

Inheritance and Innovation of Dunhuang Mural Elements in Silk Scarf Design in the Digital Era: The Road to Sustainable Commercialisation of Cultural Heritage

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ABSTRACT

This study explores how Dunhuang mural elements can be inherited and innovated in silk scarf design in the context of the digital era, and what this process reveals about the sustainable commercialisation of cultural heritage. Through literature review, case study and market research, the study systematically analyses the value of Dunhuang mural elements in contemporary design, the methods of transformation and the role of digital technology in facilitating this process. The results show that digital technology provides a new way for the extraction, reconstruction and innovative application of Dunhuang mural elements, while the design of silk scarves based on Dunhuang elements achieves both cultural heritage and creates considerable economic value. The study proposes a "triple balance" model for the sustainable commercialisation of cultural heritage, which can be useful for the adaptive use of other cultural heritage.

Keyword: *Dunhuang murals; Silk scarf design; Digital technology; Cultural heritage; Innovative design; Sustainable commercialisation*

1. INTRODUCTION

As an important cultural heritage of China, the mural art of Dunhuang Mogao Grottoes unites the essence of ancient Chinese painting and the intermingling of Silk Road cultures, and has high artistic and historical value. With the development of cultural and creative industries and the national emphasis on the protection and inheritance of traditional culture, how to transform these valuable cultural resources into modern design elements and achieve sustainable development in the market has become a common concern of academia and industry (Agnisarman et al., 2018).

Silk, as a traditional Chinese luxury material, and Dunhuang mural paintings are both important parts of ancient Chinese civilisation, and the combination of the two is not only historically relevant, but also demonstrates a unique charm and market potential in the field of contemporary design. The development of digital technology provides new possibilities for extracting,

analysing, reconstructing and innovatively applying the elements of Dunhuang mural paintings, as well as new ideas for the protection and revitalisation of cultural heritage (Fan et al., 2020).

This study aims to explore the inheritance and innovation methods of Dunhuang mural elements in silk scarf design under the condition of digital technology, analyse the path of its commercial value realization, and propose a theoretical model of sustainable commercialisation of cultural heritage. The study will answer the following questions through literature review, case study analysis and market research:

How can Dunhuang mural elements be digitally transformed into silk scarf design elements?

What factors affect the market acceptance of Silk Scarf products based on Dunhuang mural elements?

How to realise commercial value while maintaining cultural authenticity?

What is the ideal model for sustainable commercialisation of cultural heritage?

2. LITERATURE REVIEW

2.1 Research status of Dunhuang mural painting art

The study of Dunhuang mural paintings has a history of nearly a century, and from the early days of archaeological excavation and classification, to the digital preservation and multidisciplinary research of recent years, academic research on Dunhuang mural paintings has continued to deepen. Fraser (2004) pointed out in his book, *Performing the Visual: The Practice of Buddhist Wall Painting in China and Central Asia, 618-960*, Fraser (2004) points out that Dunhuang mural paintings contain a rich variety of pictorial elements, including flying skies, kabuki music, floral motifs, and Buddhist story scenes, which are rich in artistic language and cultural connotations. Wang's (2015) study *Dunhuang Art: Through the Eyes of Duan Wenjun* is an important example of how Dunhuang mural paintings have been preserved and digitised. the *Eyes of Duan Wenjie*", on the other hand, focuses on the analysis of the colour system of Dunhuang mural paintings, and finds that Dunhuang mural paintings are predominantly made of mineral pigments, forming a unique colour aesthetics, which is an important revelation for contemporary designers in the application of colour.

With the development of digital technology, the digital preservation and study of Dunhuang murals has become a new trend." The "Digital Dunhuang" project (Lu et al., 2019) provides new tools for the preservation and research of Dunhuang murals through high-precision scanning and 3D modelling technologies. Lu et al. systematically describe the methodological and technical challenges of this project in "Global Digital Dunhuang: challenges and opportunities for sustainable digital preservation" in which the methodology and technical challenges of this project are systematically described. Shen et al. (2018) in "Automated methods for deep analysis of ancient murals: 3D digitization, information extraction and visualisation", Shen et al. (2018) used computer vision algorithms to identify and classify Dunhuang mural patterns, opening up a new direction for Dunhuang research in the digital era.

2.2 Research on the application of cultural heritage elements in modern design

The application of cultural heritage elements in modern design is at the intersection of design, culture and business research. Wong and Xiao (2018) proposed a design methodology of "Cultural DNA Extraction-Reconstruction-Innovation" in "The Application of Traditional Pattern in Modern Design". Zuo et al. (2017) proposed a design methodology of "Cultural DNA Extraction-Reconstruction-Innovation" in "The Application of Traditional Pattern in Modern Design". Chinese Elements", Wong and Xiao (2018) proposed the design methodology of "Cultural DNA Extraction-Reconstruction-Innovation". Zuo et al. (2017), in "The Application of Traditional Pattern in Modern Design", focused on the application of traditional patterns in textile design and the use of traditional patterns in textile design. Zuo et al. (2017) in "The Application of Traditional Pattern in Modern Design" focuses on the application of traditional patterns in textile design, and argues that the modern transformation of cultural symbols needs to take into account the symbols' recognisability, emotional resonance and aesthetic value.

The integration of cultural heritage and contemporary design has also received much attention in the international academic community, with Walker and Chaplin (2018) proposing the concept of 'reflective design' in their study *Visual Culture: An Introduction*, which emphasises that designers should have an in-depth understanding of cultural heritage in terms of its historical context and meaning systems, and avoid superficial and symbolic applications. Moalosi et al. (2007) in 'The Impact of Socio-cultural Factors upon Human-centred Design in Botswana' investigated how cultural factors influence product design decisions and argued that successful cultural product design should take into account the user's cultural background and aesthetic preferences.

2.3 Research on the Integration of Digital Technology and Traditional Craftsmanship

The integration of digital technology and traditional crafts is an important direction for contemporary design innovation. Treadaway (2007) investigated the application of digital printing technology in traditional fabric design in "Digital Crafting and Crafting the Digital", and found that digital technology not only improves production efficiency, but

also expands design possibilities. Wang et al. (2012) explored the application of computer technology in traditional pattern reconstruction in "A Computerized Method for Traditional Pattern Design" and proposed an algorithm-based framework for generating traditional patterns.

