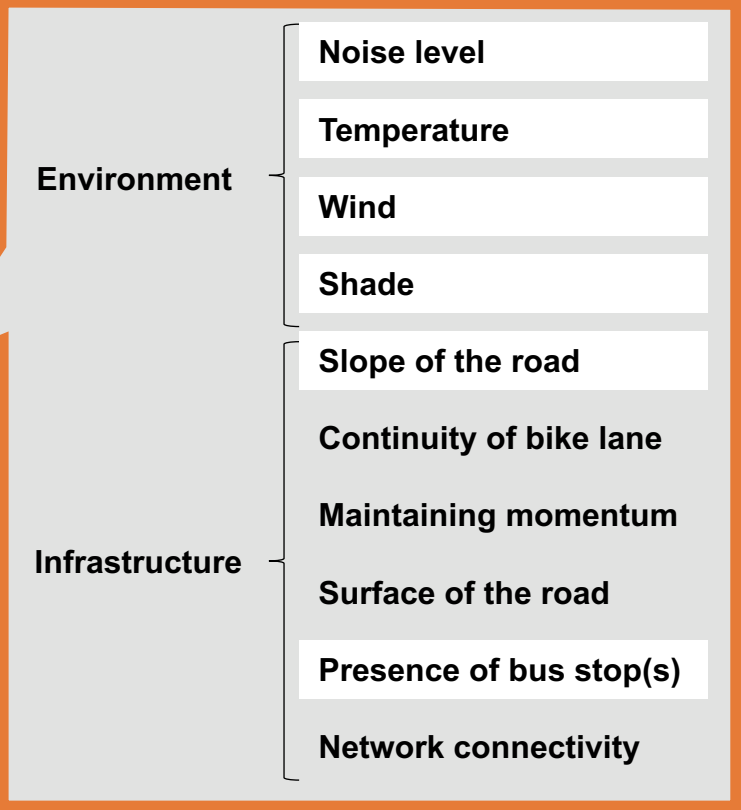
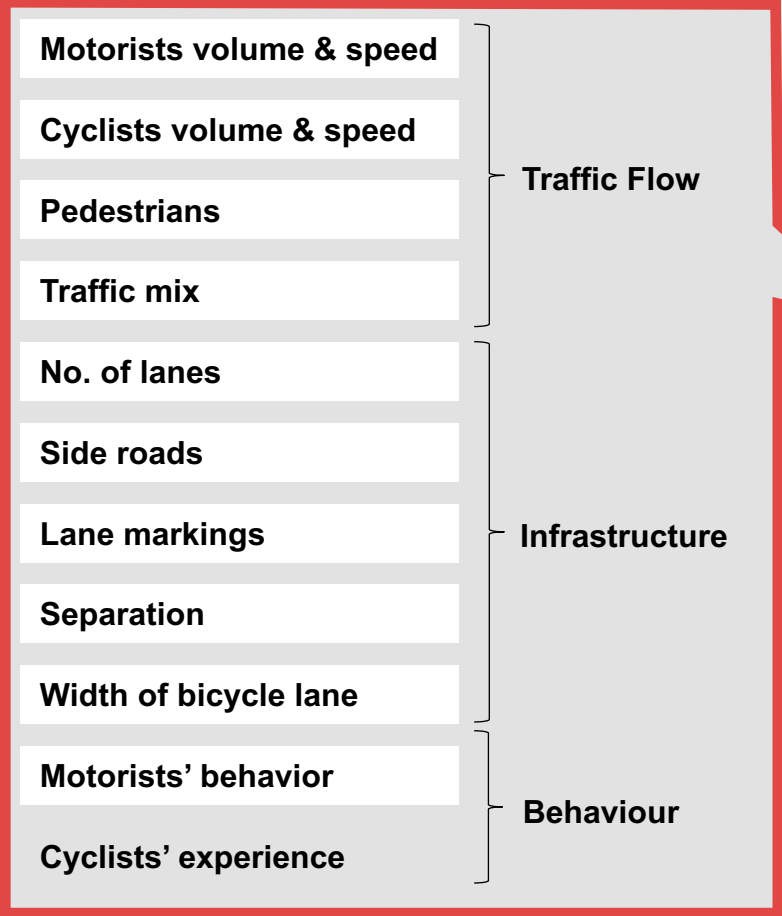
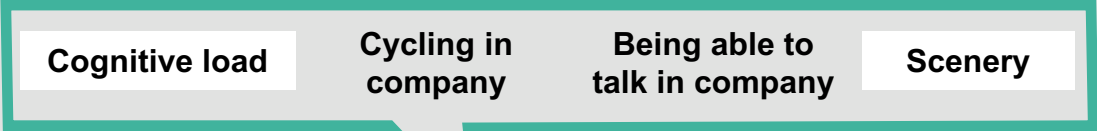
MEASURING SAFETY, COMFORT & PLEASURE

