Street architectural models. Research on improving readability, ergonomics and safety of use

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Abstract. In the first decade of the new millennium, new urban furniture - tactile architectural models dedicated to the blind, began to appear in the spaces of Polish cities and towns. These facilities aroused great interest of tourists and city dwellers, enjoying special popularity among children. By 2017, this type of collection had over 70 objects, which placed Poland at the forefront of Europe. The new form of urban modelling dispelled spontaneously, without specific guidelines and regulations, which unfortunately led to the emergence and reproduction of many faulty solutions. In the years 2016 - 2018, the research team A. Kłopotowska, M. Klopotowski conducted the first comprehensive research in Poland, based on analyses of the whole set of models, available until mid-2017. This text is the substantive continuation of the author's 2017 publication entitled: Tactile architectural models as universal "urban furniture" (WMCAUS Conference, 2017). At that time, partial results of the research were presented, including the reasons for a street modelling career, the diversity of the Polish collection, problems arising from incorrect design, execution, sharing and use, and the reasons for faulty solutions. Currently, the author presents a report of the final stage of the team's research to the date, consisting of the development of specific design and implementation guidelines, as well as technical and operational guidelines that can improve the quality of such studies as the universal urban furniture. The research results can be used as guidelines for the correct design of newly planned models, but also for the introduction of repair solutions for existing models.

1. Introduction

1.1 Purposefulness of research and purpose of publication
In the first decade of the new millennium, new "urban furniture" - architectural models and models dedicated to the blind - began to appear in the spaces of Polish cities and towns. These projections, presenting important and interesting elements of urban space in an attractive way, from the very beginning aroused great interest of tourists and won the acceptance of city dwellers. They presented cities and their elements from a new, unknown perspective. They showed elements of urban assumptions and compositions inaccessible or hard to access through the ordinary experience of a passer-by. Such models have gained particular popularity among children who appreciate the possibility of free touching, pointing, circling, and thus exploring the world in accordance with children's nature. They also gained great recognition among people with mobility problems, including
wheelchair users for whom they have become a new, substitute form of exploring real space which for various reasons is beyond the reach of physical contact.

By 2017, this type of architectural model collection had more than 70 objects, which put Poland at the forefront of Europe. The new form of urban modelling developed spontaneously, without specific guidelines and regulations, which unfortunately led to the emergence and reproduction of many faulty solutions. In the years 2016 - 2018, a Research Team from Białystok University of Technology, composed of A. Klopotowska and M. Klopotowski, conducted the first comprehensive research in Poland, based on the analyses of the whole set of models available to the public until mid-2017. That set of models was examined in terms of their usefulness as a help for the blind, but also in terms of their universal value for other space users. The results of the first stage of the Team's research were presented by the author in the publication entitled "Tactile architectural models as universal "urban furniture" (WMCAUS Conference, 2017) [1]. The author then pointed out the reasons determining such a great career of street modelling in Poland, and presented the diversity of the Polish collection which includes both single and serial models such as landscape assumptions, cities or their parts, urban complexes, buildings and their details - presented in various scales and conventions: realistic, geometrized, plasticized. The main emphasis of this work was put on the presentation of problems and irregularities identified by the Team related to faulty designing, making, sharing and using of the models. In addition, the reasons for the emergence of inappropriate solutions that reduce the utility value of the analysed objects were also indicated.

Currently, the author presents the results of the final stage of the Team's research which aimed to develop the specific design, implementation, technical and operational guidelines that could increase cognitive values, as well as improve the ergonomics and safety of using the models by various groups of recipients. The final results of the Team's research can be used as guidelines for the correct design of newly planned models, but also for the introduction of repair solutions for the existing ones. The proposed solutions can form the basis for the development and implementation of uniform, national design and implementation standards in this type of universal 3D assistance.

The purpose of this text is to draw the attention of a wider international community of architects and other industries responsible for creating tactile models and making them available to the public to the huge potential of this type of architectural representation, and to highlight a number of important aspects that determine their actual usability. Due to the wider than local nature of the phenomenon and related problems (similar errors are made in other European countries), the developed guidelines, after appropriate adaptation, can support the proper development of urban model making in various parts of the world.