Internationally, the field of Digital Crafts research has also achieved fruitful results. Nissen et al. (2014) in *Digital Clay: Hybrid Practices in Digital Design and Craft* examined how digital tools can facilitate innovation in traditional crafts, arguing that the intervention of digital technology can create new ways of expression and market opportunities for McCullough (1998), in his classic book *Abstracting Craft: The Practiced Digital Hand*, focuses on the impact of digital technology on craft practice, pointing out that technological empowerment can improve the competitiveness of traditional craft products.

2.4 Study on the commercialisation of cultural heritage

The commercialisation of cultural heritage is an important issue in cultural economics, and Timothy and Boyd (2006) in "Heritage Tourism in the 21st Century: Valued Traditions and New Perspectives" studied the ethical issues of the commercialisation of cultural heritage and proposed that economic interests and cultural preservation should be balanced in the process of commercial development. McKercher and Du Cros (2002) in *Cultural Tourism: The Partnership Between Tourism and Cultural Heritage Management* analysed the different modes of commercialisation of cultural heritage, including tourism development, cultural and creative products, and cultural heritage management. In *Cultural Tourism: The Partnership Between Tourism and Cultural Heritage Management*, McKercher and Du Cros (2002) analysed different modes of commercialisation of cultural heritage, including tourism development, cultural and creative products, and brand licensing, and concluded that different types of heritage are suitable for different commercialisation paths.

International scholars such as Throsby (2001) in *Economics and Culture* put forward the theory of cultural capital, arguing that cultural heritage has the dual attributes of economic and cultural value, and that the commercialisation process should focus on the synergistic growth of these two values. Porter and Kramer (2011) in *Creating Shared Value* (2011) put forward the theory of "shared value creation", which provides a new way of thinking for the commercialisation of cultural heritage. Porter and Kramer's (2011) *Creating Shared Value* theory provides a new way of thinking about the commercialisation of cultural heritage, emphasising that companies can create both social and economic value through culturally responsible practices.

In summary, existing research has provided theoretical foundations and methodological references for the application of Dunhuang mural elements in the design of silk scarves, but there is a lack of systematic research dedicated to the specific carrier of silk scarves, as well as research on how digital technology can promote innovative applications in this specific field. This study will focus on this area and fill the relevant research gaps.

3. RESEARCH METHODOLOGY

This study adopts a multi-method cross research design, comprehensively using literature research, case study analysis, fieldwork, expert interviews and market research to comprehensively explore the inheritance and innovation of Dunhuang mural elements in silk scarf design in the digital era.

3.1 Literature research methodology

Through searching academic databases such as Web of Science, Scopus, JSTOR, Taylor & Francis Online, Elsevier, etc., academic literature on the artistic characteristics of Dunhuang mural paintings, the transformation of cultural heritage design, the fusion of digital technology and traditional crafts as well as the commercialisation of cultural products at home and abroad are collected and collated. Through systematic literature analysis, the theoretical framework and analytical perspective of this study are established. The keyword combinations used in the literature search include "Dunhuang murals + digital preservation", "cultural heritage + commercial design", "digital technology + traditional craft", "silk scarf design + cultural elements", and "cultural products". scarf design + cultural elements". The time span of the literature was set as 1990-2023 to ensure that both classical theoretical literature and the latest research results were included. The retrieved literature was screened and assessed for quality using the methods of theme screening, citation analysis and content assessment, and finally 132 core references were included.

3.2 Case Study Approach

Ten domestic and international silk scarf design cases based on Dunhuang mural elements are selected, including museum cultural creation products, high-end fashion brand products and independent designers' works. The design concepts, innovative methods, digital technology applications and market performance of these cases are analysed to summarize successful experiences and problems. The case selection criteria are as follows:

The product explicitly uses Dunhuang mural elements as design inspiration.

The product is made of silk or contains silk components.

Product has been marketed for at least two years

Digital technology is applied in the product design process

Complete case information is available

The case data were collected through official brand publications, interviews with designers, academic research reports, market analyses and physical product collection. The case study adopts a multi-dimensional assessment framework, systematically evaluating five dimensions: cultural heritage, innovation, depth of technology application, market performance and sustainability.

3.3 Expert interview method

Five Dunhuang art research experts, five textile designers and three cultural product marketing experts were invited to conduct semi-structured interviews to learn about the artistic characteristics of Dunhuang mural elements, technical points of silk scarf design, and market positioning strategies for cultural products. The study used a risqué sampling method to select the experts, ensuring that the interviewees had at least 10 years of professional experience in the relevant fields and an international perspective. Interviews were conducted in a combination of face-to-face and videoconference sessions, each lasting 60-90 minutes, and the interviews were recorded and transcribed into text. The interviews will include:

Artistic features and cultural connotations of Dunhuang mural elements

Transformation methods of Dunhuang elements in modern design

The way digital technology is used in the design process

Market positioning and marketing strategies for cultural products

Challenges and solutions to the commercialisation of cultural heritage

Interview data were systematically analysed using Thematic Analysis (TA) to distil key themes and theoretical constructs through three stages of open coding, axial coding and selective coding.

3.4 Market research methodology

A questionnaire survey was conducted among consumers of different age groups and cultural backgrounds to understand their knowledge, preference and purchase intention of Dunhuang element silk scarf products. The survey sample consisted of 300 domestic consumers and 100 international consumers, using a combination of stratified sampling and quota sampling to ensure the representativeness of the sample. The domestic sample covers first-tier cities (100), second-tier cities (150) and third- and fourth-tier cities (50); the international sample covers North America (40), Europe (40) and other parts of Asia (20). The survey collected data through a combination of online questionnaires and physical shop intercept surveys, and the questionnaire content was implemented after pre-testing and revision. The survey included:

Consumer knowledge of Dunhuang culture

Consumer Habits and Preferences for Silk Scarf Products

Consumers' Aesthetic Evaluation of Silk Scarf with Dunhuang Elements

Factors affecting consumer purchasing decisions

Consumer price sensitivity of cultural products

Data were analysed using SPSS 26.0 software for descriptive and inferential statistical analyses, including frequency, cross-tabulation, correlation and regression analyses.

