Virtual Design and BIM in Architecture and Urban Design - Potential Benefit for Urban Emotions Initiative

Peter Zeile, Ivonne C. Zelling

(Dr.-Ing. Peter Zeile, Karlsruhe Institute of Technology, Faculty of Architecture, STQP, peter.zeile@kit.edu)
(Dipl.-Ing. Ivonne C. Zelling, Dipl.-Ing., Karlsruhe Institute of Technology, Building Lifecycle Management BLM, ivonne.zelling@kit.edu)

1 ABSTRACT

The contribution deals with the topic of using virtual design Environment and Building Information Modelling technology (BIM) to create immersive urban situations for real-time experiments. Three questions will be answered: How can architects and urban designer work in the future with simple and consistent workflows to check their models during their draft and how can they communicate the result better to non-professionals? Is this methodology a framework to build up virtual laboratory environments for the Urban Emotions Initiative to exclude unpredictable incidents? Students and scientists worked out solutions in an interdisciplinary research project, where virtual reality offers planners the opportunity to examine their models not only on their computer but also to experience in the new planned building or urban situation to analyse spatial impressions, paths and lighting conditions. Supported by generative tools a multi-scale "Swiss army knife" workflow between model creation and design discussing platform in VR was developed which can be adapted to a virtual tour for examination "urban emotions" via head-mounted displays.

2 INTRODUCTION

How to create a test track or test environment, where people react only to urban beauty or ugliness to measure peoples' perception of architecture and urban design? This was a core question at the beginning of the Urban Emotion Initiative in 2009, started in these times as the "emomapping experiment" in Mannheim (Zeile et al. 2009) and "emotionales Kiezporträt" (Höffken et al. 2008). Through several experiments in real urban situations, we try to detect in these early stages to detect places of ugliness and beauty – retrospective a more naïve approach! Too many impacts happen in a city, all the test persons perceived a variety of different impressions, which were hard to classify, and attribute. As a private investigator, we looked for a cause of arousal, orientating on the inspiring work of Christian Nold's Biomapping (Nold 2009). During these first experiments, we detect many negative impressions, which triggers arousal, but never something that belongs to "beauty". Noise, barriers, waiting time, dark corners and narrow alleys, smell, dirt, wind, other bicycle riders, overcrowded situations and a lot more, but all related more to real city life than to the question, why is it a good urban situation.

Frustrating these times, but the hour of birth of emomapping and in conclusion the urban emotion initiative, how we know today. The insight, that it is easier to measure "stress" than "joy" was a lucky chance. The clearance of the so-called "wicked problems" (Rittel and Webber 1973), one planning principle, is more related to what psychologists called "stress" than the look for beauty (which can be a result of a good and proper planning project). According to psychologists, stress is an emotional construct out of anger and fear (Kreibig 2010), and can be measured via skin conductance and skin temperature. One of the first ambulatory device to measure these parameters in an urban environment was the "smartband" (Papastefanou 2009).

Using in emomapping the parameter skin conductance level, EmbaGIS (Bergner et al. 2011) figured out the pattern of increasing skin conductance and decreasing skin temperature is a hint of negative arousal, called "stress". Good to measure pattern, proofed in several projects in walkability (Bergner et al. 2013; Taha et al. 2012) and bike traffic projects (Groß and Zeile, 2016; Zeile et al. 2016; Nuñez et al. 2018). However, one question is still alive: how is it possible to measure the impact/beauty/ugliness of build environment in a laboratory situation? Hints to solve the problem are the contribution by Ash (2010) who examined the architecture of affect and Osborne and Jones (2017) who did "biosensing" in a virtual

environment. Conclusion, we need fast to create and manipulate virtual 3D real-time ambient where test persons can perceive "only" the impact of surrounded houses and landscapes.

3   STATE OF RESEARCH

Talking about building up virtual environments is closely linked to 3D city models as well as game designing workflows. First, 3 D city models used Game-Engines and classical 3D designing software, like the combination out of Maya 3D / 3 D Studio Max and C++ Game-Engine (Zeile et al. 2005), Quest3D (Kretzler 2005), Torque Engine with linked geodata or Unreal-Editor (Jones and Lowe 2005). For a long time, Quest3D Workflow, a container-based, DirectX real-time visualization tool seems to be the most independent tool for the visualization of 3D city models in real time (Schildwächter and Zeile 2008).

Other city related approaches like Cyber City Modeler in urban design competition projects with a – in these times - fast photogrammetric creation of city models (Petschek and Lange 2004), LandXplorer with a more parametric approach of model creation and CityGML enabled (Döllner et al. 2006), Terrain View in a more "Google Earth" style (Mach 2007) as well as parametric City Engine (Müller et al. 2006) gave planners the opportunity to present their models in an immersive, near realistic environment to get an "aesthetic attractiveness, as well as the high level of detailing, will lead to further application of virtual worlds in urban contexts, adding dynamics as well as fun to the topic "city" itself" (Zeile et al. 2005: 7).

