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AUGMENTED REALITY AS A TOOL FOR DEVELOPING EVALUATION CRITERIA FOR AESTHETIC QUALITIES OF DESIGNED ARCHITECTURAL OBJECTS

Abstract. *The article describes an experimental study conducted by the Department of Innovative Technologies in Architectural Environment Design and the Department of Urbanism and City Planning of O. M. Beketov National University of Urban Economy in Kharkiv. The experiment is the result of combining two scientific areas, namely: 1) Study of the communicative capabilities of VR in architecture; 2) Implementation of criteria for assessing the aesthetics of the architectural environment in the developed national rating system of environmental certification. As a result of the synthesis of these two areas, the* ***purpose*** *of the experiment was formed: to identify the performance and objectivity of statistical analysis methods based on a questionnaire survey of respondents in the VR environment. The results of this analysis are the criterion for assessing the aesthetic qualities of architectural objects in the national 'green standard' developed by the authors. The object of the study is the 'Virtual Art Gallery in Kharkiv'.* ***Methods****: through a system of QR codes located around the design site, through the augmented reality environment, respondents were able to visually interact in real time with the design object. Respondents were also asked to fill out a questionnaire linked to a virtual object and evaluate its aesthetic qualities. The* ***results*** *of the experiment confirmed the*

potential value of the criteria for evaluating the aesthetic qualities of architectural objects as a method for calculating the corresponding points in the national environmental certification system being developed. The experiment also successfully identified a number of aspects of virtual reality as a communication tool between the architect and the city community. ***Conclusions.*** *The experiment demonstrated the potential of using VR technologies to enhance public participation in shaping the architectural environment. The proposed method for assessing the aesthetic qualities of architectural objects is relevant for further use in the national environmental certification system.*
Key words: *Aesthetics of Architecture, Visual Ecology, Green Standards, Augmented Reality.*

ДОПОВНЕНА РЕАЛЬНІСТЬ ЯК ІНСТРУМЕНТ ФОРМУВАННЯ КРИТЕРІЇВ ОЦІНКИ ЕСТЕТИЧНИХ ЯКОСТЕЙ ПРОЄКТОВАНИХ АРХІТЕКТУРНИХ ОБ'ЄКТІВ

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Анотація. *У статті описано експериментальне дослідження, проведене кафедрою інноваційних технологій у дизайні архітектурного середовища і кафедрою урбаністики та містобудування Харківського національного університету міського господарства імені О. М. Бекетова. Експеримент став результатом поєднання двох наукових напрямів, а саме: дослідження комунікативних можливостей віртуальної реальності (VR) в архітектурі; впровадження критеріїв оцінки естетики архітектурного середовища в розроблену національну систему екологічної сертифікації. В результаті синтезу цих двох напрямів було сформульовано* ***мету*** *експерименту: виявити ефективність і об'єктивність методів статистичного аналізу на основі анкетного опитування респондентів у VR-середовищі. Результати цього аналізу є критерієм оцінки естетичних якостей архітектурних об'єктів у межах національного «зеленого стандарту», розробленого авторами. Об'єктом дослідження виступила «Віртуальна художня галерея в Харкові».* ***Методи****: через систему QR-кодів, розміщених навколо ділянки проєктування, у середовищі доповненої реальності респонденти мали змогу в режимі реального часу візуально взаємодіяти з об'єктом проєктування. Також респондентам було запропоновано заповнити анкету, пов'язану з віртуальним об'єктом, і оцінити його естетичні якості.* ***Результати*** *експерименту підтвердили потенційну цінність критеріїв оцінки естетичних якостей архітектурних об'єктів як методу розрахунку відповідних балів у національній системі екологічної сертифікації, що розробляється. Крім того, експеримент успішно виявив низку аспектів віртуальної реальності як комунікативного інструменту між архітектором і міською спільнотою.* ***Висновки.*** *Експеримент показав потенціал використання VR-технологій для підвищення участі громадськості у формуванні архітектурного середовища. Запропонована методика оцінки естетичних якостей архітектурних об'єктів є релевантною для подальшого використання в національній системі екологічної сертифікації.*
Ключові слова: *естетика архітектури, візуальна екологія, зелені стандарти, доповнена реальність.*

Analysis of recent research and publications. Within the architectural community, there is growing interest in research devoted to the transformative impact of artificial intelligence (AI) on design practices. Matias del Campo explores generative approaches based on the management of large data sets, moving beyond traditional design paradigms [1]. Andrew Kudless examines the dynamics of machine-learning technologies, particularly in the field of text-to-image generation, and their influence on the development of virtual architecture [2].