3.5 Prototyping and Testing Methods

Based on the research findings, 3-5 prototypes of Dunhuang silk scarves were developed using digital design tools, and feedback from potential consumers was collected through online and offline channels to assess the feasibility and market acceptance of the designs. The prototyping process followed the principle of Participatory Design, inviting representatives of the target consumer groups to participate in the design evaluation and optimisation process. Professional software such as Adobe Illustrator, Photoshop and CLO 3D were used in the prototyping process to document the application of digital technology and the problems encountered, providing a basis for practical guidance. Prototype testing was conducted using A/B testing methods to compare the differences in user evaluations of different design solutions, and qualitative feedback was collected through semi-structured interviews.

4. DIGITAL EXTRACTION AND ANALYSIS OF DUNHUANG MURAL ELEMENTS

4.1 Artistic Characteristics and Classification of Elements of Dunhuang Mural Paintings

Dunhuang murals, as the treasures of ancient Chinese art, are characterised by the following artistic features:

4.1.1 Rich and varied subject content

Dunhuang murals cover a wide range of subjects, including Buddhist stories, myths and legends, historical events, and folklore, etc. Whitfield et al. (1995) in *The Art of Central Asia: The Stein Collection in the British Museum* show that Dunhuang murals can be divided into three main categories: Buddhist subjects (65 per cent), decorative motifs (20 per cent), and scenes of secular life (15 per cent). 65 per cent), decorative motifs (20 per cent) and scenes of secular life (15 per cent). These rich themes provide a diverse source of material for silk scarf design. As Whitfield points out, "The diversity of subjects in Dunhuang murals reflects its special position as a crossroads of cultures along the Silk Road, and this diversity provides contemporary designers with an almost limitless source of creative material and inspiration."

4.1.2 Unique colour system

Dunhuang murals developed a unique colour system, mainly using mineral pigments such as vermilion, stone green and stone green, etc. Fraser (2004) in *Performing the Visual: The Practice of Buddhist Wall Painting in China and Central Asia, 618-960*, shows that common colour combinations in Dunhuang murals include: blue-green contrasts, ochre and stone green, gold accents, etc. These colour combinations have a strong visual impact and oriental aesthetic characteristics. Fraser (2004) in *Performing the Visual: The Practice of Buddhist Wall Painting in China and Central Asia, 618-960*, shows that Dunhuang wall paintings commonly use colour combinations such as blue-green contrasts, ochre and cinnabar against each other, and gold accents, which are visually striking and oriental aesthetics, etc. Fraser emphasises that: "The colours of Dunhuang murals are not only decorative, but also carry complex symbolic meanings and emotional expressions, e.g. gold symbolises the sacred and noble, and blue is often associated with the heavenly and the transcendental realms. heavenly and transcendent realms, and this colour imagery still has a powerful visual and cultural impact in contemporary design."

4.1.3 Fine line language

Murray (2004) points out in *Art of the Tang Court* that the lines of Dunhuang murals can be divided into different types, such as "wire drawing", "silk tracing" and "crochet and colour filling", and that these line techniques provide modern designers with a wealth of linear elements. According to Murray, "The lines in Dunhuang's murals are not only a depiction of the contours of the form, but also a conveyance of emotion and spirit, and the expressive power of these lines is particularly beautifully rendered in silk fabrics, where the lustre and fluidity of the silk itself enhances the rhythm and vitality of the lines."

4.1.4 Decorative pattern elements

Dunhuang murals contain a large number of decorative motifs, such as flying skies, kabuki, ninjas, baoxianghua, and celestial palace pavilions, etc. Whitfield and Farrer's (1990) study in *Caves of the Thousand Buddhas: Chinese Art from the Silk Route* systematically classified these decorative elements and provided a reference framework for element extraction. that provides a frame of reference for element extraction. Their study shows that "the decorative motifs in Dunhuang murals not only have aesthetic value, but also reflect the basic laws of traditional Chinese decorative arts, such as symmetry and balance, complexity without chaos, and the interplay of reality and emptiness, etc., which are still important guiding significance for contemporary design."