All these approaches were limited for "traditional" designers and architects. Applications were very specific, with newly developed data formats and not close to design processes. With the introduction of "Lumion" in 2010, with a concept of fast importing of existing 3D models and the uncomplicated and high-quality visualization without special expert know-how, this gap was nearly closed (Mach 2018), proofing of alternative planning scenarios as well as live manipulation of proposed designs was / is still not possible. Consumer-friendly Head Mounted Displays (HMD) for the use in architecture and urban planning boosted the complete virtual reality technology, it was the first time that it was possible to get a real immersive impression at the own desktop (Nguyen et al. 2016; Schlickman and Domlesky 2017).

Proposed workflows, but with sometimes tricky data exporting or manipulating for planners by using HMD will be found in Dübner (2014) and Leidecker et al. (2017).

4   DESIGN ORIENTED ARCHITECTURAL AND URBAN PLANNING PROCESS IN VIRTUAL REALITY

In a small study, we try to figure out, how this design process could be enriched and accelerate. In cooperation with Karlsruhe based KIT spin-off Enscape (www.Enscape.com), different workflows were figured out, using traditional tools from architectural design processes like Autodesk Revit, Rhino, ArchiCAD as well SketchUp. We will present some of the most promising approaches.

4.1 Student living house Karlsruhe

In the presented workflow (Maier Chimeno et al. 2018), Rhino (with VRay), Revit, as well as Enscape were integrated. In the first step, Rhino was used to create the urban structure, as it is particularly suitable for viewing and modeling on an urban planning scale. The design process was developed in two stages in Rhino and Revit. Visualization in VR then took place via the Enscape plug-in. Enscape is available as a plug-in for both Rhino and Revit, so there is no need to switch between both programs to get into the VR world. For example in the working process, users can investigate changes to the building cubature directly within Enscape. Designing as an iterative process is a keyword. After working out the building form with Rhino, detail planning took place in Revit. The data transfer took part via DWG and SAT export functions from Rhino to Revit. The transferred 2D and 3D objects of the course building cubature served as a template in Revit to create a new BIM building model on this basis. Enscape was also used here for visualization in VR. However, the methods used to validate the various aspects of the architecture varied more, and the process method of repetitively changing parameters and analyzing them in real time remained in place. Finally, in order to present and communicate the project via visualizations, the workflow has the choice between re-exporting to Rhino and further editing in Revit. For a more efficient workflow, Revit became the applied design software at this stage (fig1.).
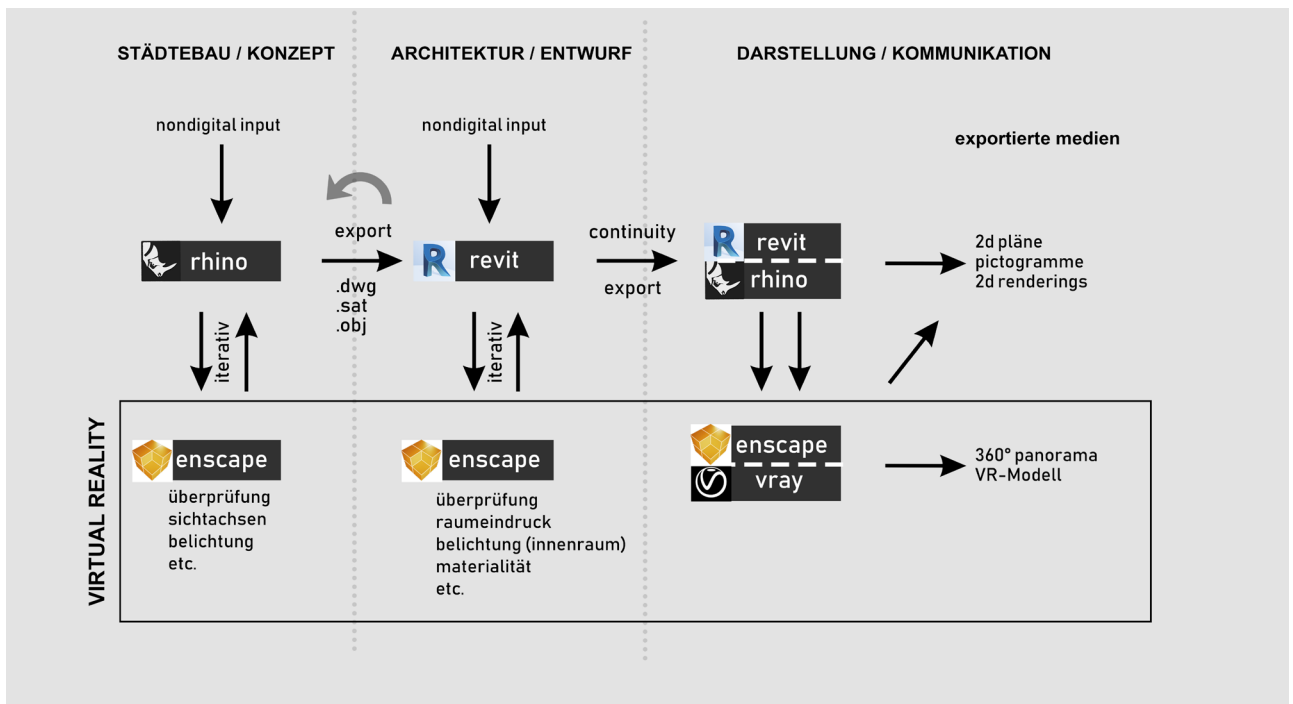
Fig. 1: workflow of using Enscape during the design process and iterative design loops (Maier Chimeno et al. 2018)