2. Research status

Before the Author's, and then the Team's studies, the subject of tactile models was not scientifically developed in Polish architectural literature. The state of affairs found by the Researchers included individual publications devoted to specific examples of models [2], as well as fragmentary threads, devoted to such representations presented in broader studies devoted to the topic of disability [3, 4]. These include the Author's monograph of 2016 devoted to the experience of space and art by blind people [5]. Also, the Authors of the study did not find much support in typhlological literature collections dealing with the topic of scalar representations of space mainly in the context of their use as rehabilitation aids for spatial orientation [6] but not describing the broad cognitive values of architectural models. These studies, however valuable, needed updating due to the passage of time and the completely new character of the phenomenon of street modelling which was primarily a cognitive compensation tool. This problem, as well as the emotional qualities of experiencing space through models, was noticed by the Polish typhlologist M. Jakubowski [7]. An attempt to fill the gap in scientific research has become a series of publications by the Author and M. Klopotowski, published
in the form of short publications in typhlological and architectural publications, at various stages of research [8-10]. The culmination of the Team's comprehensive, extensive studies was a two-volume Polish monograph entitled "Tactile architectural models in the spaces of Polish cities" constituting the first such analysis of the subject. The first part of this work is devoted to examining problems and formulating guidelines for creating and making models available to the public [11], while the second part is a presentation of all examined objects (together with their catalogue), supplemented with a number of indexes, enabling further multi-criteria analysis of information developed by the Authors [12]. There is currently no English translation of this publication, which makes it difficult for foreign researchers of the subject to learn about the results of Team's research. This fact, as well as the Team's belief in the wider than local and universal social values of the above-mentioned issues, seems to be an important premise for writing this text.

3. Area, research progress, methods and adopted paradigms
The research area covered a full set of street tactile models and mock-ups made available for public use until mid-2017 (study termination). Modelling objects presented inside buildings, architectural models completely inaccessible to tactile perception as well as tactile urban models presenting non-architectural content were excluded.

The second stage of the research described here was preceded by extensive preliminary research including preliminary analysis (building a multi-criteria database of objects), field research (detailed measurements, photographic and drawing documentation of the collection), specialist and social consultations (discussions with designers, contractors, clients, users) and multi-criteria critical analyses. The conclusions drawn by the Team in the first stage became the basis for defining the following research assumptions (paradigms defining the strategy of proper research):

- Make models and mock-ups as accessible as possible. According to the spirit of universal design, no group can be discriminated or privileged.
- The tendency to meet safety requirements, ergonomics and comfort for the most vulnerable psycho-physical user group, while assuming no harm to the rest of the target audience.
- Equal access to all cognitive content for the visually impaired people. In line with the spirit of the Convention on the Rights of People with Disabilities [13], these people should have full access to the same information that people who can see obtain in a visual form.
- Maximum compliance of copyright regulations with applicable standards for the production and adaptation of typhographics (including typhochartography), which facilitates learning to use models in a blindfolded environment [14, 15].
- Systematize the modelling process by applying a fixed placement of specific elements to facilitate the orientation of the blind in the model space.

Based on the above-mentioned principles, the main part of the research started - searching for optimal, model solutions and methods of action allowing achieving the highest quality modelling studies. Constructing the guidelines was based on the Authors' knowledge and design experience (including competences related to universal design and typhlological issues). The Team also repeatedly benefited from specialist consultations (including the help of specialists in typhology and guidance from the blind). Good standards known to the Authors from personal experience and research trips at home and abroad as well as experiments and research conducted by centres in Italy (State Touch Museum in Ancona) and Spain (Typhoon Museum in Madrid) were extremely helpful in the development of advice and recommendations.
4. Research results, discussion

Tracing the process of creating these types of studies (from their planning, design and execution to assembly and public disclosure) allowed us to see that it is a very complicated engineering task, often requiring the co-operation of a whole team of specialists. The final spatial result depends on the proper preparation and appropriate experience of the people responsible for the implementation of specific tasks of the project, but also on the mutual co-ordination of the activities of all participants in the process. The results of the Team's research, therefore, apply to all stages, from supporting decision making and choosing optimal solutions conducive to creating models with satisfactory readability, ergonomics and safety of use.