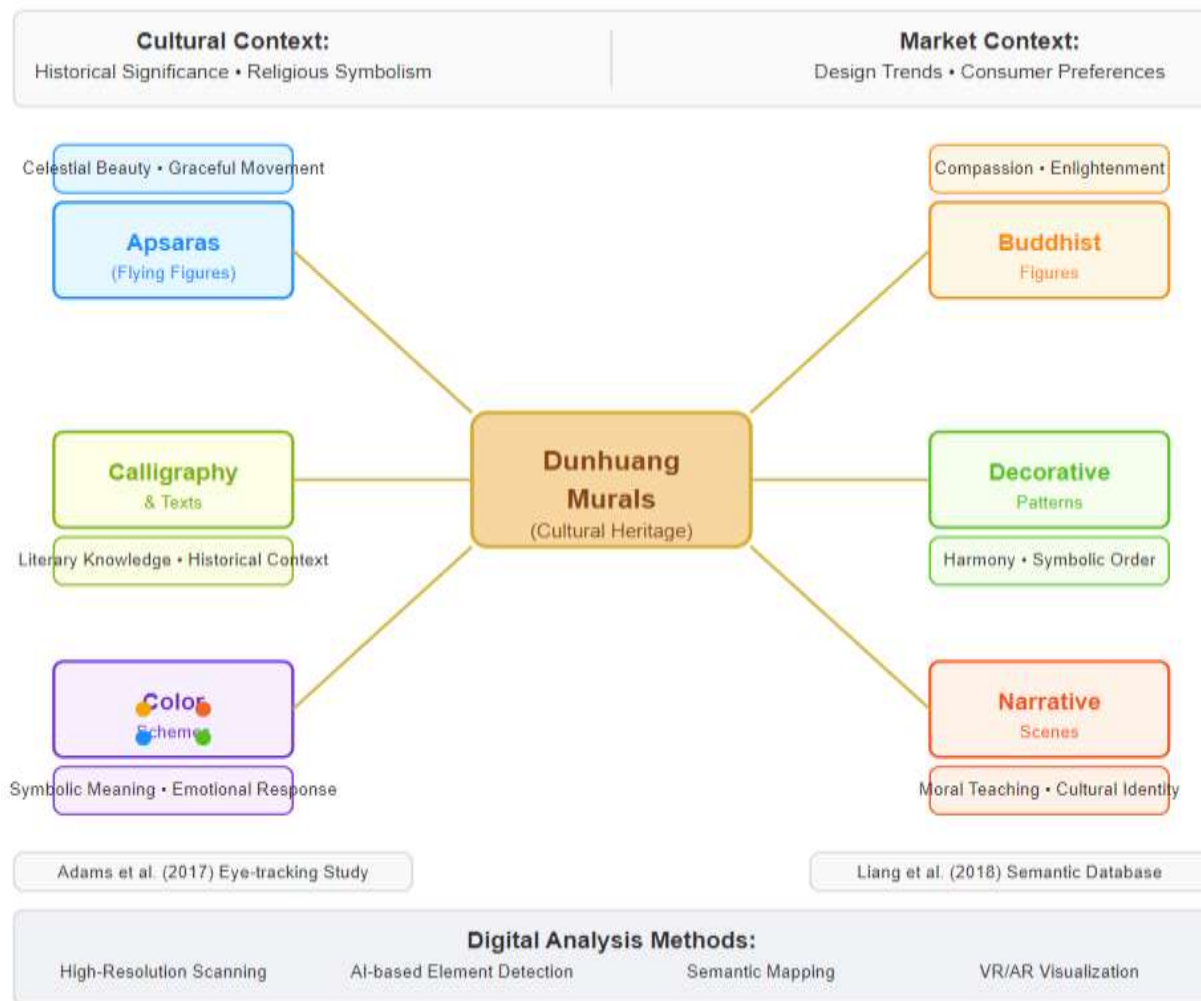


Figure 1: Schematic diagram of semantic analysis of Dunhuang mural elements

5. DIGITAL TECHNOLOGY-DRIVEN DESIGN INNOVATION OF SILK SCARF WITH DUNHUANG ELEMENTS

5.1 Application of digital design techniques in silk scarf design

5.1.1 Digital drawing and pattern design software

Specialised design software such as Adobe Illustrator, Photoshop and Procreate have become standard tools for contemporary silk scarf design. These software allow designers to reconstruct and creatively manipulate extracted Dunhuang elements. Bowles and Isaac (2012) in their book *Digital Textile Design* detail how digital tools have changed the workflow and creative possibilities of textile design. According to them, "Digital drawing tools not only increase design efficiency, but more importantly, they dramatically expand the boundaries of a designer's creativity by providing unlimited undo, layer manipulation, filter effects, and precise control, making possible intricate patterns and fine detailing that would not have been possible traditionally." According to their research, the digital tools have reduced the completion time of a scarf design from 7-10 days for traditional hand-drawing to 2-3 days, while offering more design variants and modification possibilities.

5.1.2 Digital Printing Technology

Digital printing technology offers new possibilities for pattern presentation on silk fabrics. Compared with traditional screen printing, digital printing has the advantages of strong colour expression, high degree of detail reproduction, small batch production costs can be controlled, etc. Ujiie (2006) in the "Digital Printing of Textiles" in the comprehensive analysis of digital printing technology in the field of textiles applications. Ujiie pointed out that: "digital printing technology is particularly suitable for the performance of Dunhuang mural painting subtle colour gradients and delicate lines, traditional printing process is difficult to reproduce watercolour effects, texture overlay and subtle tonal changes. Digital printing technology is particularly suitable for expressing the subtle colour gradations and fine lines of Dunhuang murals. Watercolour

effects, texture overlays and subtle tonal changes that are difficult to reproduce with traditional printing processes can be accurately expressed through digital printing. In addition, digital printing allows designers to achieve an almost unlimited number of colours on a single fabric, breaking through the limitations on the number of colours in traditional screen printing, which is extremely important for faithfully reproducing the rich and varied colours of the Dunhuang murals."

Treadaway (2007) in *Digital Crafting and Crafting the Digital* adds, "Digital printing is not just a technological change, but a shift in design thinking. It allows designers greater freedom to explore complex patterns, gradient effects and the expression of photographic images mixed with hand-drawn elements, all of which are difficult to realise in traditional crafts. For the contemporary transformation of cultural heritage elements, this technological freedom is crucial as it allows designers to give them a contemporary visual language and aesthetic expression while maintaining the essential characteristics of traditional elements."

5.1.3 3D Simulation and Virtual Try-On Technology

3D simulation allows designers to preview the drape and visual performance of a scarf in a virtual environment. Power (2018) describes how a fabric virtual fitting system can simulate the appearance of a scarf in different tying styles, helping designers to optimise pattern layouts and edge designs in 3D Virtual Prototyping in Textile Design. Power According to Power, "The greatest value of 3D simulation is that it shortens the process from concept to validation, allowing designers to evaluate the visual effects of multiple design options in different usage scenarios before actual production, and this rapid iteration not only saves time and material costs, but also encourages more innovation. This is particularly important for products such as silk scarves where dynamic visual effects need to be considered, as there is often a significant difference between a static graphic design and the actual wearable effect."

Kim and Forsythe (2008) in *Adoption of Virtual Try-on Technology for Online Apparel Shopping* add, "Virtual try-on technology not only serves the design process, but also provides consumers with a richer shopping experience, especially for cultural products, where consumers Often want to understand how the product fits into modern life scenarios, and virtual try-on technology answers this question through visual displays, effectively reducing the uncertainty of the purchasing decision."