LITERATURE REVIEW



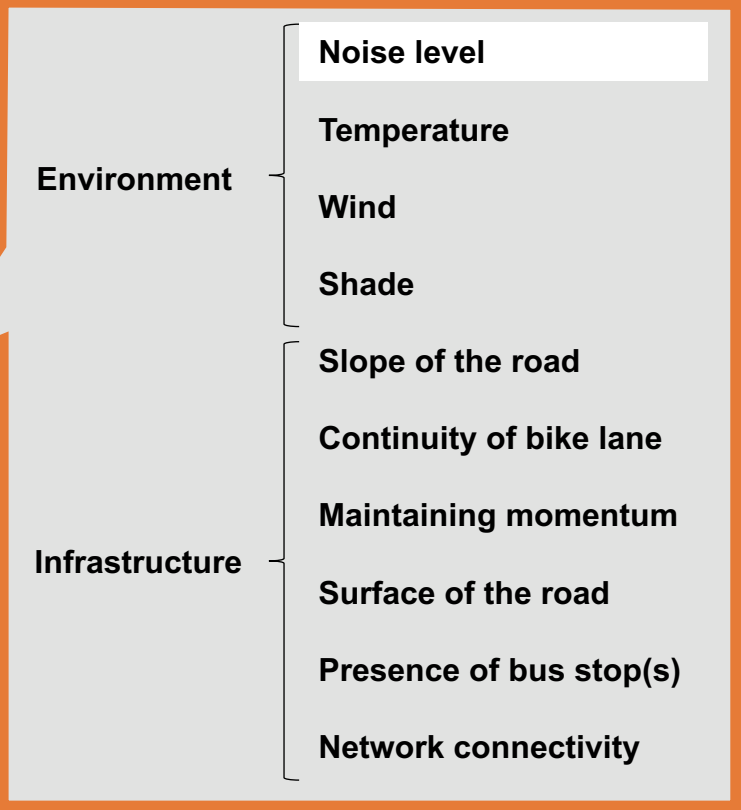
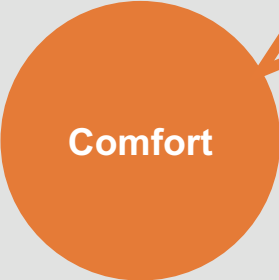
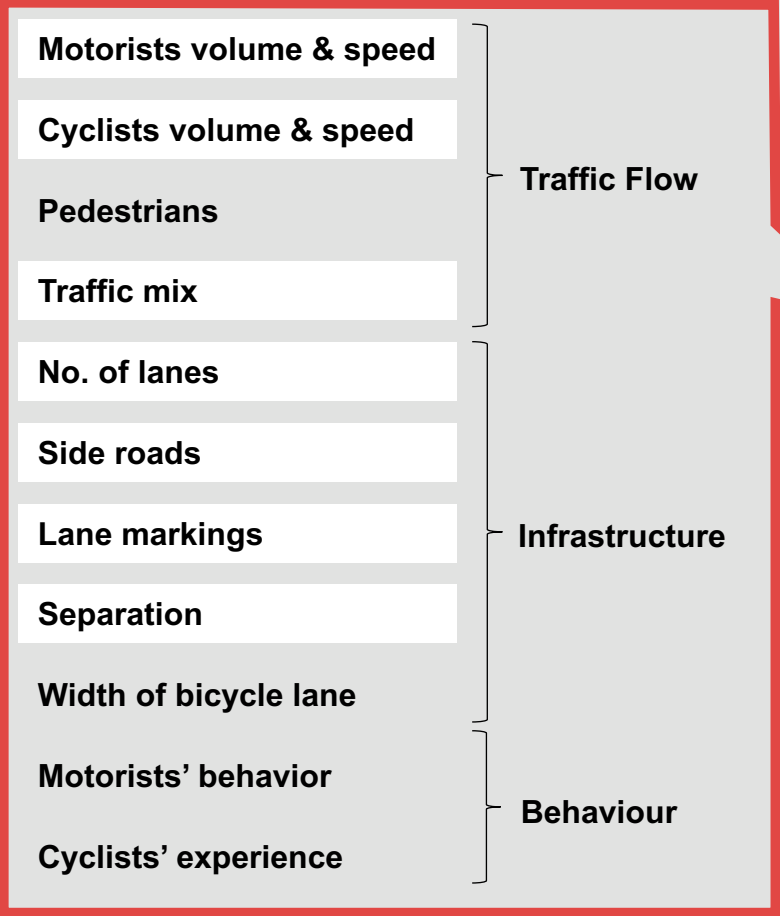
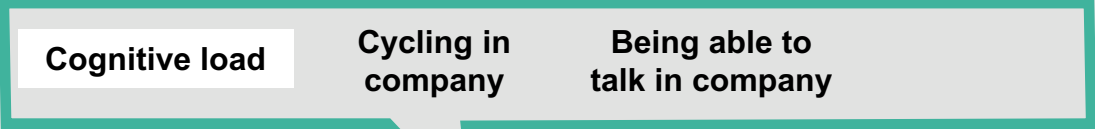
MEASURING SAFETY, COMFORT & PLEASURE