The results of the research were compiled by the Team in the form of recommendations - specific written and drawing guidelines enabling the correct execution and presentation of the models. They are complemented by further forms of result compilations such as:

- patterns - theoretical, model diagrams showing spatial solutions considered most desirable,
- measuring tools - drawings, lists, tables - enabling control of the correctness of adopted solutions and their valorisation,
- list of features and activities - capturing the competences of individual entities responsible for creating models and their proper functioning in the urban space.

A brief description of the recommendations which are the main result of the Team's research, the Author presents below in several problem categories related to such issues as the location of a model in a specific spatial context, the issue of architectural and construction solutions in the field of pedestals, the design and implementation of the model sculpture and the accompanying markings and information, the use of specific technological and material solutions, and finally the maintenance of the completed facility.

4.1. Recommendations related to the location of models

Considering, in particular, the needs of people with disturbed spatial orientation (including blind people), as well as the convenience of other groups of users, it was found that street, tactile architectural models should be located in an unchanging, carefully planned place, easy to unambiguously name and locate in space. For safety, this place should be outside strict pedestrian transfer routes and at the same time within the visual control range of pedestrians (be clearly visible from the main traffic routes). A suitable access route should lead from the main communication route to the model's location - a safe corridor free of obstacles and hazards, and with wheelchair access. An important element of that route should be a textural path (in accordance with local tactile markings of urban surfaces, the so-called TGSiS, or constituting a "normal" surface with contrasting texture indicating the direction of traffic). Inspired by a series of modelling projects from Krakow, the Authors state that an additional, very useful convenience may be the use of additional acoustic guidance systems compatible with users' personal devices (e.g. navigators using GPS technology, or the new Beacon technology tested in Poland) [16]. The Authors also emphasize the need for precise presentation of location data (including the address and geographical coordinates) to facilitate access to the models. The access route should end with an appropriately marked textural floor area marking the place where the tour begins. Such a place will allow a blind person to find the point from which they set off after visiting the model. According to the Team's recommendations, the so-called exposure zone needs to be created (guaranteeing the possibility of free and safe walking or driving a wheelchair around the entire model). In addition, a properly marked (with a feature floor) viewing area should be provided (guaranteeing the safety and ergonomics of viewing of the entire model). All spatial parameters and features of the access corridor, attention fields, exposure and viewing zones were strictly defined by the Authors, depending on various spatial situations. According to the indications of the Research Team, the model should be located in the vicinity of its original in such a way that their
spatial orientation is the same (regardless of whether the model applies to the currently existing space, existing in the past, or likely to occur in a specific future time frame).

4.2. Recommendations related to the incorrect construction of pedestals
As demonstrated by the Author's research, an extremely important issue which co-determines the cognitive values, as well as the ergonomics and safety of its use, is the appropriate pedestal used for the presentation of architectural sculpture. The dimensions and construction of the pedestal should take into account the convenience of observing the model (including the haptic view) by people standing as well as by wheelchair users. Due to the varied size of the displays (depending on the design, scope or scale), the Authors allow different sizes of the display countertop, but they state that such a countertop cannot exceed strictly defined boundary dimensions. The upper limit value is defined by a square which allows the entire exhibit to be embraced with outstretched arms, while the lower limit is a square that guarantees appropriate prestige and presence in space. A similar range, resulting from usability, was also developed for the height dimensions of the countertop. Noticing the ergonomic correlation between the extent of the countertop and the height of the pedestal, the authors determined that there is a need to maintain appropriate (inversely proportional) relationship between these variables. The Authors indicated an algorithm (cross-sectional area) defining this relationship. It can be a tool enabling a proper design of new pedestals, but also an assessment of the correctness of the existing ones. The optimal shape of a countertop was considered to be one that, thanks to its proportions, allows a blind person to easily find themselves in the space of the model (e.g. a rectangle) although the team also allows other shapes of the countertops provided that they are properly marked to support orientation. Particular attention was paid to the implementation of the appropriate (determined by the dimensions) undercut of the countertop, enabling wheelchair access directly under it (this recommendation applies to larger pedestals). Also, the profile of the best countertop under the model was determined to be a convex plate with an oblique profile, enabling the presentation of text or graphic information in a way that is especially convenient for visual-haptic reading. Due to the representative nature of "urban furniture", the form of the entire pedestal should be well thought out and elegant, while not overly exposed (neutral or well matched and in both cases secondary to the content of the exhibit).