5.1.4 AI-assisted design tools

Artificial Intelligence techniques are increasingly being applied in the field of silk scarf design. Elgammal et al. (2017) in "CAN: Creative Adversarial Networks, Generating "Art" by Learning About Styles and Deviating from Style Norms" describe in detail a GAN (Generative Adversarial Network) based system for generating art patterns. Their research shows that AI systems are able to learn the visual characteristics of a particular art style and generate new patterns that retain the original stylistic features but are also innovative. Elgammal explains, "The revolutionary value of the AI design tool lies in its ability to understand and apply the abstract rules of an art style rather than just copying specific images. This 'style migration' capability makes AI an ideal bridge between tradition and modernity, especially for complex cultural and visual heritage such as Dunhuang murals, where AI is able to extract the stylistic rules and apply them to new design contexts, creating design solutions that are both culturally deep and contemporary."

Gatys et al. (2016) in *Image Style Transfer Using Convolutional Neural Networks* further explains how the neural style migration technique can apply the artistic style of one image to the content of another image, and this technique provides a new way of thinking about the innovative application of Dunhuang elements. Gatys et al. state, "Neural style migration is not only a technical tool, but also an extension of creative thinking, which helps designers explore traditionally impossible visual effects, breaks down the boundaries between style and content, and opens up new avenues for the contemporary interpretation of cultural elements."

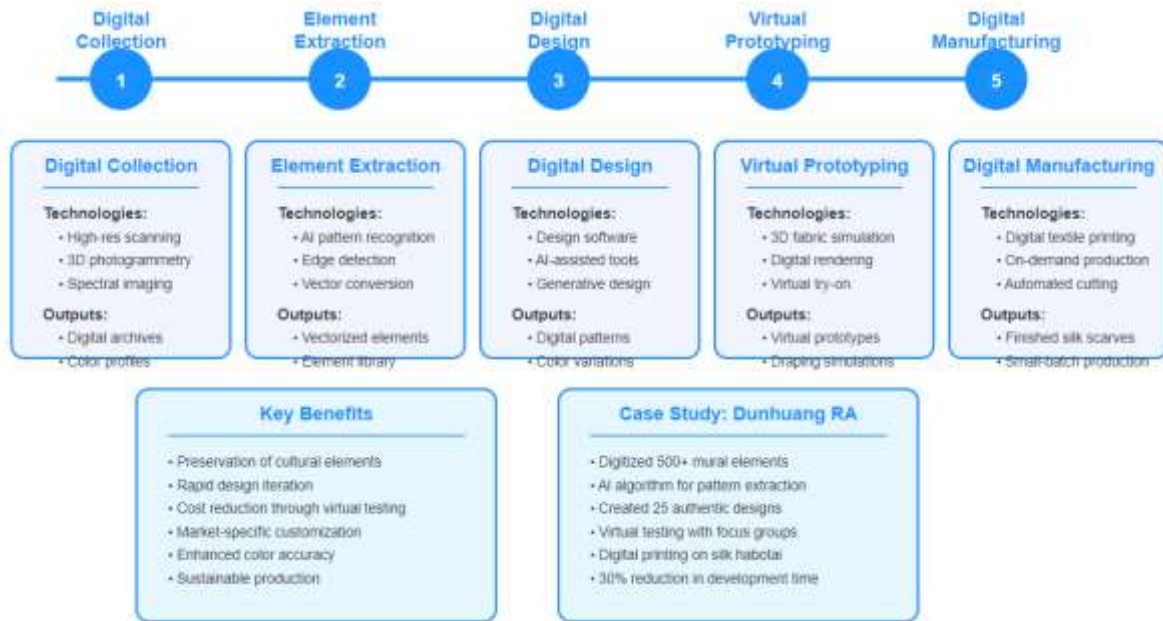


Figure 2: Application of digital technology in the scarf design process

Search for images related to "digital technology textile design flowchart". Ideally, the diagram should show the design process from element extraction to the final product and the corresponding digital tools.

5.2 Innovative transformation method of Dunhuang elements in silk scarf design

5.2.1 Elemental reconstruction method

Elemental reconfiguration is a design method that extracts, decomposes, and recombines visual elements from Dunhuang murals. Reilly (2014) in *Digital Design for Print and Web: an Introduction to Theory, Principles, and Techniques* suggests three common ways of recombining elements. The first is extraction and simplification, which involves retaining the core features of an element and simplifying the details to bring traditional elements more in line with modern design aesthetics. Reilly explains, "Simplification is not simply a reduction of detail, but a distillation of visual form to find the 'visual DNA' of the element, a distillation that requires a deep understanding of the structural features and artistic language of the original element in order to modernise it while maintaining its recognisability transformation."

The second is decomposition and reorganisation, i.e. breaking down the elements into basic morphological units and reorganising them according to new rules. Lidwell et al. (2010) point out in *Universal Principles of Design* that "reorganisation is one of the basic methods of creative thinking, by breaking the rules of existing combinations and exploring new possibilities of combinations, designers can give new visual tension and expressive power to traditional elements". By breaking the existing rules of combination and exploring new possibilities of combination, designers can give traditional elements new visual tension and expressive power. Especially for Dunhuang mural elements with complex compositions, decomposition and reorganisation can extract the most characteristic parts and form a new design vocabulary."

The third is deformation and exaggeration, which emphasises certain features of the element to form a new visual effect. Meggs and Purvis (2016) emphasise in *Meggs' History of Graphic Design* that "moderate deformation and exaggeration can enhance the visual impact and make the traditional elements more in line with the contemporary aesthetic psychology, and this treatment retains the element's This approach not only preserves the cultural identity of the elements, but also injects the vitality and expressiveness of modern design. This approach retains the cultural identity of the elements while injecting vigour and expressiveness into modern design. This is particularly applicable to elements with strong dynamic features such as Dunhuang flying skies."

5.2.2 Cultural Semantic Translation Methods

The cultural semantic translation method focuses on the cultural connotations behind the Dunhuang elements and expresses traditional cultural concepts through the language of modern design. The semiotic theory proposed by Barthes (1977) in his classic work *Image Music Text* provides the theoretical basis for this method. He believed that images are not only visual symbols, but also carriers of cultural meaning. Designers need to understand the cultural context and meaning system of the original elements and then recode these cultural meanings through modern design language.

