ILLUMINATION OF URBAN SPACE USING DIGITAL SIMULATION METHODS

Exemplified on the UNESCO World Heritage Site of Bamberg

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Abstract. The photorealistic visualisation of lighting-scenarios with the help of virtual 3d city models is gaining importance as a tool, helping to make decisions in the process of planning. This form of presentation makes sense to every spectator very quickly and in a definite way, thus it makes collaboration easy especially in interdisciplinary planning teams. Moreover the light-planner has the possibility to check his design in a virtual surrounding and therefore gain additional reliability for his planning. The displayed, exemplary, workflow and the techniques belonging to it, allow to show situations during the course of planning and to present the current state of planning realistically. Hence the quality of planning can be enduringly improved, through experimental use of new materials and ideas. Moreover alternative planning that does not show the right results can be eliminated very early in planning process, with not need for special investments to do so.

1. Bamberg

The World Heritage Site of Bamberg consists of nearly 1000 individual buildings. In addition to that are historic and cultural outstanding monuments like the cathedral of Bamberg. To preserve the aesthetic entirety of the city, it is important, to the setting of lighting-installations and the “daily” lighting, to archive a continuous illumination adequate to the memorial. These hotspots are being displayed as examples in the World Heritage Site of Bamberg.

2. The Use of digital method during planning processes

During planning digital simulation methods can be used in the most different situations and stages of the planning process: They can be used during the concept phase, as a discussions foundation for the “intention-finding process”, to define the basic outline of the light-installation. They can further be used to check the resulting plan-parameters after the design phase; to inspect the intended light situation “on site” virtually, and to test the values, suggested by the light planner, in an environment that nearly meets reality.

Therefore a model of the existing situation is, next to the technical components, the second most important component of concept planning. In advance of the actual planning, the intended level of detail for the model has to be given accordingly exact. Different from object-planning, which has already been planned 3d for the most part, on a urban scale, this approach today still is difficult: Problems arise from a lack of standards, concerning data and archive formats, as well as the so called “level of detail” (LOD), that indicates how sharp an existing urban model is, regarding differentiation of roof shapes and structures, as well as accuracy of location of points contained in the model (Gröger et al.2004). According to this, a rather abstract model in LOD 1-mode, with a digital terrain model and simplified building cubature is adequate for light-master-plans of a whole urban area.

2.1. LIGHT PLANNING

2.1.1. Qualitative light planning

Contrary to functional or quantitative light planning that generates a single, universal set of light quality, out of the particular project’s inevitable requirements, which almost automatically leads to an equal and even uniform design of light and lights, qualitative light planning is all about dealing with complex grids of intended light qualities and constitutive criteria.

Qualitative light planning originates from artistic stage lighting. Different from the physiological, light-technical research, the interest here not only lies on the eye; the pure quantitative limit for cognition of abstract visual seeing tasks. Furthermore it lays on the perceiving human, hence the question how the actual perceived reality is composed in the event of seeing. Cognition is not just a simple imaging process; it’s not just taking pictures of the surroundings. Countless optical phenomena show that a complex interpretation of surrounding attractions happens during the event of cognition, our eye and brain less display the perceived reality, furthermore they compose it.

Figure 1. Atmosphere and stage light: a) Light for seeing (ambient light) b) Light for taking al look (focal glow) c) Light to watch (ply of brilliance), Tristan and Isolde (State opera house Berlin, stage light production Herzog & de Meuron)

Against this background Kelly and Lam define a completely new meaning of illumination in the 1960s (Ganslandt Hofmann 1992): “Activity needs” (quantitative necessities), the lightings functional requirements to satisfy for the visual task of seeing, as well as “biological needs” (qualitative necessities) the illuminations psychological requirements in context with its spacious surroundings. Moreover Kelly and Lam are against uniform illumination with equal quality of light; they demand sophisticated analyses of all seeing tasks in matters of location, character and frequency of occurrence, as well as an adaptation of the level of lighting to its particular requirements and a differentiation of light according to its task.

According to their thesis, light can fulfill three different tasks in urban space. 1): a.) Light for seeing (ambient light), b.) Light for taking a look (focal glow, spotlighting, accentuation with light) and c.) Light to watch (play of brilliance, e.g. light sculptures). These are terms and techniques that frequently show up in modern 3d render programs, which are used to generate high-end illumination scenarios. Through these three basic categories of illumination, an easy and effective basic grid of light design, which meets the needs for illuminating an urban object, as well as the needs of the perceiving human, has been created. The actual challenge of a more qualitative light planning lies in creating a design concept, that is able to full fill the different requirements of illumination with a technically and aesthetically consistent light arrangement.