Feasibility with Bicycle Simulator



BIKE TO THE FUTURE II

Controlled Experiment



BIKE TO THE FUTURE II

Aim

Measure cyclists' perception of safety, comfort & pleasure in a controlled environment

Methodology

Development of interactive cycling simulator

Test impact of various stressors and mitigation strategies

Trigger traffic events (conflicting traffic)

Sensing of physical reactions (head movement, pedalling, steering, braking)

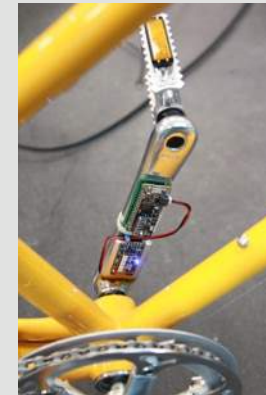
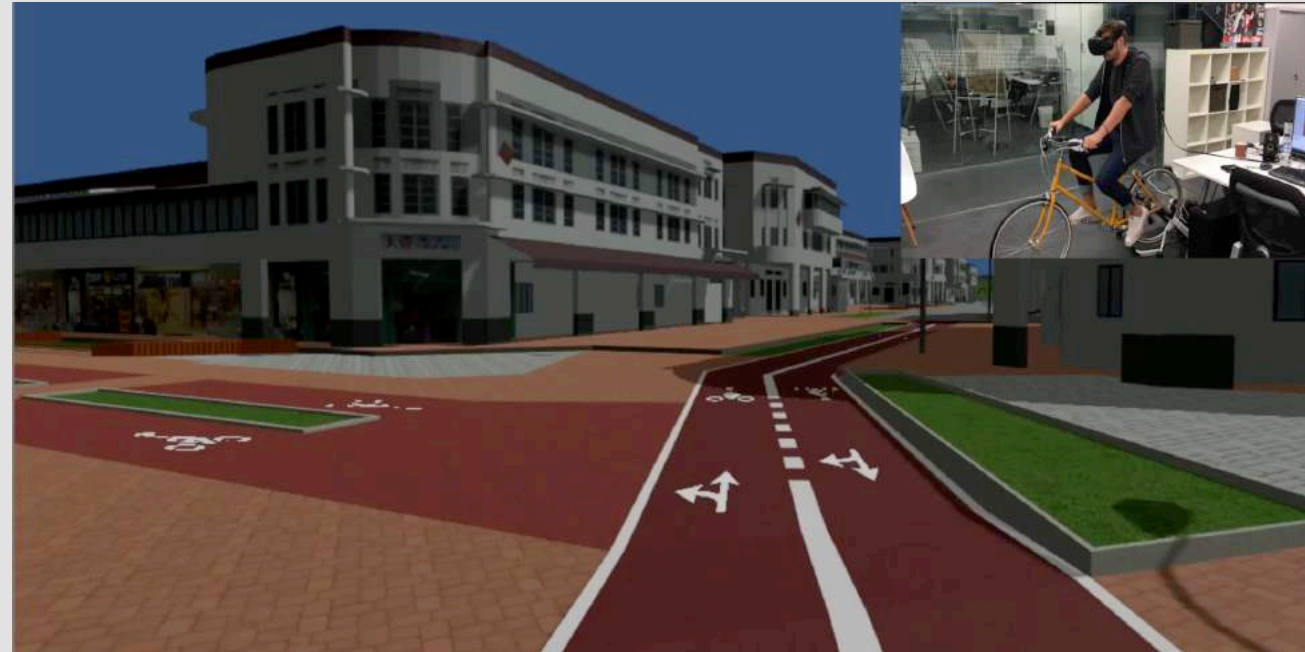
Before / after experiment surveys