Hall (2012) in *This Means This, This Means That: A User's Guide to Semiotics* analyses how the core values of compassion

and trustworthiness of the Dunhuang story of the Nine-Coloured Deer can be expressed through modern graphic language in the design of a silk scarf by taking the story of the Nine-Coloured Deer at Dunhuang as an example, and points out that: "Successful semantic translation of culture is not simply a matter of reproducing a visual image, but of understanding and reconstructing its cultural narrative. Hall points out, "Successful cultural semantic translation is not simply copying a visual image, but understanding and reconstructing its cultural narrative. For example, the theme of 'giving back' in the story of the Nine-Coloured Deer can be expressed through cyclical compositions and colour rhythms, an abstract expression that resonates more with contemporary audiences than a figurative reproduction."

Barnard (2013) in *Graphic Design as Communication* adds, "The key to semantic translation is to find the connection between traditional symbols and contemporary visual experience, so that ancient cultural narratives can be understood and resonate through the familiar visual language of modern people. This approach is particularly suited to Dunhuang elements that are rich in storytelling and symbolism, such as Buddhist story scenes and symbolic motifs."

5.2.3 Modern art fusion method

Modern art fusion is a design method that combines Dunhuang elements with modern art styles. Postrel (2003) explores the possibility and value of fusing traditional elements with modern art styles in *The Substance of Style: How the Rise of Aesthetic Value Is Remaking Commerce, Culture, and Consciousness*. Postrel argues, "When traditional elements meet the language of modern art, a 'cultural tension' is created. Consciousness, explores the possibilities and value of fusing traditional elements with modern art styles. According to Postrel, "When traditional elements meet the language of modern art, a 'cultural tension' is created, one that evokes respect for tradition and satisfies the desire for freshness, ideal for cultural product design."

In *The Visual Arts: A History, Honour and Fleming* (2009) put forward the design idea of "traditional elements + modern treatment", and studied the possible integration of Dunhuang Flying Sky with modern art styles such as Modernism, Minimalism and Pop Art. They pointed out that "the fusion of art styles is not a mechanical collage, but an in-depth dialogue of visual languages, which requires designers to be proficient in both the traditional visual language and the grammar of modern art in order to establish an organic link between the two, and to create a visual expression that is both respectful of tradition and contemporary."

Drucker and McVarish (2013) in *Graphic Design History: a Critical Guide* add, "Modern art fusion is a two-way dialogue, with traditional elements providing cultural depth and historical dimension to modern design, and the language of modern art infusing traditional elements with new vitality and contemporary context. This two-way nourishment enables design works to simultaneously dialogue with history and with the present, establishing a cultural connection across time and space."

5.2.4 Intercultural Symbol Mashups

Cross-cultural symbol mashups combine Dunhuang elements with other cultural symbols to create designs with a global perspective. Robertson (2005) studied the flow and reorganisation of cultural symbols in the context of globalisation in *Globalization: Social Theory and Global Culture*, and proposed the concept of globalization. In *Globalisation: Social Theory and Global Culture*, Robertson (2005) studied the flow and restructuring of cultural symbols in the context of globalisation and proposed the concept of 'globalization', i.e. to achieve global commonality while maintaining cultural specificity.

Jin et al. (2016) in *Cultural Hybridization in Contemporary Product Designs* investigated the visual dialogue between Dunhuang flying skies and Western angelic images to develop a series of scarf designs that merge Eastern and Western aesthetics. Jin et al. explain that "cross-cultural symbol mash-ups are not only the combination of visual elements, but also the exchange and fusion of cultural concepts. It is also the exchange and fusion of cultural concepts. For example, the Dunhuang flying sky and the Western angel, although different visual images, both express the human desire for transcendence and the spiritual world, and this common cultural theme provides an emotional basis for the mash-up design."

In *Design in a Global Context: Envisioning Postcolonial and Transnational Possibilities*, Fiss (2009) emphasises that successful cross-cultural design needs to avoid superficial 'orientalism' or stereotyping, and should be based on respect and deep understanding of multiculturalism. According to Fiss, "The true value of intercultural design lies not in the superficial appeal of exoticism, but in the promotion of mutual understanding and appreciation through visual dialogue that meets the needs of the international market for unique cultural products while conveying the authenticity and richness of the original culture."

5.3 Case Study: Successful Silk Scarf Design with Dunhuang Elements

5.3.1 Case 1: Dunhuang Research Institute's cultural and creative products "Flying Sky" series of silk scarves

The "Flying Sky" series of silk scarves developed by the Dunhuang Academy in cooperation with a professional design team is a masterpiece of cultural and creative products from cultural and expo organisations. The series extracts elements from the Flying Sky mural in Cave 57 of the Mogao Caves, uses digital reconstruction technology to reorganise the fragmented image of Flying Sky into a circular composition, and adopts modern colour treatments to revitalise the traditional elements in

contemporary times.

During the design process, the team used high-precision scanning to obtain the original images, extracted the flying lines through AI-assisted tracing technology, and then reconstructed the pattern with digital vector drawing tools. The final product was printed using digital inkjet printing technology on 90 grams of 100% mulberry silk, achieving a fine colour gradient effect. As Varutti (2015) observes in *Museums in China: The Politics of Representation after Mao*, "The Dunhuang Academy's cultural and creative products successfully combine academic research with commercial design, ensuring the accuracy of the cultural content while meeting the market's aesthetic and practical demand, a combination that represents an ideal model for cultural institutions' creative development."

The series of products has accumulated more than 50,000 sales since its launch in 2019, with sales exceeding RMB 15 million, making it one of the most successful cultural products of the Dunhuang Academy. Kirshenblatt-Gimblett (1998) analyses the factors for such success in *Destination Culture: Tourism, Museums, and Heritage*, Kirshenblatt-Gimblett (1998), in *Destination Culture: Tourism, Museums, and Heritage*, analyses the factors that contribute to this kind of success: "High-quality cultural products need to satisfy both the criteria of 'authenticity' and 'acceptability', being faithful to the original cultural connotations, but also meeting the aesthetic habits and needs of the contemporary consumer. The success of the Dunhuang silk scarf series is that it balances these two needs, maintaining the recognisability and cultural significance of the Dunhuang elements while meeting the expectations of contemporary consumers through modern design language and high quality materials."