Via Enscape, standard renderings and 360 ° panoramas could be created quickly (fig. 3). In addition, another benefit are walkthroughs, a manual-guided tour of the project through the pedestrian perspective (see fig. 2).
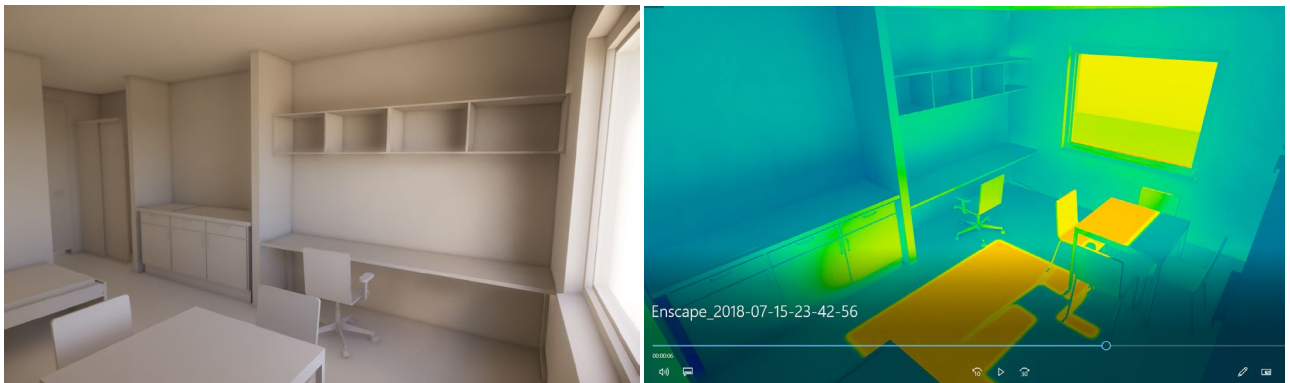

Fig. 2: "white model" real-time rendering with real lighting conditions in a student flat on the left, exported light view on the right (Maier Chimeno et al. 2018)

By means of simple solid bodies in Rhino and the visualization of these in Enscape, it was already possible to investigate urban planning axes and alignment. Based on the quick and simple atmospheric depiction by Enscape, statements about the insertion of the cubature in its dimensions and proportions in the cityscape could be made. Enscape is particularly convincing thanks to its intuitive and fast visualization, such as in the bird or pedestrian perspective (also Walkthroughs possible). The real-time transmission through Enscape allows "playing through / simulating" different solid body variants with an immediate presentation. In addition, the video function can also be used to create solar simulations. The program Enscape independently takes over already stored information from other programs. The initial cost of the program and the VR glasses, as well as the structure and the somewhat awkward handling of the glasses, can be identified as possible obstacles. In this context, the real-time display on a screen initially appears more attractive in terms of the cost-benefit factor than the representation via the VR glasses. Also in terms of more detailed planning, such as the interior design or the facade design as well as the incidence of light Enscape provides good services. In particular, the 360° panorama view allows simple viewing of building facades from all sides via the VR display on the glasses. In contrast to the usual representation in 2D, Enscape allows different spatial atmospheres to be conveyed and understood much faster and more

intuitively. Enscape can also convey textures and materiality in real time. However, real-time representation, such as walkthroughs, is also becoming increasingly prone to display errors, such as physically improper propagation of light or "walkthrough" through walls, as the level of detail increases. Likewise, compute-intensive geometries such as trees can cause long load times and crashes. The main criticism in the workflow and the handling is the exchange between the programs. Despite the simple exchange between Rhino and Revit, data is lost with every export and import. It would also be desirable to have a 4-field view with different perspectives within Enscape, such as 3D Max or Rhino. So different angles could be displayed and viewed simultaneously in Enscape. Essential control elements, such as the handling of the camera paths (previously only as a plug-in) or the creation of panoramas (previously only possible in an external program), should in future be firmly integrated into the program in order to simplify and speed up the handling.

Fig. 2: Panoramic view from the courtyard, live view from HMD (Maier Chimeno et al. 2018)