Outcomes

Insight in the perception of safety for different design options

Evidence-based design guidance

Realizing strength and limitations of using virtual reality



EXPERIMENT SETUP

Research questions

Which distance and separation to vehicles works best is needed to feel safe?

Any differences of perception in VR with regards to speeds, (passing) distance, noise

Can we observe the same physical reactions in VR as in reality?



Experiment Design

2 Road types

- 4 lane, bi-directional
- 2 lane, bi-directional

Treatments:

- Traffic
 - Speed
 - Volume
 - Mix
 - passing distance
- Separation
 - None
 - Paint
 - Planter
 - Poles
- Conflicting traffic

Road segments stretch over about 700m

Warm-up cycling with out traffic (3-5min)

Measurements

Physical reactions:

- Head movement
- Steering
- Braking
- Pedalling
- Cognitive load
- Reaction times (incoming traffic)
- Cycling speed

Pre-/post survey

- Experience with cycling
- Attitudes
- Stated levels of safety, comfort, pleasure



FIRST OUTCOME

Schramka, Filip, Stefan Arisona, Michael Joos and Alexander Erath (2017). 'Development of Virtual Reality Cycling Simulator', in *3rd International Conference on Virtual Reality*, paper presented at 3rd International Conference on Virtual Reality, Hong Kong.

Code available here:

<https://github.com/fcl-engaging-mobility>

Development of a Virtual Reality Cycling Simulator

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Manuscript submitted March 26, 2017; accepted April 13, 2017

doi:

Abstract

This paper presents a cycling simulator implemented using consumer virtual reality hardware and additional off-the-shelf sensors. Challenges like real time motion tracking within the performance requirements of state of the art virtual reality are successfully mastered. Retrieved data from digital motion processors is sent over Bluetooth to a render machine running *Unity3D*. By processing this data a bicycle is mapped into virtual space. Physically correct behaviour is simulated and high quality assets are added to create a full immersive virtual reality experience. Our whole source code is published under an open source licence on github. Ultimately, the cycling simulator will be used for behavioral studies to measure how different street design configurations and traffic levels impact perceived cycling stress level, cognitive reactions and mobility behaviour.

Index Terms

Computer graphics, simulation, game engines, human mobility, virtual reality, movement tracking

I. INTRODUCTION

Urban transport policies are shifting their focus to active modes of transportation: walking and cycling. To make these modes of transport attractive for a wide audience, transport infrastructure must cater for the needs of active mobility for a safe and comfortable cycling experience. Incorporating such infrastructure in the existing urban fabric and adapting existing street designs proves to be a considerable challenge, especially with regards to the limited available road space and budget constraints. Urban designers and transport planners who want to improve the infrastructure conditions in particular for cycling often face difficult trade-offs, since there is a lack of understanding with regards to basic questions how different road users perceive and value possible infrastructure scenarios. To address this matter the right tools need to be chosen. According to Simpson[17] creation and interaction within a three dimensional visual simulation is the key to modern urban planning. Recent research also shows that it becomes feasible to develop immersive virtual reality for spatial planning support. The advantage of these systems is the sensation of being in the environment [18]. Also can such an environment be used to measure actual perception and discuss design decisions within the scenario. By taking these factors into account we developed a functional *virtual reality cycling simulator* prototype within the environment of a state of the art game engine. New experimental street designs can easily be imported into our existing framework. Those can be enriched with additional assets and other objects provided by *Unity* to create a more realistic environment. With built-in measurement and evaluation tools proper scientific data can be extracted.