2.1.2. Qualitative light planning

Although the general population in Germany got used to taking the quantitative illumination of our cities during night time as implicitness, the words “light master plan” and “light design” are foreign words to most of the persons in charge. This deficit in the methods of planning concerning the illumination of many of our cities, led to the evolvement of a new market, which is able to compensate the conceptional deficits. The new generation of “light designers”, especially in the field of city marketing, has recognized the positive effects of qualitative light planning on the Image and the shape of a city. Effective projects in Germany, e.g. the “Speicherstadt” in Hamburg, the “Innenhafen” of Duisburg or the “Zollverein” in Essen show

how former scary places can be animated again, through good light design. Light design should always take the formal framework of its surroundings into account. Composing with light, in this case, resembles the work of a sculptor, who shapes his sculptures (Lange/ SLG 1998). Just like the sculptor, painter, photograph or musician, the light designer pursues a general (design) idea. The planner's main focus lies, besides the cities areal context, its function and history, on the master plan and on single remarkable urban objects, which have to be illuminated in the details of the general planning. The following facts are of great importance for designing with light in urban context (Flagge 1991):

(1.) The city and its topography

Creation and promotion of a cities formative characteristics: Its topographic situation, its rivers and watersides (Waterside Boulevard of Nice, image 2a.), its arterial roads, its areal buildup ("Stadtkrone") and its building pattern as well as its unmistakable features, like for instance its churches and monuments.

(2.) Orientation through hierarchy of illumination

Under the basic psychological demands on a visual surrounding, the need for a clear spacious orientation is the most important. Orientation can be meant universal (infrastructure, view relationships) and local (clearness of the closer surroundings, human standard in the urban context). It is related to the clearness of targets and to the paths leading to them. To give an example, some mayor buildings, which are important for the individual orientation and for the identity of the area, can be specially floodlit to make them optical target objects. Another fundamental option to improve the orientation is the accentuation of the routing itself (e.g. Watersides, Avenues, see Image 2b., Champs Elyssees). A basic requirement of accentuation through light is the simultaneous dimming of the illumination level in surrounding, peripheral areas. (hierarchy of illumination).

(3.) Spacious homeliness / psychological feeling of safety

Another, psychological need aims for homeliness of the area and for clearness of the surrounding building pattern. (image 2c.). Important therefore is, first of all, the adequate visibility of all surrounding spaces, this is vital for a feeling of safety in a visual surrounding. Especially in potential dangerous places, complete visibility and an understanding of the space's composition is of the greatest importance. Basically a structured and identical delineation of space adds to ones well being in a visual surrounding.

Figure 2. a.) City and its topographical lay out: Nice and its characteristic water side (Flagge 1991), b) Orientation through lighting: Champs Elyssees and c.) Feeling of safety through brightness: Light flooded crossing in Lyon (Narboni 1995)

(4.) Light and ambience

Especially in common places, squares, parks and places for events, light-technical measurements should contribute to a nice ambience and should, with today's possibilities of light techniques, do our senses some good. The visual ambience and the emotional comfort are vital to the success of a light staging. An artistically basic requirement for an effective staging, as the case may be a qualitatively high illumination, is the careful use of color of light (Image 3), the concentration of light and the heights of light dots. The illumination of architecture, parks and squares just for the cause of it, can become an expensive adventure on all sides.

(5.) Involvement of additive lights

Next to street and object illumination, additional illumination elements like, bright shop windows, illuminated advertising, (e.g. image 3c., Times Square), lit entrances and private houses can be part of the cityscape. These lights may, under circumstances, strongly affect the intended effect of an illumination and, for that reason, have to be recognized, as far as possible, during planning.

(6.) Lights as street or city furniture / cityscape

Nowadays the number of different pieces of street furniture is very large. Including: Signs, masts, traffic lights, fences, benches, trashcans, advertising pillars, advertising plates and the visual lighting elements in urban space. The lights' importance as a feature that forms cityscape should not be underestimated; it poses, especially in the composition of street space, a basic design feature for urban design (e.g. Light pillars, image 3d.). For this reason one has to very carefully pick lamps for the illumination of existing buildings, which match the building's style. Or one should give up installing lights visible if they are used to floodlight a building.