4.2 Tobacco Shelter in Hayna

After the analog reconstruction of the existing building in Hayna, a small dwelling in the south of Palatinate, characterized in former times by its history of tobacco cultivating, the 3d model was created by using Rhinoceros and Grasshopper and adopting the two-dimensional drawings. For this purpose, the polygonal surfaces were extruded and blended around the respective lengths measured to an extent. For the digital model of the surrounding buildings, the building plan was used to extrude the foundations of the buildings in Vectorworks; the heights and roof areas could be determined from google earth. Actual designs like first three-dimensional conceptual models can easily be visualized and the user is enabled for a direct spatial examination. For this purpose, draft and stock models are combined in SketchUp and rendered with Enscape. As the design process progresses, the digital design model becomes increasingly detailed, and textures for the design and the design are applied with sketch-up and Enscape. The editing of colors, creation of the bump-maps as well as the alignment of the textures according to the objects is done with Photoshop. At the same time, the appearance of the textures could be checked directly in Enscape under different light conditions, day and night, in order to obtain as a realistic representation as possible. After completion of the model and the settings for the scenery camera points ("keyframes") can be set in Enscape and then combined into a "camera movement". A transition of both the time of day and the "running speed" can be created via the settings of the individual cameras. A targeted camera movement in "walk-mode" (not in "fly-mode") makes a realistic view possible from the perspective of the user. The rendered tracking shot can then be exported and played back as a video in mp4 format. It is also possible to adjust the light and color mood as well as to improve the transitions in the context of post-production in Photoshop. The product of this process can be an atmospheric short film that covers a specifically limited field of vision and reproduces it as realistically as possible. Above all, this conveys an impression of the size of the site and the spatial situation created by the design.
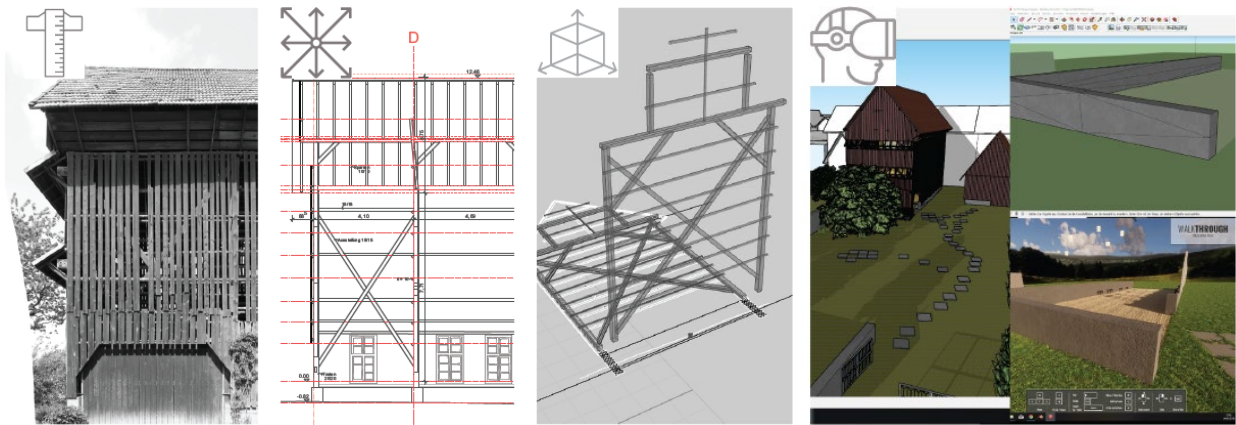
Fig 3: Workflow of creation the shelter, beginning with the site survey, modeling the shelter and visualizing it in Enscape (Esakk and Hermann 2018)

Panoramic views, such as points of view in the interior, can supplement these representations of the design. With the aid of the program Enscape, visually appealing images can be generated in just a few steps without many presets. In particular, the simple handling of grass and light elements is particularly effective in connection with the SketchUp warehouse. The use of the elements available in the warehouse such as e.g. Lamps in rendering in Enscape as luminous objects are intuitive and captivatingly simple. Similarly, the creation of walkthrough videos is simple, despite a minimum amount of work in 3D modeling and textures. The spatial situation, which can be experienced through the 360 ° panoramas, is even superior to the rendered video for the architectural process due to its quick creation and easy sharing.

Fig 4: tobacco shelter in Lumion, rendering from the real-time environment with integrated IES lighting system (Esakk and Hermann 2018)

The handling in SketchUp and Enscape regarding light settings and textures makes the work process so far tedious. Especially in the case of day/night transitions, this leads to problems. Simpler handling of the textures, such as the extension of the simple texture parameters, as they are already used in grass and water for other textures, would be useful and desirable in this context. The panorama views are a particular potential. They can be directly experienced by anyone via cardboard or something more elaborate with VR goggles, and even now, they can be very well integrated into the presentation of architectural designs in university and professional life. By QR-code on plans or by sending to the public

can interrupt too much without the lecture itself (such as a video) a three-dimensional impression can be conveyed and experienced individually by the respective mobile phone. While the architect determines the fixed location of the observer, as with 2d-rendering, the viewer himself is free to choose the explicit object of contemplation, which represents an important aspect for the communication between architect and user.