4.3. Recommendations for model content
Architectural sculpture representing the existing, reconstructed (currently non-existent) or designed real spaces should allow the viewer to build the most adequate and complete mental images of the presented architectural space. For this to happen, the model image must be a coherent, complementary and substantively justified (appropriately separate) whole. Considering the needs of groups subject to the greatest cognitive deficits in particular, all distortions (including the plasticization of images) that may shape incorrect perceptions and cognitive distortions in the recipient should be avoided. The form of presentation should be realistic, appropriate to the adopted scale of the presentation (the smaller the objects, the greater the geometry - simplification of the objects). The reproduction scale requires special consideration, as it translates into the size of the model. It should enable a clear presentation of all important parts of the model, provided that its size does not exceed the reach of the recipient's arms and allows free use of hands in all areas of movement. On the other hand, it is not justified to reduce objects excessively, beyond the limit value determined by the possibility of finger viewing. According to the Team, one should strive to preserve the numerical scale adopted for a specific type of mapping in architectural art.

The Authors of the research are convinced that the presentation of architectural content in tactile street models should be in maximum compliance with the currently applicable rules (informal standards) relating to the creation and adaptation of typographs, including typographic materials. Such an approach may facilitate learning to read this type of models, which, in the Authors' opinion, should be implemented in centres for the education and rehabilitation of the blind. The 3D image,
intended for tactile viewing, should be created with the necessary generalization (simplification and exclusion of unnecessary elements that hinder haptic reception for a blind person). Properly made markings relating to the content such as information about the scale (numerical scale, scale, human silhouette), geographical orientation markers, the designation of the point "Here you are" should be an integral part of the exhibit. Additional elements of the presentation may supplement the main content, such as a mini (abbreviated) version of the whole, wider spatial context and selected details. In addition to the general recommendations that apply to all models, the Research Team set out precise guidelines for the design of specific types of mappings: landscape, cities, urban assumptions, buildings and their assemblies, and details. Due to the difficulty in orienting oneself in the model (especially for the blind but also for a large group of sighted users), it was found that all elements of content, signs and supplementary content should have a fixed, unchanging location for all models. To this end, the Research Team defined and graphically presented the model principles of such a composition (including the principles of spatial location and separation of individual elements).

4.4. Recommendations related to the information presented on models
The basic 3D image and other elements of content should be complemented by information skillfully selected, developed and presented in a written form. As in the case of content, the elements of information should be presented in a fixed location. The Research Team indicated two basic places for the correct location of textual information including their placement on oblique elements of the plate or pedestal (preferred) or directly on the model plate (allowed after proper separation from the content of the study). According to the Team, each of the models should have a clearly defined front (helping blind people to find themselves in the space of the model) whose marking is related to the order of information distribution. Taking into account the tendency appearing in a large group of existing models, the Authors stated that the emblem (graphic sign) of the model should be used as the starting point of the model, placed above the starting location of the visit.

The rules set out by the Team also include precise guidelines for the substantive content of information such as unambiguous formulation of the model title (considered mandatory for all models) and compact, correctly edited descriptions that include the circumstances of the implementation or the design of the architectural prototype, the belonging of the work to a specific context, the features defining architectural identity, and possible curiosities. In addition, precise guidelines were developed regarding the location of the main message and its language versions (postulating an English translation and possible translations into other languages), as well as Braille transcription (considered indispensable). Referring to the recommendations functioning in Poland, architects recommend that Polish-language Braille messages should be created in accordance with the standards existing in the country (Marburg Medium font) and created in a way that guarantees the durability of the highlighted elements. Based on models already existing in Poland in the Krakow area which are equipped with audio communicators, the Team also proposes to further develop this trend in street modelling, based on new technologies, e.g. the above-mentioned Beacons. The use of an alternative or additional cognitive path can be a useful and universal tool supporting visual and haptic viewing of models by all user groups.