Aljawharah A. Alnaser investigates the intersection of AI-driven digital twins and the Internet of Things (IoT) in the creation of a sustainable built environment [3]. Interest in this direction, especially in the context of green building technologies, is confirmed by a large-scale review conducted by Samar M. Zayed [4]. Further development of this research field links green standards to the Sustainable Development Goals [5]. The breadth of new opportunities enabled by the symbiosis of artificial intelligence tools, the advancement of virtual and augmented reality, and automated prototyping technologies has become the subject of new publications that synthesize accumulated architectural experience [6]. In this context, Nermen M. Matter examines the relationship between creative design and advanced construction technologies [7].

Introduction. This study is the result of interaction of two scientific directions: study of communicative possibilities of VR in architecture; implementation of criteria for assessing aesthetic qualities of architectural environment in the developed national rating system of ecological certification. In the process of creative and scientific interaction of these directions, we conducted an experiment (described below in the text), the purpose of which was to determine the prospects for using augmented reality tools in the formation of criteria for assessing the aesthetic qualities of buildings in the developed national rating system of ecological certification.

The national architectural school does not have the practice of conducting research similar to the experiment described in the paper. This ensures the prospects for the development of the national school of architectural virtualistics. Also relevant is the development of a national green standard, enriched with knowledge from visual ecology. We have not identified similar approaches in global practice.

This paper originates from an engaging discussion held during the seminar titled ‘Sustainable Development Goals in Green Standards’, organized for postgraduate students from the Department of Innovative Technologies in Architectural Environment Design and the Department of Urbanism and City Planning at O. M. Beketov National University of Urban Economy in Kharkiv. The central topic of the discussion was the ‘Quality Views’ criterion within the ‘Indoor Environ-mental Quality’ category of the LEED (Leadership in Energy and Environmental Design) credit library [8]. The discussion followed a structured format [9], comprising the following stages:

Topic introduction. The seminar discussion was moderated by Valentyn Holius, a postgraduate student with research interests focused on developing a framework for a national rating system for environmental certification of buildings. The discussion revolved around the LEED standard’s ‘Quality Views’ criterion, which specifies that views from windows should include elements such as ‘nature, urban landmarks or art’, among other requirements. Many participants interpreted this criterion as a focus on the aesthetic qualities of the environment. Consequently, the central question of the discussion was framed as follows: ‘If a green standard includes a requirement for window views, should designers be held responsible for how a building affects the views from neighboring structures?’. Notably, this question significantly influenced the research directions of two novice scholars who attended the seminar.

Presentation of positions. Valentyn presented the position that architects should consider the impact of buildings on the aesthetics of their surrounding environment. He argued that this consideration should be integrated into green rating systems as a criterion for allocating credits.

Valentyn’s primary opponent, postgraduate student Denys Shataliuk, whose research focuses on ‘Communicative Tools of Virtual Reality in Architecture’, held a contrasting view. Denys argued that aesthetic qualities, while important, cannot be objectively quantified and thus should not form the basis for credit allocation in green standards. He interpreted the ‘Quality Views’ criterion as being primarily related to insulation, visual accessibility, and unobstructed views, rather than imposing specific aesthetic requirements. Other participants aligned themselves with one of the two main positions and are therefore not discussed further in this paper.

Discussion of arguments and counterarguments. Argument 1 (Valentyn): Aesthetic qualities of the architectural environment significantly influence mental health and well-being. This notion is strongly supported by John Dewey's seminal work 'Art as Experience' [10]. Accordingly, Valentyn proposed introducing a criterion in green standards to evaluate the designed object's impact on the aesthetic qualities of the development area.

Counterargument 1 (Denys): While agreeing with the premise that aesthetics influence well-being and productivity – an area that has gained considerable research attention over the past two decades – Denys noted a lack of methodologies to quantitatively assess a building's aesthetic qualities. This challenge extends across various disciplines, including architecture, psychology, and art history, and highlights the difficulty of incorporating aesthetics into standardized evaluation systems. Moreover, Denys pointed out that research into aesthetics and mental health often remains qualitative, leaving its integration into green standards unresolved.