4.3 Pavilion at national garden show Heilbronn

This chapter demonstrates the difference of classic presentation of architectural designs like using suitable rendered and "photoshopped" perspectives and the use of real-time VR (Machowski, 2018). The well-known workflow Rhino + ArchiCAD + Cinema 4D + Photoshop was modified for this purpose. Instead of importing a Rhino 3D model into ArchiCAD, Revit or SketchUp to show different variants and intermediate states, using real-time VR via Enscape propose more variations in planning processes. After designing the environment for the Pavilion in Revit, the model was checked and tested in Enscape, it was possible to create renderings, panoramas, and videos with camera shots in a few steps to create a sense of planned architecture in various ways to get his "natural" environment. In particular, dealing with people as a size reference and the right lighting mood can convey a concrete idea of the situation here. Compared to similar representations in Photoshop, which are based on individual filters and effects for each individual 2D image, similar settings in Enscape for the entire 3D model are available.
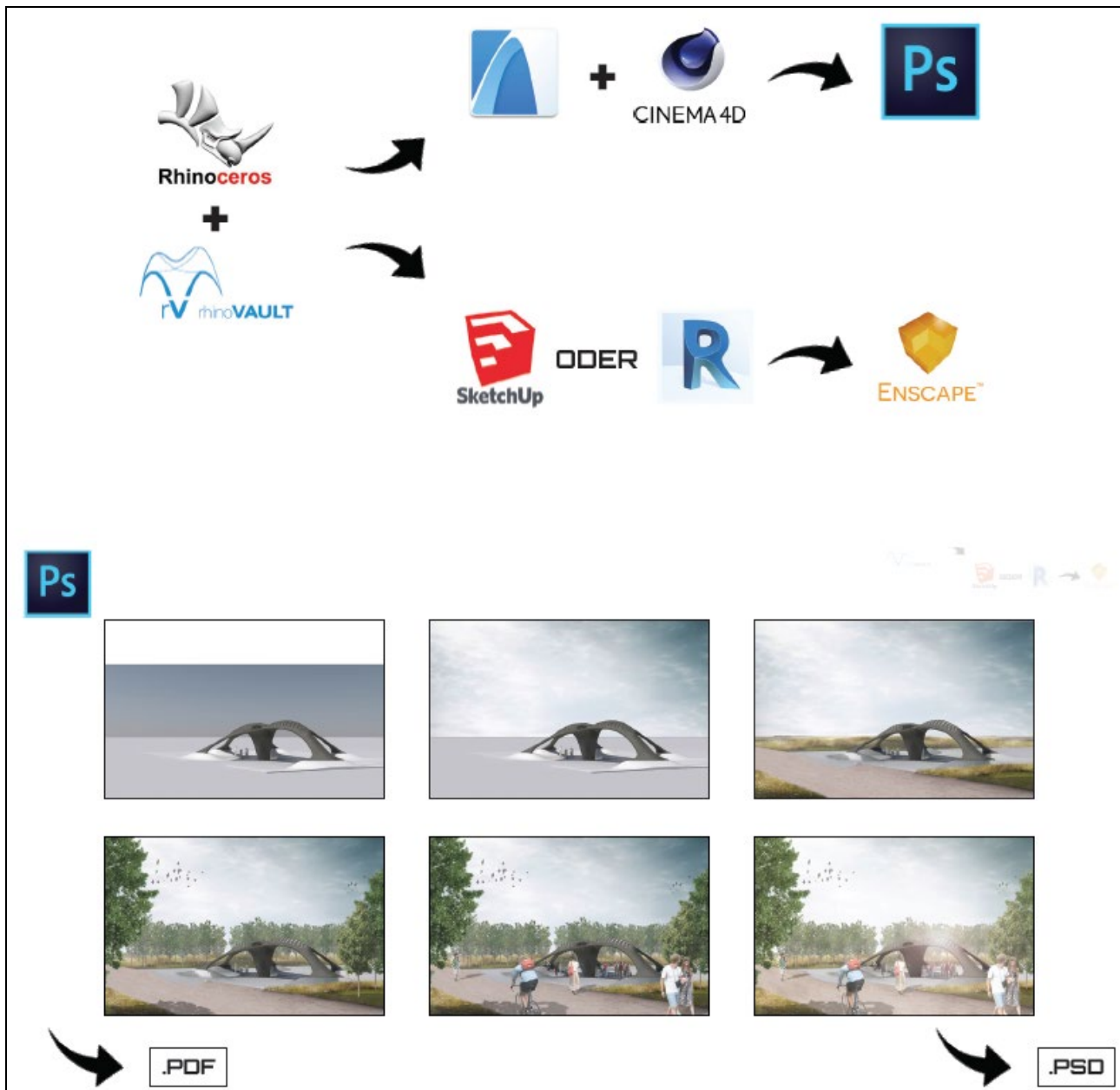
Fig 5: Workflow of the creation of the „million dollar shot", rendered model, exporting in Photoshop and sketched ambient (Machowski 2018)

A big problem when dealing with different architecture software is the exchange and compatibility between the programs. The whole thing starts already with the different operating systems since many programs exist only for Windows. If you want to use a certain function of a program and then export a file and import it into another program that you normally work with, you will always encounter a number of problems. Even the "more universal" file formats (DWG, DXF, 3DS, …) are often not an optimal solution. A usual workflow cheats to "somehow manage to work with a file", which is sometimes only possible with a detour through a third party program. Especially in times, were an optimization in workflows and save time (and money) are key issues for a successful project, these tinkering approaches cannot be a permanent solution. Exporting and re-importing due to incorrect settings, reduction of polygons, etc. results in changes to the files are only well-known examples. Future research on "real universal file formats" is mandatory. One good solution is the collaboration between Revit and Enscape that works flawlessly due to a plugin from Enscape in Revit. Real-time rendering and the panoramas convince with their quality. Especially materiality, shadow and simple change of the weather conditions and daytimes can be highlighted here. In addition, a larger embedded material library, where you can easily change colours and have multiple variations, would help to achieve an even more realistic VR experience. Also setting options such as the grass height, the reflectance of the water or the like, would be useful for the same reason.