4.5. Technical and operational recommendations
An indispensable guarantee of the appropriate technical quality is the proper professional preparation of the executing persons including their experience in performing typographic studies intended for non-visual recipients. It is extremely important that the implementation process takes place without undue haste, with sufficient time given to necessary executive consultations and corrections related to the deficiencies found. The participation of blind people and people in wheelchairs should be obligatory in such consultations. The Authors stipulate the creation and proper training of a team of disabled consultants specializing in assessing prototypes of models and who can constitute an advisory body across the country or in its regions. Tactile models placed in external space and put into public
use must be resistant to many permanent or periodic factors of nature: weather, thermal, biological, chemical, mechanical. Due to the fact that recipients might be people with impaired perception and movement abilities, sculptures must be built in a way that guarantees the highest safety of use (all hazardous elements and features that may result in accidental injury, cuts, abrasions, burns to the recipient, must be eliminated). The design of the model and the pedestal if subjected to weight and force must be appropriately resistant and stable (it also includes taking into account the wrong ways of using the model and acts of vandalism). The areas around the models and the models themselves must be subject to regular inspection, maintenance and cleaning (for sanitary and aesthetic reasons). This last issue requires special emphasis due to the exposure of blind recipients to unpleasant and even dangerous haptic experiences and the so-called "tactile defence" (fear of touching unknown surfaces, characteristic of many blind people). In the case of models with troughs, the plate on which the sculpture is presented should have drainage (it should be cleaned regularly). At the location of the model, appropriate lighting should be provided, ensuring good visibility of the area, but also a correct, not distorted by shadows, picture of the architectural sculpture itself. In the access and exposure zones, floor lighting, which may blind the visually impaired, is excluded.

4.6. Valorisation of activities related to the creation and publication of modelling studies

The conducted research and postulative conclusions of the Authors also allowed for the construction of a research tool for the valorisation of specific, individual solutions ( spatial, ergonomic, modelling, typhological, artistic, technological-material and functional). They were classified as features and actions as follows: desirable, acceptable and unacceptable. The first group includes examples of solutions considered model, the so-called good patterns. This group includes features and activities used currently, but also those that have not yet been implemented or sufficiently popularized, and which, according to the Team, may develop in the future into desired trends and tendencies. The second group includes solutions acceptable in certain specific situations when it is not possible to obtain fully satisfactory solutions. These deviations should always be compensated for by using additional facilities presented by the Team. The last group includes sets of features and solutions considered by the Team to be negative - dangerous, uncomfortable, unfavourable or unsuitable for the recipient. Solutions of this type should be completely excluded due to their harmfulness in a specific, individual implementation but also in the context of their potential impact on further shaping of urban model making. This summary, presented in the form of a table, also allows indicating the scope of responsibility of individual entities (those performing specific tasks and activities relating to creating models and their functioning in urban space). Determining and indicating the competences and scope of duties of specific people seems to the Team to be an important element, important for raising personal responsibility and social control (relating e.g. to the correct use of public funds).

5. Conclusions

The collection of street architectural models that has developed in Poland for over a decade is currently one of the largest European collections. New "urban furniture" set up in public spaces are not only attractive urban gadgets - useful for tourists and making the inhabitants proud. Due to their extra-visual (touch-kinesthetic and sometimes also acoustic) transmission of content, they have typhlorehabilitation potential, and for people with impaired mobility they can be an alternative way of exploring the city. Also, the type of modelling presented illustrates the thoroughly positive mental changes taking place in the Polish society which gradually opens up to the needs of the blind and is attempting a practical implementation of the idea of universal design in further areas of life. In order for these attempts to lead to real equality of opportunities for users with special needs, the models put into service must be of adequate quality, which includes such elements as legibility, ergonomics and safety of use. The Team's research results compiled in the form of specific guidelines (referring to various stages of creating and making models available to the public) as well as benchmarking solutions and control tools can become a way to optimize this type of mapping in the country and abroad.
The author also proposes further, interdisciplinary scientific research, the aim of which should be to develop and then implement into Polish legislation such design and implementation standards that guarantee the appropriate quality of urban tactile models. Due to the intensive development of street modelling and some noticeable trends and tendencies changing within this sub-discipline, it is very important to continue monitoring the phenomenon in order to systematically update the knowledge about emerging problems, threats and ways to effectively eliminate them.

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