Figure 3. a.) Accentuation and ambience through light, Coloseum in Rome b) Detail of light-color differentiation (www.iguzzini.com) c.) Light-smog trough additive illumination, Times Square New York (www.imagegalery.com) and d.) Lights as elements of urban-space, highway exit LAX (www.aeg.de)

2.1.3. Process of planning

Planning of illumination systems is a very complex, interdisciplinary and communicative act. The influencing factors and needs for all people involved in the process of planning are very wide spread and require cooperative planning, conception and consideration. The methodic approach consists of three phases (figure 4):

(1.) Analysis

The phase of analysis is subdivided into: Basic evaluation, the analysis of all factors that could influence the design and evaluation of functional, light-technical and design related requirements, including a comparison of the existing to the intended status.

(2.) Planning

Afterwards the phase of real planning begins. It is dominated by concept drafting and master planning of all light-technically and usage-specific factors, including light-technical calculations and as the case may be controlling (simulation, IT, CAD) and economic calculations.

(3.) Execution

In execution phase, technical execution, controlling and maintenance, as well as a locking up of the light plan in a zoning map, a land use plan, or in a community design edict, should be executed, to guarantee an enduring planning.

2.1.4 3d city models as a foundation for light planning

Depending on the size of the plan area, different depths of detail for the 3d-city-models are required. Local urban plans and designs for places and squares require a differentiation of the 3d model between LOD2 and LOD3, with fully modeled roofs and corresponding façade textures. For the actual object planning -LOD4-, the “architectural model”, geometries have to have the actual shape of the original, including its constructive elements and openings. This is necessary to make the model as recognizable as possible and to give a spectator the possibility to see the real proportions and to take measurements. The great amount of time it takes to create a 3d model in the first place (Zeile 2004), is, in the long run, a good investment, because a 3-dimensional planning basis in a urban context is a very useful communication instrument for interacting planners, not only for light planning (Zeile et al 2005).

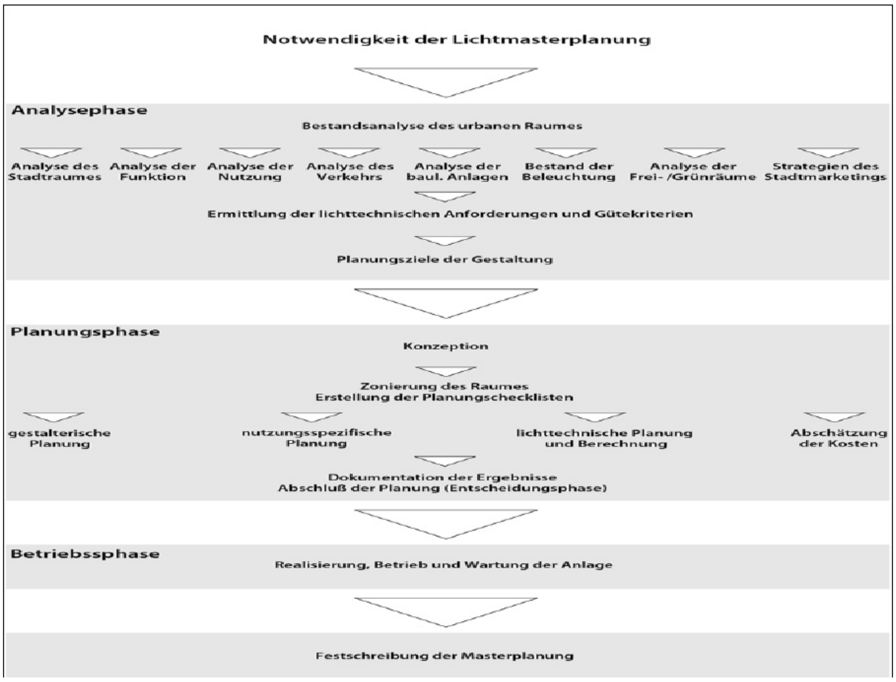

Figure 4. Ideal process-scheme for light-planning

3. Trends in visualization and its transformation on the task of planning

3.1 HDRI (HIGH DYNAMIC RANGE IMAGES)

HDR-images are digital image files, with a very high dynamic range of exposure. Different than normal pictures, taken with standard digital cameras, which only have the ability to capture a small part of reality's dynamic range of exposure, HDR pictures, which can be composed through digital photography using a set of images taken with a range of exposures, or with render algorithms designed to generate HDR images, are in matters of the dynamic range of exposure close to reality (figure 5.). In a generated HDR file, even the real range of contrast is saved, so the picture's color and tonal value can be changed, even afterwards.