Argument 2 (Valentyn): While I have not found extensive data on the quantitative assessment of beauty, I do not exclude the possibility that such studies exist. For example, the research school led by Professor Oksana Fomenko has developed methods to evaluate the informativeness of architectural imagery, operating within the framework of 'Visual Ecology', a subfield of ecology [11]. The importance of integrating aesthetics into green standards is evident. The WELL standard, for instance, explicitly emphasizes the creation of aesthetically pleasing projects in paragraph C02 'Integrative Design', part 2 [12]. Furthermore, the trend of incorporating voluntary environmental certification systems into national building standards highlights the necessity of addressing aesthetics. I believe that the adaptability and responsiveness of green standards to evolving trends in the construction industry are critical to tackling this challenge effectively.

Counterargument 2 (Denys): Indeed, the WELL standard includes such a requirement, and it references data from the International Living Future Institute [13], which outlines the key aesthetic requirements for architectural structures. However, I believe that attempting to develop criteria for the quantitative evaluation of architectural aesthetics is a dead end. Instead, I propose an alternative approach to addressing the issue raised.

Search for Agreement or Compromise: During the discussion, Denys Shataliuk proposed a compromise approach to evaluating the aesthetic qualities of architectural objects by leveraging Virtual Reality (VR) tools and conducting surveys among city residents. This method acknowledges that concepts of beauty and aesthetic preferences evolve over time and vary significantly across population groups based on factors such as education, gender, age, and cultural background. Consequently, any attempt to rigidly quantify beauty is inherently flawed and risks creating a foundation for future conflicts within the framework of a standard. As a result of the discussion, the participants formulated a research hypothesis, which is outlined below.

Research Hypothesis: The use of Augmented Reality (AR) tools appears to be a promising direction, particularly through the development of a mobile application interface (potentially using the ARKit platform). This application would enable the overlay of a three-dimensional projection of a proposed project onto the actual construction site using geolocation systems and QR code access. Additionally, an interactive survey template, similar to Google Forms, should be integrated into the application to facilitate quick feedback collection from users.

Research Methodology. Following the seminar, a research group was established, comprising two post-graduate students and their supervisors. A comprehensive research strategy was devised, encompassing several tactical tasks:

Development of a Method for Assessing the Aesthetic Qualities of a Designed Structure. After deliberation, it was determined that a statistical survey represents the most objective approach to establishing criteria for evaluating the aesthetic appeal of buildings. The Quantitative Survey method was selected for the following reasons:

– relevance to Social Sciences – surveys are a widely accepted quantitative method in social sciences, providing response options that can be converted into numerical data for statistical analysis;

– local Adaptability – this method is highly effective for designing survey templates addressing locally specific issues [14];

– compatibility with Visual Research – the method integrates seamlessly with visual sociological research, which is critical in the context of architectural aesthetics [15].

Luc Pauwels [16], a key contributor to visual sociology, offers an approach termed 'Researcher-Initiated Production of Visual Data and Meanings', which aligns with our objectives. This approach emphasizes analyzing 'secondary' (mediated) visual reality, often inaccessible directly, making it an excellent match for Denys Shataliuk's proposed use of augmented reality (AR).

In this context, visual research begins with a primary reality onto which a new reality (a 3D architectural object) is superimposed. This enables researchers to identify and document specific events and phenomena, either as intermediate stages or final scientific outputs. Designing high-quality visuals ensures better control over data collection, producing more contextualized material. This approach is expected to enhance the understanding of the produced data by ac-counting for external factors and sample characteristics.

Conducting an Experiment Using Augmented Reality Tools. To assess the aesthetic qualities of the architectural environment, an experiment was designed to combine the Quantitative Survey Method with the interactive capabilities of augmented reality. This decision was informed by the wide-spread availability of computers, tablets, and smartphones with internet access, enabling the experiment to be conducted online in a digital format.

Key conditions for the experiment included:

– identifying target groups to ensure a representative sample;

– formulating clear questions for the respondents;

– developing a straightforward survey mechanism for ease of participation;

– organizing data collection and processing efficiently.