Fig 6: comparison between the prepared Photoshop illustration and a live view from Enscape (Machowski 2018)

5   INTEGRATION IN URBAN EMOTIONS TEST ENVIRONMENT

As presented in the previous chapter, the fast creation and editing of 3D models is now possible, even with an immersive look and feel via a head-mounted display. After promising experiments using 360° video streams for cycling traffic analysis in a virtual environment (Zeile and Resch 2018), the first idea to measure VR immersion and perceptions with stringing together different models and load it into the virtual environment in oculus rift. With the help of camera/viewpoint presets it would be possible to examine different models and the effect on the viewer.

The bottleneck of this was the large data of the different models, joining them together in one file is possible, but with a lot of data conversion and data reduction in the models. One compromise can be to prepare different panorama positions and create a 360° movie file. Under these assumptions, a first test was made by watching existing 360° videos from the oculus video library and also testing out, how a person reacts on the VR demo of the head mounted display, where the viewer is integrated in a vector-based environment, standing on a skyscraper and watching an incoming t-rex in a museum. Also, some videos of a safari, race courts and some live music events are available.

● Virtual GPS Point
★ Stress Trigger [MOS]
● Seconds of Stress [SOS]
594 Timestamp MOS

Dreamdeck Tower   Dreamdeck T-Rex   New Stupid Game   Confusing Navigation   „Disturbing" People   Flying Kite
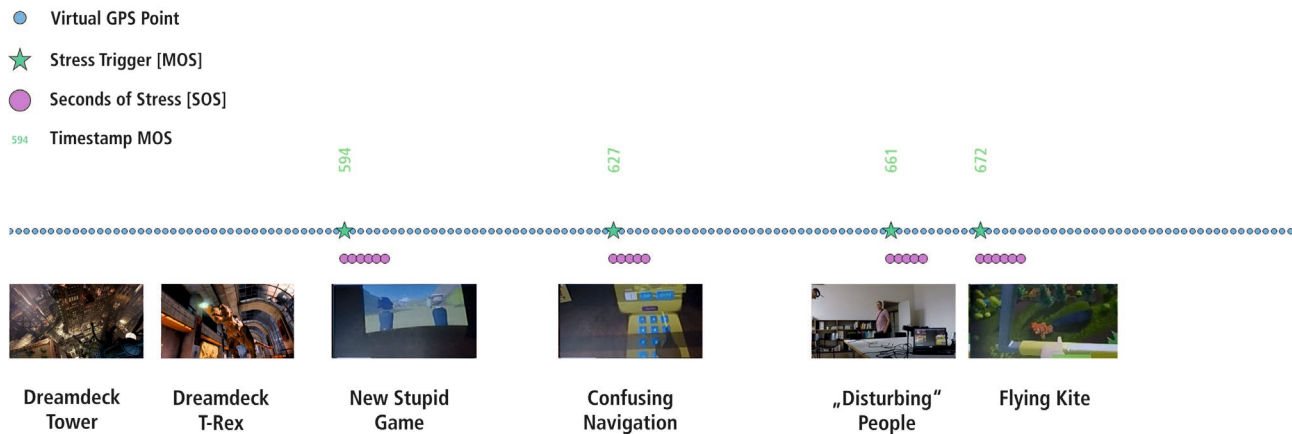
Fig. 7: Extract of the first test measurement, stress triggers appear in unexpected situations

The main task for this setup was to create a workflow, where you can automatically measure the stress reactions via Smartband with the R-based integrated QGIS-Workflow (Beyel et al. 2016). The only limit is that there is not an available GPS-Track for the virtual environment as a geolocated base to visualize the detected stress spots. A found solution for that issue is to create a virtual GPS track with the following working steps in QGIS: Creating a polyline in an arbitrary projection system, intersecting this polyline with points along the line and attribute them with a timestamp. We got an artificially created GPS track with a Point ID, timestamp, latitude and longitude information, which is sufficient to analyze the Smartband raw file and visualize it in a timeline. Figure 7 shows the first result of self-tests. Blue virtual GPS-Points starts with zero seconds. First nine minutes was a period with navigating, installing, etc. and starting the Oculus Dreamdeck demo application. As I know the content of the demo, nothing happened during these different scenarios; even T-Rex did not trigger a stress reaction. Some navigation issues in the virtual environment, as well as a materializing colleague, triggered more stress reactions than "real VR content".