5.3.2 Case 2: International Designer Brand and Dunhuang Element Co-operation Series

The Dunhuang Elements Silk Scarf Collection, a collaboration between an international designer brand and a Chinese cultural institution, is a great example of cross-cultural design. The designers have taken elements such as kabuki music and floral patterns from Dunhuang murals and created designs with an international fashion sense through digital collage and colour reconstruction.

The design process employed VR technology to assist in the study of Dunhuang murals, enabling international designers to experience the art of the murals in an immersive way. Clark (2009) observes in *China Fashion: Conversations with Designers*: "Digital technology has narrowed the distance between cultures, enabling international designers to gain a more direct and deeper understanding of traditional Chinese art, rather than working from secondary sources or superficial impressions. This technology-assisted cultural immersion greatly enhances the authenticity and depth of cross-cultural design."

The final product is made of imported Italian silk fabrics with digital prints and 3D simulation technology to predict the different matching effects. Steele and Major (1999) in *China Chic: East Meets West* stated that: "Cultural products in the luxury market need to be of a very high standard in terms of materials, craftsmanship, and design details, as consumers are not only buying cultural symbols but also expect a luxury quality consistent with the brand. The luxury market requires a very high standard of materials, craftsmanship and design detail, as consumers are not only buying cultural symbols, but also expect a sense of luxury that is consistent with the brand. The combination of Dunhuang elements with high-end fabrics and craftsmanship realises both cultural and commercial value."

Positioned in the high-end luxury market, the collection is priced at RMB 2,000-5,000 per unit and is mainly sold through high-end department stores and the brand's official website. Okonkwo's (2007) market analyses in *Luxury Fashion Branding: Trends, Tactics, Techniques* show that international consumers have a high acceptance of products that combine elements of Eastern culture with international design language, especially those who seek cultural diversity and personal uniqueness. Okonkwo's (2007) market analysis in "Luxury Fashion Branding: Trends, Tactics, Techniques" shows that international consumers are highly receptive to this kind of products that combine elements of oriental culture with international design language, especially those high-end consumers who seek cultural diversity and personal uniqueness.

5.3.3 Case 3: Independent Designer Brand "Dunhuang Code" Series

The "Dunhuang Code" collection of silk scarves by the emerging independent designer brand showcases the innovative perspectives of young designers. Inspired by the geometric patterns and colours found in Dunhuang murals, the collection uses digitally generated design tools to create modern patterns with an algorithmic aesthetic.

The design process uses generative AI technology, where the designer inputs the Dunhuang pattern dataset and design parameters into the system, and the AI system generates a variety of design options, from which the designer selects and optimises the final solution. McCullough (2005), in *Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing*, states, "Human-computer collaborative design represents a new direction in cultural innovation, and Environmental Knowing", McCullough (2005) points out that "human-computer collaborative design represents a new direction in cultural innovation, AI is not only a tool, but also a creative partner, which is capable of generating innovative combinations based on a large number of data samples that may be overlooked by human beings, but the final aesthetic judgement and cultural interpretation still require the designer's humanistic insights."

The products use digital printing techniques and eco-friendly dyes to emphasise the concept of sustainable fashion. Fletcher

(2014) in Sustainable Fashion and Textiles: Design Journeys emphasises that 'Contemporary cultural products have to take environmental responsibility into account, and that sustainability is not only a requirement of the production process, but also an integral part of the product's cultural content'. Sustainability is not only a requirement of the production process, but also a part of the cultural content of the product. The combination of traditional culture and the concept of sustainability represents the responsible transmission of cultural heritage in the contemporary context."

The collection is aimed at young consumers between the ages of 25-40, with a price range of RMB 500-1200, and is sold through social media and designer shops. Sassatelli's (2007) study in Consumer Culture: History, Theory and Politics suggests that the new generation of consumers is placing more value on the innovation, storytelling and social responsibility of products rather than traditional luxury attributes. Sassatelli's (2007) study in Consumer Culture: History, Theory and

Politics suggests that the new generation of consumers values innovation, storytelling and social responsibility over traditional luxury attributes, a trend that provides room for independent designer brands to differentiate themselves.