A significant advantage in organizing the experiment was the participation of Valentyn Holius, who had completed seven courses in Google UX Design [17] and earned a Google Professional Certificate. This training equipped him with a step-by-step methodology for product development, applicable to both digital applications and physical objects.

The Product Development Life Cycle he learned comprises five stages: brain-storm, define, design, test, and launch (see Fig. 1). This structured approach facilitated the creation of an AR-based interface for presenting architectural objects and collecting data in a systematic, user-friendly manner.

Fig. 1. The product development life cycle [18].

Source: Image from Google UX design professional certificate course

The development of the product followed the structured stages of the Product Development Life Cycle, each contributing to the creation of a robust and effective solution for integrating augmented reality (AR) tools into the evaluation of architectural aesthetics.

Stage 1: Brainstorming. During the brainstorming stage, a research team was formed, including two dissertation supervisors, two PhD students, and four Master's degree students. The primary goal of this stage was to develop a strategy for an experiment exploring the use of AR in calculating credits for the aesthetic qualities of architectural designs within a national green standard.

Key activities included:

– identifying target respondent groups: architects, students from architectural and art universities in Kharkiv, and parents of students;

– determining an appropriate sample size of 50–120 respondents;

– defining the main parameters of the questionnaire;

– selecting the optimal software tools for project implementation;

– identifying the object and location for the experiment.

Stage 2: Defining the Product. The second stage focused on defining the core aspects of the product. This included formulating the questionnaire, tailored to the specific needs of each target group:

– professional language for architects;

– everyday wording for students' parents;

– a mixed style for students.

Stage 3: Designing and Developing the Product. At this stage, the structure and organization of the product were developed. Key outputs included:

– a prototype of the questionnaire, including parameters for access and methods for data collection and interpretation;

– selection of the optimal methods for presenting a virtual architectural object, ensuring clarity and engagement.

Stage 4: Testing. The testing phase involved several iterative processes:

– alpha testing – conducted internally by the research team to identify technical failures and usability issues;

– beta testing – conducted with students and teachers of O. M. Beketov National University of Urban Economy in Kharkiv.

During this stage, algorithms for collecting and processing statistical data were developed. Feedback from multiple testing cycles allowed for refinements to ensure smooth interaction between the product and users.

Stage 5: Launch. In the final stage, the product was officially launched, marking the completion of the development process. This stage ensured that the product was fully opera-tional and ready for use in the experiment to evaluate the integration of augmented reality in assessing architectural aesthetics.

Results and Discussion. *Results and Discussion.* In April 2024, a roundtable was organized with the aim of developing a strategy for conducting an experiment to establish criteria for assessing the aesthetic qualities of designed architectural objects. The study's hypothesis posits that such assessments can be effectively carried out through a statistical survey of targeted citizen groups.

Challenges and Limitations. In accordance with the Law of Ukraine dated March 24, 2022, No. 2160-IX [19], circumstances significantly restricted our ability to implement the experiment. The initial plan involved placing QR codes around the project site, allowing respondents to view an augmented reality (AR) overlay of the project within its real world context through their digital devices and subsequently complete a questionnaire. However, due to the ongoing war, we could not execute the experiment in full. The chosen site for the project is situated near a bridge classified as a strategic object, where photographic documentation is prohibited during wartime.

Confidence in the Approach. Despite these constraints, we maintain high confidence in the success of the proposed method. This confidence is based on the growing global application of AR tools to facilitate communication between architects, city governments, and urban populations. The integration of ARKit and ARCore into standard GIS applications has introduced innovative tools for visualizing construction projects, offering planners and city councils new means of interaction. AR technology enables citizens to engage with virtual projects in real world settings under varying conditions, such as different weather and lighting scenarios, and from diverse viewpoints. This approach builds on positive global experiences of employing digital technologies for urban planning dialogue.

Global Insights and Examples.

– England – the smartwatch app ChangeExplorer explores the potential of digital wearables to involve citizens in urban planning. This app encourages users to reflect on and comment on their surroundings [20].

– Singapore – bige Tunзer, founder of the Informed Design Lab at the Singapore University of Technology and Design, is advancing AR principles to enhance urban design strategies [21].