Using this technique, two ways of visualizing light plans are possible: For the light technical control of light planning on the one hand, very exact

360° panorama pictures can be taken using HDRI-techniques, which not only save the areal pixel arrangement, but even the correct contrast range. Using such exact picture information as a basis, it is nowadays possible to illuminate virtual models; meaning that light spots in the picture are transformed into "real" lights in a rending program.

On the other hand, one can generate HDR images using rendering software, which illustrate the planned illumination effects much better than before, when the "classical" imagining techniques where used, because of the dynamic range of contrast.

Figure 5. a.) to c.) Exposure set Historical Bridge City Hall, HDR-generation d.) Result with full contrast range.

3.2 USE OF IES FILES

The light distribution curve, which exists for every lamp, illustrates the areal light intensity distribution as the so called "polar diagram". Because these diagrams, which are unique for every lamp, are very hard to understand for layman, but also very important for planning, the Illuminating Engineering Society of North America (www.iesna.org) imposed the so called IES-format. An IES-file, loaded into a rendering software simulates the light intensity distribution, without the need for difficult calculations. Thus it is possible to simulate the exact light intensity distribution for each lamp (figure 6.).

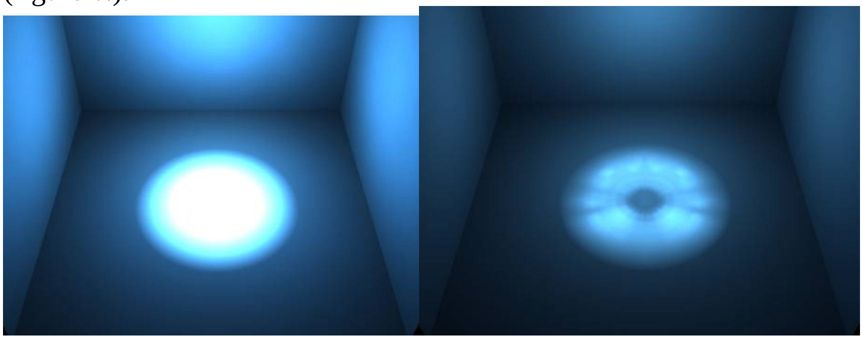

Figure 6. a.) Normal spotlight and b.) Spot with simulated light-distribution-curve using the IES-format (LG cpe, Tony Poesch)

3.3 BUMP / NORMAL MAPPING

With the help of the so called bump mapping, surface structures are being simulated out of digital images, without changing or improving the geometry. Here additional layers of images are being laid over the actual texture, these indicate how light or dark the actual texture is on a specific position. So the resulting “light/dark pattern” simulates different heights of the geometry and the resulting shadows, although the geometry stays untouched (figure 7).

More modern and technically more advanced methods are high mapping and normal mapping, which are used for visualizing digital terrain models or for real-time reality applications (Computerbase 2005). This technique is very important, especially for the illumination of architecture models, because this “trick” allows the simulation of surface structures which would have to be lavishly model additionally otherwise.

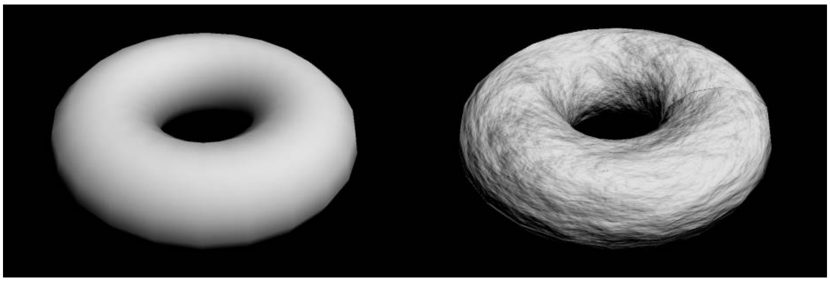

Figure 7. a.) Pure geometry and b.) Surface structure simulated using bump mapping (LG cpe, Tony Poesch)

3.3.1 TEXTURE BAKING

Texture baking or unwrap maps are a technique that multiplies the illumination settings in a model on its original texture, and projects these, new textures, on to the model's surface. This means that a new texture is been rendered. This technique is, just like bump mapping, used in real time environments to save the time, which would be necessary to generate light and shadows in real time (image 8.). Another advantage is that even different views of a situation can be generated quick and easily, without having to do the whole light simulation, which can take several hours in a high detailed image.