To achieve all this, a robust hard- and software framework is developed which is able to track all essential parts of the bike. Technologies like *Bluetooth Low Energy*, *Gyroscopes* and *Accelerometers* were combined into small tracking sensors. Furthermore all components achieve the performance required by state of the art virtual reality applications.

The results of our development brought us a good tool for further research. In its current state, the cycling simulator is capable of supporting behavioral studies to measure how different street design configurations and traffic levels impact perceived cycling stress level, cognitive reactions and mobility behaviour. The source code is published on github under *MIT* license [4].

II. RELATED WORK

In this section we introduce existing work in the area of bicycle simulation, followed by problems of the latest generation of virtual reality technologies and how different approaches handle them. Furthermore we introduce a theory that explains why motion sickness occurs during *VR* simulation.

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Bike to the Future II

Bike Pulse

BIKE PULSE

Wigginton Conway, M. (2015) Better Measures of Bike Accessibility, Conveyal, Available [here](#)

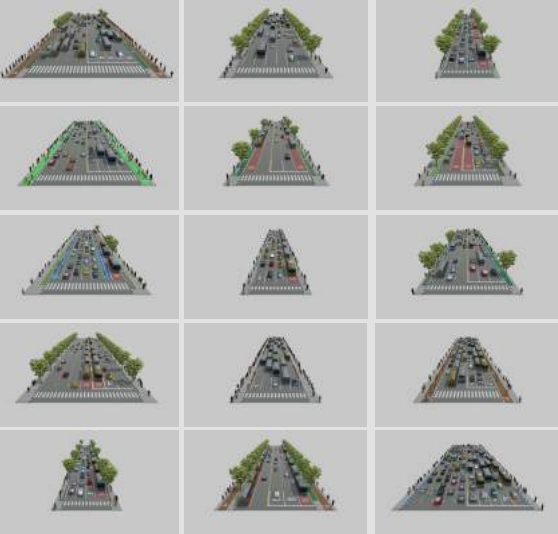
Inspiration & Vision

Web-based survey inspired by [MIT Place Pulse](#) project

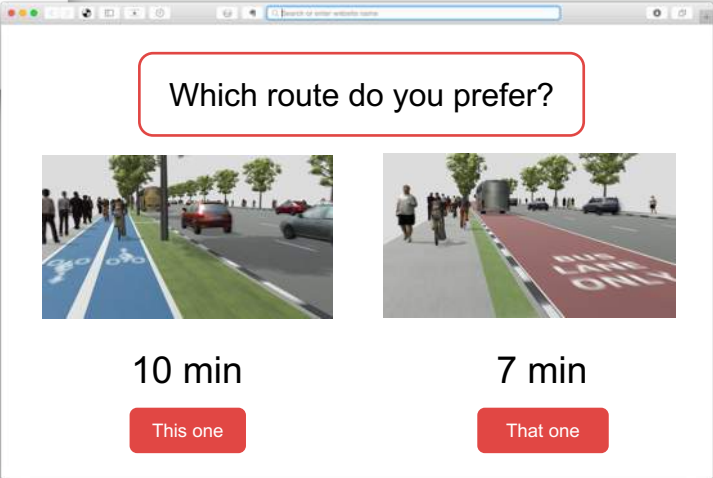
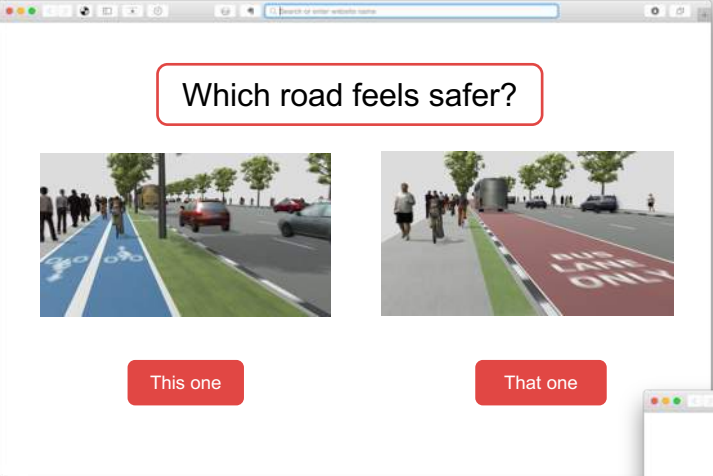
Parametrically generating hundreds of relevant street design configurations