Testing some of the newly created VR content from the student's studies via SketchUp Live View Plugin for Enscape did not result from any stress trigger (see Figures 1-6, 8).
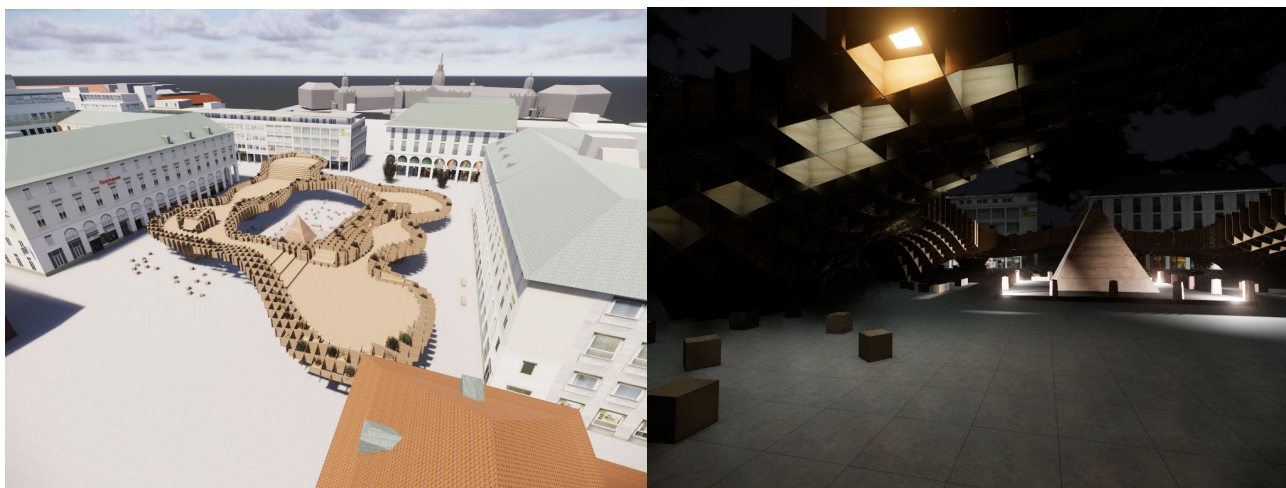

Fig. 8: Wafflepavillion at Karlsruhe Marktplatz, view from above and night view (Sedlmaier and Scheid 2018)

6   CONCLUSION

The result after this first test was double-edged: Workflow in creation (beautiful) models and presenting them in a real-time VR environment was more than satisfactorily. Handling of the models in Enscape is easy, even fore VR beginners. Exporting panorama shots for cardboards as well as for using them as stills for 360° movies are another positive value of the presented workflow. A drawback is that it is not possible to export 360° movies for a prefabricated, customized camera track and for producing a more dynamic laboratory test environment for stress measurements. After the promising results of watching 360° bicycle riding video streams and detecting stress triggers during real-world test ride as well as during

virtual test ride (Zeile and Resch 2018) support this needed export option – knowing about the issues of producing very large video files and heavy rendering operations.

Real VR stress measurement was – at a first glance – disappointing. In contrast to other experiments, no expected stress trigger occurred during the test. Cause of this could be the known test process (I know what will happen next), the comfortable laboratory set up, slow speed of changing conditions and new sceneries. For the next sets, it is recommendable to create a set up with fast-changing situations and testing these issues with people, which not know the playlist of situations.

Technology and methodology of doing stress detection in a virtual urban and architectural environment are with some small exceptions done, next to research steps have to be to find the right urban situations, creating a playlist with more variable situations, creating "bad" conditions for calibrating identifying stress triggers in VR environment.

At least, especially in these perfect modeled environments, it is really a bad circumstance, that it is still not possible to detect "beautiful" places with the presented method.

7 ACKNOWLEDGMENT

8 REFERENCES

ASH, J.: Architectures of Affect: Anticipating and Manipulating the Event in Processes of Videogame Design and Testing. Environment and Planning D: Society and Space 28, 4, 653–671. 2010.

BERGNER, B.S., EXNER, J.-P., MEMMEL, M., ET AL.: Human sensory assessment linked with geo-and mobile-data processing methods in urban planning exemplified on different cultures in Germany and Egypt. Proceedings of CUPUM 2013: 13th International Conference on Computers in Urban Planning and Urban Management - Planning Support Systems for Sustainable Urban Development, 1–18. 2013.

BERGNER, B.S., ZEILE, P., PAPASTEFANOU, G., AND RECH, W.: Emotionales Barriere-GIS als neues Instrument zur Identifikation und Optimierung stadträumlicher Barrieren. In: J. Strobl, T. Blaschke and G. Griesebner, eds., Angewandte Geoinformatik 2011. Wichmann Fachmedien, Salzburg. 2011.

BEYEL, S., WILHELM, J., MUELLER, C., ZEILE, P., AND KLEIN, U.: Stresstest städtischer Infrastrukturen -- ein Experiment zur Wahrnehmung des Alters im öffentlichen Raum. In: M. Schrenk, V. Popovich, P. Zeile, P. Elisei and C. Beyer, eds., REAL CORP 2016. Wien, 689–698. 2016.

DÖLLNER, J., KOLBE, T.H., LIECKE, F., SGOUROS, T., AND TEICHMANN, K.: The virtual 3d city model of Berlin: Managing, integrating, and communicating complex urban information. In: Proceedings of the 25th International Symposium on Urban Data Management. Aalborg. 2006.

DÜBNER, S.: Virtual Reality im Planungsprozess: Anwendung am Beispiel des Bahnhofareals in Neustadt an der Weinstraße: Master Thesis. http://cpe.arubi.uni-kl.de/wp-content/uploads/2013/11/MSC_Duebner_Virtual.pdf 2014.

ESAKK, D. AND HERMANN, J.: Virtual and augmented reality - ein tabakschuppen in hayna. 2018.