– Switzerland – the Department of Geography at the University of Zurich conducted a comparative study evaluating AR against traditional methods for presenting future building designs. Their findings revealed the most effective degree of abstraction in AR presentations for accurately interpreting virtual objects and achieving the optimal level of detail [22].

Relevance to Our Study. These international examples highlight the transformative potential of AR in urban planning. By allowing citizens to experience a virtual project in its intended environment, AR not only enhances public understanding but also fosters a collaborative approach to design evaluation. These insights reinforce the feasibility and value of employing AR tools in the development of aesthetic criteria for architectural designs.

Implementation of AR Prototypes and Current Development Stage. A notable example of AR application in architectural design comes from Sweden, where a prototype was developed as a native AR app for iOS devices using Swift and Apple's ARKit 3. This toolkit enables the tracking of movements through the device's camera, plane detection for depth perception, and real-time light evaluation. The building design was integrated into the AR app as a world-scale scene using the ArcGIS Runtime SDK for iOS [23]. The app also tracked the viewer's GPS location in the background at one-second intervals.

Current Project Progress. Drawing from such global examples, we are confident that our project will be fully realized in peacetime. At this stage, we are focusing on technical preparations by simulating select fragments of the proposed experiment.

To expand the project's scope during its development phase, we added an additional component – a link to the Autodesk Fusion website, where we uploaded a 3D model of the Virtual Art Gallery (see Fig. 2).

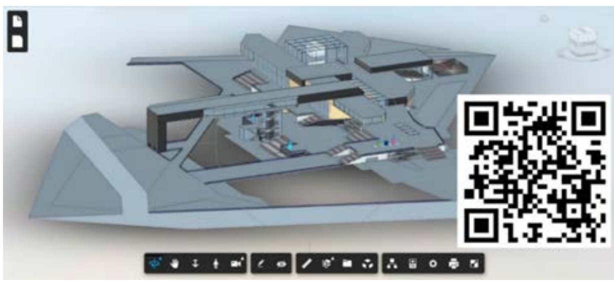

Fig. 2. Virtual Art Gallery

Source: diploma project of Ostras V. and Vedenyeva E., binding of the object to the locality – Shataliuk D., students of the Department of Innovative Technologies in Architectural Environment Design. O. M. Beketov National University of Urban Economy in Kharkiv

This link was shared on the web-site of the Department of Innovative Technologies in Architectural Environment Design at O. M. Beketov National University of Urban Economy in Kharkiv, under the section 'Scientific Activity – Experiment Using AR' [24].

Multidisciplinary Strategy and Goals. The project has been structured as a multidisciplinary initiative with a diverse set of objectives, including:

– developing methods for teaching students to work in groups using BIM

Technologies;

– mastering virtual reality tools;

– creating virtual spaces with varying functional purposes;

– designing communication strategies between investors, architects, and urban communities;

– practically exploring the design of gaming spaces;

– learning multidisciplinary approaches to collaborative work;

– implementing principles of barrier-free architecture.

Data Collection and Survey Adjustments. A link to the survey, created using Google Forms, was also published on the department's website (see Fig. 3). Considering the early stage of the study and the constraints imposed by the current situation in Ukraine, several adjustments were made:

– the number of survey questions was reduced;

Fig. 3. Link survey in Google Forms, posted on the website of the Department of Innovative Technologies in Architectural Environment Design, O. M. Beketov National University of Urban Economy in Kharkiv

Source: Holius V., postgraduate student of the Department of Urbanism and City Planning. O. M. Beketov National University of Urban Economy in Kharkiv.

– respondent groups were combined to simplify data collection.

These modifications were influenced by practical considerations, including the fact that most respondents are located in Kharkiv, where access to electricity and the Internet is often unstable. However, the research team believes that these adjustments do not significantly diminish the overall value of the study.

By adapting our methods to current challenges, we aim to establish a solid foundation for future research and full-scale experimentation.

Survey Design and Statistical Framework. At this stage of the project, the questionnaire includes three key items:

1. Does the building look aesthetically pleasing? Answer: Yes/No.

2. Does the gallery fit harmoniously into the urban space? Answer: Yes/No.

3. Rate your overall gallery experience on a scale of 1 to 10.

The first two items aim to capture the respondent's general emotional reaction, yielding unambiguous results for statistical analysis. These responses are processed using the Coefficient of Positive and Negative Evaluations (K_{PN}), calculated with the following formula (1):

$$K_{PN} = x/(x+y), \quad (1)$$

where is:

K_{PN} – Coefficient of positive to negative evaluations (range: 0–1).

x – Number of positive evaluations.

y – Number of negative evaluations.