Testing it from different view angles (pedestrian, cyclist, bus driver, car)

Choice modelling



Bike Pulse



Team



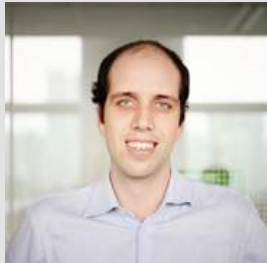
Dr. Alex Erath
Project Leader



Prof. Dr. K. Axhausen
Co-PI
Transport Planning



Prof. Dr. C. Hölscher
Co-PI
Cognitive Psychology



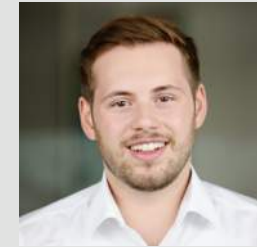
Michael v. Eggermond
Senior Researcher
Spatial Analysis



Tanvi Maheshwari
Researcher
Urban Design



Jonas Kupferschmid
Researcher
Traffic Simulation



Filip Schramka
Hardware genius
Game developer



Mohsen Nazemi
PhD Researcher
Traffic Simulation



Michael Joos
Senior Software
Engineer
Gaming Developer



Prof. Dr. D. Schaffner
Psychologist
Cognitive experiment

APPENDIX

A BIKE LANE IS NOT A BIKE LANE

Trucks and cars!

Our children need to ride here??



Dangerous design!!

We demand bicycle lanes!

THE HARDWARE

Schramka, F., Müller Arisona, S., Joos, M.
(2017) Development of a Virtual Reality
Cycling Simulator. Working Paper

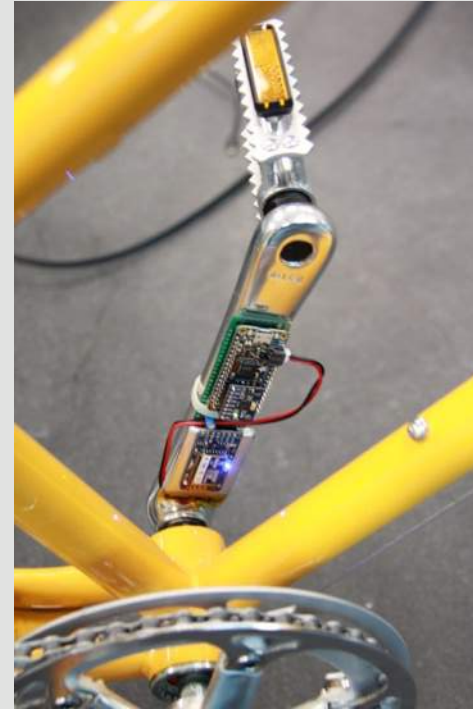
Steering



Tilting



Peddalling



Acceleration / Braking



SURVEYS

YOUR VIRTUAL REALITY EXPERIENCE – PART 2

What did you *personally experience* in Virtual Reality?

	Not at all	1	2	3	4	5	6	7	Very much
Motion sickness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling comfortable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feeling excited	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Getting a realistic impression of the future situation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Given the *new design*, would you feel **SAFE** cycling along...?

	1 – not safe							7 – very safe						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Given the *new design*, would you **CONSIDER** cycling along...?