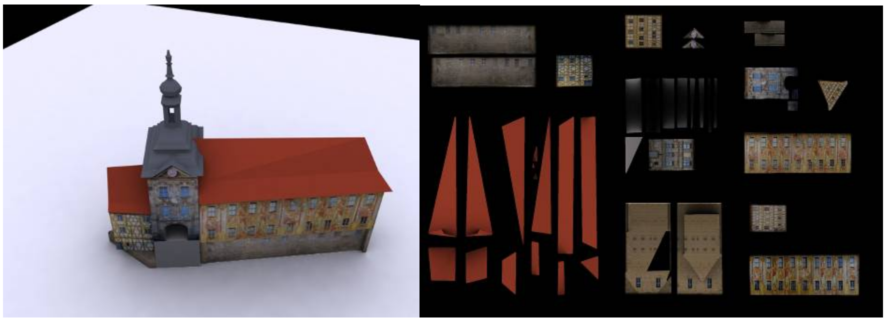

Figure 8. a.) Light-tracing illumination of the bridge-city-hall in Bamberg b.) Relating unwrap map. The shadow on the roof is very good (Own figure)

4 (Light-) technical control and simulation

The free, light-technical program DIALux is the result of an initiative of several Lamp-producing companies, which are representing their interest under the roof of the "Deutsches Institut für Angewandte Lichttechnik" (DIAL / Lüdenscheid). A specific lamp's data (Eulumdat, IES) has to be requested at the specific company. In the program the planer can choose between a new project for outdoor and street lights. Afterwards a basic picture e.g. of a standard street with a middle lane or a square shows up. Furthermore smaller DXF-/ DWG- files can be imported and serve as a foundation for the planning (Reichrath 2006).

Contrary to this is the method of checking the design goals using 3d modeling software, like 3dMax and additional plug-ins like VRay, Maxwell, Final Renderer or Brazil.References

4.1 RELUX

The given 3-dimensional data of a virtual city model can be imported through the DXF / DWG gateway in special software designed for light calculation in Relux. Thereby however additional file information such as material and surface characteristics (e.g. photo mapping, bump maps) is not being transferred. Formats, which have such features, like 3ds-files, are being offered, but it showed in Relux that program mistakes may happen during file conversion, especially with complex models. For this reasons it is advisable to make easy illumination scenarios, or to keep the file size for import files as low as possible, e.g. through discarding mappings (image 9.). Calculation inclusive rendering of a street project using the same lights a few times, takes 5-10 minutes, a complex plaza situation with assigned materials however can take several hours. The comparatively small program can not handle designs in large scale with complex databases (Reichrath 2006).

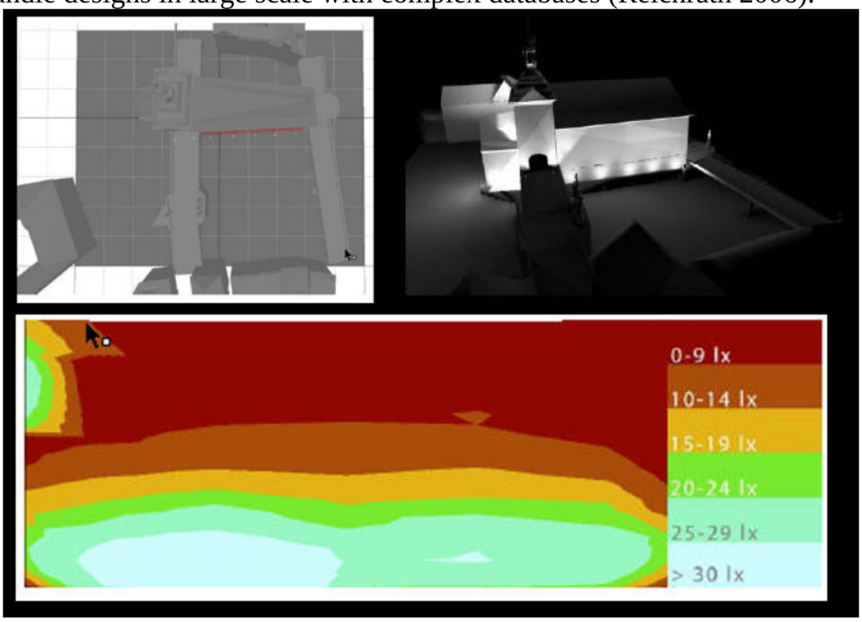

Figure 9. a.) Light-technical calculation using Relux, bridge-city-hall in Bamberg (Reichrath 2006)