The third item provides deeper insights into emotional correlations within target populations. These responses are analysed using the Coefficient of Emotional Reactions (K_{ER}), calculated as:

$$K_{ER} = (1\times n_1 + 2\times n_2 + \ldots +10 \times n_{10})/n/10, \quad (2)$$

where is:

K_{ER} – Coefficient of emotional reaction correlations in target population groups.

n_1–n_{10} – Number of respondents who rated the virtual object in gradations from 1 (n_1) to 10 (n_{10}).

n – Total number of respondents.

As a result, three statistical data were obtained, describing the emotional reactions of respondents with a slope from 0.1 to 1. The final coefficient (K_F) is the arithmetic mean of the above coefficients.

Integration of Findings into the National Green Standard. Based on the study's hypothesis, the national green standard could award up to three credits (out of 110) for the aesthetic qualities of a designed object. The credits are distributed as follows:

1 Credit – K_F = 0,5-0,6.

2 Credits – K_F = 0,7-0,8.

3 Credits – K_F = 0,9-1.

Challenges in Dynamic Assessment. Due to the ongoing war, the experiment's dynamic component – assessing architectural objects in motion and over time – could not be fully realized. Initially, we envisioned respondents moving along a predetermined trajectory around the project's location, evaluating the object through AR at multiple designated viewpoints (at least seven). These viewpoints were to align with the primary visual axes of the location, allowing us to collect data dynamically and from multiple perspectives.

While this aspect of the experiment remains untested, the research team believes the primary goals were successfully achieved. The static data collected provides a solid foundation for integrating aesthetic quality assessments into the national green standard. Future studies will expand upon this groundwork by exploring dynamic evaluation methods and determining the optimal number of viewpoints for comprehensive analysis.

Conclusions. The described experiment allowed us to collect and summarize a number of data necessary for the further development of two interrelated studies: study of the communicative capabilities of VR in architecture; implementation of criteria for assessing the aesthetic qualities of the architectural environment in the developed national rating system of environmental certification.

The following results were obtained:

1. Currently, augmented reality as a tool for communication between architects and the urban community is actively developing all over the world. In this study, the task was to identify the key features of such communication typical for the Kharkiv region. During the experiment, the following generalizations were made:

– the majority of respondents are in the age group from 15 to 30 years. Obviously, this distribution is due to the fact that performances related to the public demonstration of a virtual object have high gaming potential and are most interesting to this particular group;

– for communication between respondents and architects in the experiment, a chat was created linked to QR codes. As a result, when respondents moved from one location to another, they had to re-enter the chat each time. Because of this, interest in communication was quickly lost. For this reason, it was decided to link the chat to a virtual object in future experiments rather than a QR code;

– support for performances similar to the presented experiment by blogs in the mass media is critically needed. This is due to the direct relationship between the number of respondents and the objectivity of the data obtained;

– for the successful development of the scientific and practical direction being developed, it is advisable to obtain support from the Department of Urban Development and Architecture and the Department of Digital Development of Kharkov.

2. In the process of testing the method for calculating credits for the aesthetic qualities of a building in the national green standard being developed by the authors, the following conclusions and generalizations were made:

– the hypothesis about the advisability of using the statistical analysis method in forming credits for the aesthetic qualities of a building was confirmed. During the experiment, the expected coefficients for calculating the rating were obtained;

– the method reflects the average statistical idea of citizens about the aesthetic qualities of buildings, which often does not coincide with the opinion of experts;

– an idea has been formed about the need to introduce an increasing coefficient for expert assessments when forming credits for the aesthetic qualities of buildings;

– the parameters of the increasing assessment must be identified experimentally. There is insufficient data for this today;

– an interesting side effect associated with a chat linked to a virtual object has been identified. The chat allows identifying the aesthetic and design flaws of an object when perceiving it in motion, from different angles and at different distances to it.

In general, the results obtained during the experiment give the right to assert that the experiment is successful, and the research directions themselves are promising.

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