	Yourself		With a 10 year old child	
	Yes	No	Yes	No
Segment 1: Lim Liak Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 2: Kim Cheng Street	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Segment 3: Seng Poh Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Bliss to the future survey Page 7/10

Traditional surveys

FCL Engaging Mobility, Survey conducted at Archifest (2016)

sunny

1:00 pm

ROUTE 1

major road, no shops, no cover, with trees

6 min

walking

2 min

waiting

overhead bridge

ROUTE 2

minor road, with shops, no cover, without trees

12 min

walking

no crossing required

Using images

Erath A, M.A.B. van Eggermond, S. Ordonez, K.W. Axhausen (Forthcoming) "Introducing the Pedestrian Accessibility Tool (PAT): Open Source GIS-Based Walkability Analysis.", Transportation Research Record

Introducing . . .

sensorama

The Revolutionary Motion Picture System that takes you into another world with

- 3-D
- WIDE VISION
- MOTION
- COLOR
- STEREO-SOUND
- AROMAS
- WIND
- VIBRATIONS

PATENTED

SENSORAMA, INC., 855 GALLOWAY ST., PACIFIC PALISADES, CALIF. 90272
TEL. (213) 459-2162

Using Virtual Reality

Heilig's Sensorama. Retrieved from [Theory and Research in HCI: Morton Heilig, Pioneer in Virtual Reality Research](#)

ENGAGEMENT

Google Cardboard,
Samsung Gear VR
HTC Vive



Virtual reality headset
S\$1,000
Computer
> S\$2,000

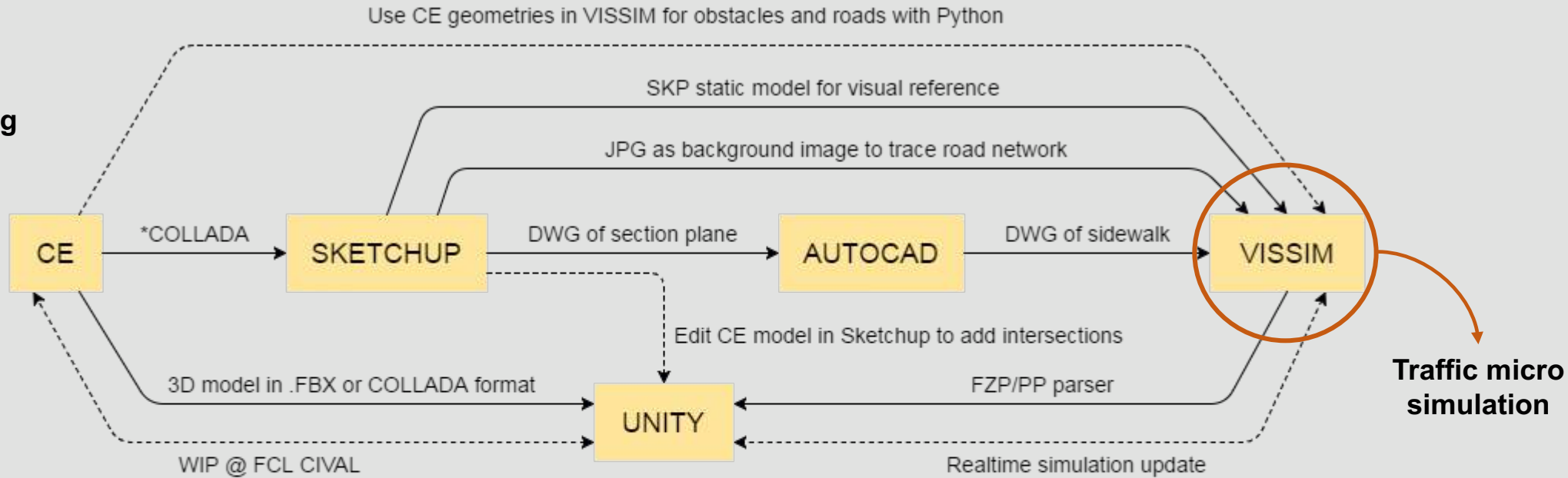


Virtual reality headset
S\$180
Smartphone
> S\$400



Virtual reality headset
S\$2
Smartphone
> S\$200

Procedural modeling



- Prototype tested
- - - - - Work in progress

* CityEngine uses a third-party library for Collada export where multi-texturing is not compatible with the collada standard

Game engine: rendering & interaction