4.2 3DMAX / VRAY

The use of this technique has two decisive advantages over the use of Dialux: An increase of drawing speed and creative possibilities. Especially the higher artistic potential of modeling and visualization software, compared to the technical lighting programs, opens a new range of possible applications for realistic and light-technically exact visualization of illumination scenes to the light designer. The advantages of the use of a 3-dimensional CAD- and / or visualization program lie especially in the following qualities:

(1.) Different from light-technical calculation software, even very complex file sizes and models (master planning, models of whole cities) can be edited and visualized with normal computers or through LAN networks in most of the 3d programs.

(2.) Material characteristics of surfaces in the virtual space can be projected and calculated in a much more realistic way. So, next to image files (maps), for example even roughness or reflection characteristics, and much more can be implied in the illumination calculation. While illuminating a scene, the light beams are not only calculated to illuminate the targeted surface, even their reflection is being traced (indirect illumination), thus the light gets, in contrary to the interflexion-method, (as DIALux) mathematically and physically correct visualized.

A negative aspect of these 3d-visualization programs is surely the high costs of the software and the great amount of time necessary for modeling and rendering (e.g. complex façade of historic buildings), if the city-area which is to be planned, does not already exist as a 3d model. Adding to this, these programs usually do not have a comfortable light technical file management (list of lamps) and information analysis (annotation texts) tool (Reichrath 2006).

Figure 10. Simulation of the bridge-city-hall in Bamberg with 3dMax / VRay (Reichrath 2006)

5 Conclusions

In the daily routine of planning, the presented digital techniques ease the handling of light in an urban context greatly, even for a not specialized (urban) planner. Because the light designer composes his designs out of empiric physical data, which is hard to understand for outsiders, his conceptional proposals only get clear to the layman after the concept has been displayed as a real prototype. With the conventional, abstract form of light concept generation, different alternate designs are hard to compare or discuss.

Using the presented visualization techniques the communication between everyone involved in the specific phase of planning can be substantially improved. The great effort necessary to generate the digital models in the beginning pays of in most of the cases afterwards through a quicker and more confident execution of the project. Many costly mistakes and delays, that happened in the past, due to troubles in the communication between different actors, can be avoided in the future.

Despite the possibilities and advantages, mentioned above, it must be noted again that it is, by now, not possible to generate an image which 100% matches reality. The handling of these new techniques requires, besides knowledge of the technical aspects of light-planning, most of all a responsible and respectful argument of all actors in the event of defining goals for the planning. Thus a high quality planning can be archived, through the use of digital supported and analog methods.

It seems important to us to point out that, by now, even under favorable circumstances the work of a technically skilled visualization expert can not fully replace the work of a light planner. The use of the presented simulation methods brings the process of planning forward and should be the dominant foundation for discussions and communication, for example for communal public relations, without showing 1:1 the actual condition after the end of the planning phase (Zeile et al., 2006).

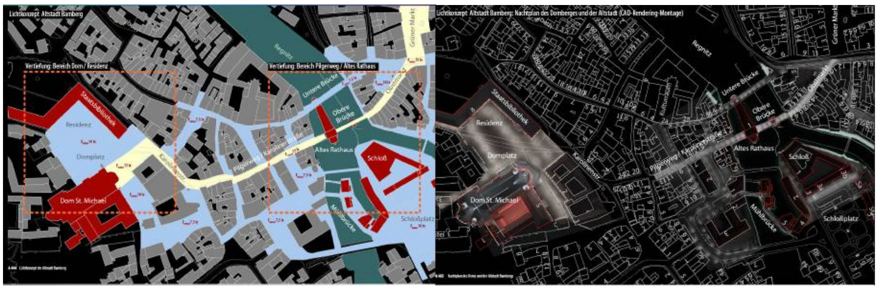

Figure 11. a.) Exemplarily light concept, old town Bamberg and b.) Relating CAD rendering montage (Reichrath 2006)

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