GROß, D. AND ZEILE, P.: EmoCyclingConcept -- Potenziale der emotionalen Stadtkartierung. In: J. Strobl, B. Zagel, G. Griesebner and T. Blaschke, eds., AGIT. Wichmann Verlag, Berlin, Offenbach, 273–278. 2016.

HÖFFKEN, S., PAPASTEFANOU, G., AND ZEILE, P.: Google Earth, GPS, Geotagging und neue Möglichkeiten für die Stadtplanung-Ein emotionales Kiezportrait. REAL CORP 2008, 275–281. 2008.

JONES, R. AND LOWE, R.: Unreal Editor as a Virtual Design Instrument in Landscape Architecture Studio. In: E. Buhmann, P. Paar, I.D. Bishop and E. Lange, eds., Trends in real-time landscape visualization and participation. Wichmann, Heidelberg. 2005.

KREIBIG, S.D.: Autonomic nervous system activity in emotion: A review. Biological Psychology 84, 3, 394–421. 2010.

KRETZLER, E.: Real-Time in Landscape Architecture Competitions. In: E. Buhmann, P. Paar, I.D. Bishop and E. Lange, eds., Trends in real-time landscape visualization and participation. Wichmann, Heidelberg. 2005.

LEIDECKER, H., ZIMMER, D., BROSCHART, D., AND ZEILE, P.: Visualisierung von Seilbahnen im urbanen Raum. In: J. Strobl, B. Zagel, G. Griesebner and T. Blaschke, eds., AGIT 3-2017. Wichmann H, Berlin and s.l. 2017.

MACH, R.: Virtual Globe: Die Erde in 3D. Digital Production 1, 55–57. 2007.

MACH, R.: Lumion 7.5: Architekturvisualisierung – schnell und einfach? Digital Production 1. 2018.

MACHOWSKI, N.: Virtual Reality vs. Photoshop. 2018.

MAIER CHIMENO, P., BAYRAMI LATRAN, AND DJAHAN: VR und Echtzeitanwendung im Entwurfsprozess: Studentenwohnheim. 2018.

MÜLLER, P., WONKA, P., HAEGLER, S., ULMER, A., AND VAN GOOL, L.: Procedural modeling of buildings. ACM SIGGRAPH 2006 Papers on - SIGGRAPH '06, ACM Press, 614. 2006.

Nguyen, M.-T., Nguyen, H.-K., Vo-Lam, K.-D., Nguyen, X.-G., and Tran, M.-T.: Applying Virtual Reality in City Planning. In: Springer, Cham, 724–735. 2016.

Nold, C.: Emotional cartography: Technologies of the self. http://emotionalcartography.net 2009.

Nuñez, J., Teixeira, I., Silva, A., et al.: The Influence of Noise, Vibration, Cycle Paths, and Period of Day on Stress Experienced by Cyclists. Sustainability 10, 7, 2379. 2018.

Osborne, T. and Jones, P.I.: Biosensing and geography: A mixed methods approach. Applied Geography 87, 160–169. 2017.

Papastefanou, G.: Ambulatorisches Assessment: Eine Methode (auch) für die Empirische Sozialforschung. In: Umfrageforschung. VS Verlag für Sozialwissenschaften, Wiesbaden, 443–468. 2009.

Petschek, P. and Lange, E.: Planung des öffentlichen Raumes - der Einsatz von neuen Medien und 3D-Visualisierungen am Beispiel des Entwicklungsgebietes Zürich-Leutschenbach. REAL CORP 2004, 569–572. 2004.

Rittel, H.W.J. and Webber, M.M.: Dilemmas in a general theory of planning. Policy Sciences 4, 2, 155–169. 1973.

Schildwächter, R. and Zeile, P.: Echtzeitvisualisierung in städtebaulichen Entscheidungsprozessen. REAL CORP 2008, 235–241. 2008.

Schlickman, E. and Domlesky, A.: Using Your Illusion. Planning 83, 5, 15–19. 2017.

Sedlmaier, S. and Scheid, S.: Wafflepavillion am Markt. 2018.

Taha, D., Raslan, R., and Bergner, B.S.: Humans as Sensors to Enhance the Built Environment: a Case Study of the Eastern Harbor, Alexandria, Egypt. In: M. Schrenk, V. Popovich and P. Zeile, eds., REAL CORP 2012. Wien, 367–376. 2012.

Zeile, P., Höffken, S., and Papastefanou, G.: Mapping people? The measurement of physiological data in city areas and the potential benefit for urban planning. REAL CORP 2009. 2009.

Zeile, P. and Resch, B.: Combining Biosensing Technology and Virtual Environments for Improved Urban Planning. GI_Forum 1, 344–357. 2018.

Zeile, P., Resch, B., Loidl, M., Petutschnig, A., and Dörrzapf, L.: Urban Emotions and Cycling Experience – enriching traffic planning for cyclists with human sensor data. GI_Forum 1, 204–216. 2016.

Zeile, P., Schildwächter, R., and Poesch, T.: Production of Virtual 3D City Models from Geodata and Visualization with 3D-Game Engines - A Case Study from the UNESCO World Heritage City of Bamberg. Trends in real-time landscape visualisation - DLA. 2005.