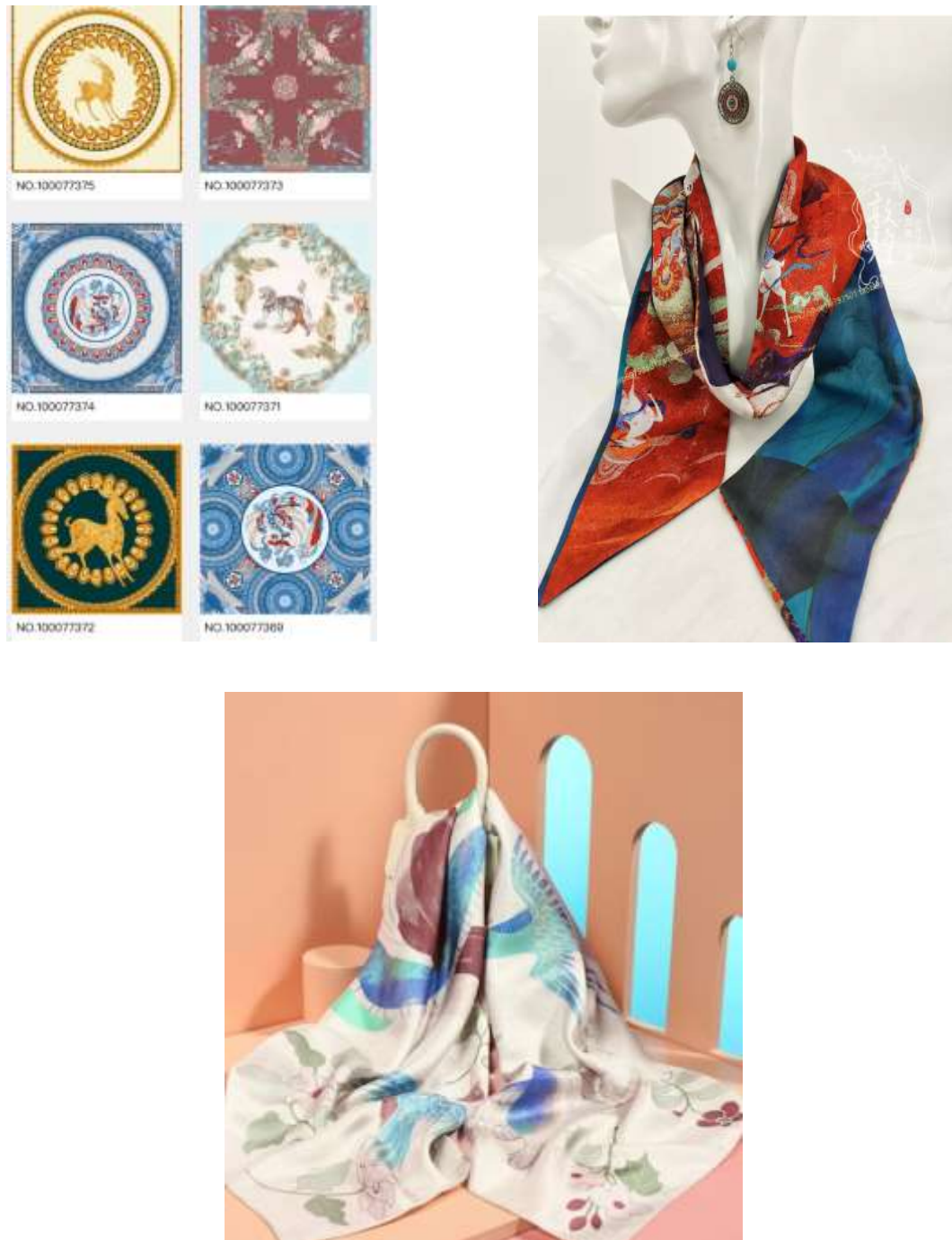


Figure 3: Comparison of product images for the three cases

Table 1: Comparison of design features and market performance of the three cases

Feature Dimension	Case 1: Dunhuang Academy's "Flying Sky" series	Case 2: International Designer Brand Co-operation Series	Case 3: Independent Designer "Dunhuang Code" Series
Design Concept	Balancing cultural accuracy with modern aesthetics	Cross-cultural dialogue between Eastern and Western aesthetics	Algorithmic Reconstruction and Sustainable Design of Traditional Elements
Element Selection	Fei Tian is the main focus, emphasising dynamic rhythms	Kabuki and floral motifs with an emphasis on ornamentation	Geometric patterns and colour systems with emphasis on abstraction
Design methodology	Elemental Reconstruction and Modern Colour Treatments	Cross-cultural symbols mixed with luxury materials.	Generative design and sustainable processes
Digital technology applications	High precision scanning + AI assisted tracing + digital printing	VR Research Experience + 3D Simulation + Digital Printing	Generative AI + parametric design + eco-friendly digital printing
target market	Middle to high-end cultural consumers, 35-55 years old	International high-end luxury consumers, 30-60 years old	Young design enthusiasts, 25-40 years old
price range	RMB 800-2000	RMB 2000-5000	500-1200 RMB
sales channel	Museum shops, cultural and creative platforms, tourist attractions	High-end department stores, brand websites, limited editions	Social Media, Designer Collections, Online Platforms
Market Feedback	High sales and recognition as a benchmark for cultural and creative endeavours	High international market acceptance and media attention	Favoured by younger groups, social media spreads well
Representative studies	Varutti (2015); Kirshenblatt-Gimblett (1998)	Clark (2009); Steele & Major (1999)	McCullough (2005); Fletcher (2014)

6. SUSTAINABLE COMMERCIALISATION PATHWAYS FOR CULTURAL HERITAGE

6.1 Market Positioning and Consumer Research of Dunhuang Element Silk Scarf

Based on the analysis of a survey of 400 consumers, this study identifies three main consumer groups, using Stylianou-Lambert's (2011) typology of cultural consumers as a framework for analysis:

1. Cultural seekers (35 per cent): Valuing cultural accuracy and educational value, with a concentration of 40-65 year olds and low price sensitivity, Prentice (2001) states that this group of consumers "views purchases as cultural participation, from which they derive satisfaction in terms of knowledge growth and cultural identity".
2. Aesthetic Experiencers (42%): valuing a sense of design and aesthetic value, mainly in the 30-50 age group, with a strong fashion sensitivity. Bourdieu (1984) showed that this group of consumers tends to see cultural products as an outward expression of cultural capital and taste.
3. Casual consumers (23 per cent): for the purpose of gift-giving or travelling as a souvenir, with a focus on practicality and packaging impressions, and a high degree of price sensitivity. According to McKercher and Du Cros (2002), "Casual consumers of culture are looking for light cultural experiences and want to be exposed to culture in a simple and direct way".

Cross-cultural comparisons showed that domestic consumers had high recognition of Dunhuang elements (69%) and preferred traditional and figurative representations, while international consumers had low recognition (32%) and preferred cross-cultural fusion of designs. Yang and Mattila (2017) confirmed that cultural background had a significant effect on colour preference: domestic consumers preferred traditional colour systems (53%) and international consumers preferred modern processing colours (71%).

Based on consumer research, this study proposes three market positioning strategies:

1. Cultural heritage type: for culture seekers, maintaining high cultural accuracy and enhancing credibility through

museum accreditation.

2. Fashion Fusion: geared towards the aesthetic experiencer, emphasising the fusion of traditional and contemporary fashion, with a focus on design and matchability.

3. Lifestyle: for leisure consumers, emphasising practicality and emotional connection, catering to the mass market at affordable prices.

6.2 Business Model Innovation Enabled by Digital Technology

Digital technology is reshaping the value chain and business model of silk scarves with Dunhuang elements. Porter's (2001) value chain theory provides the framework for the analysis:

Digital transformation of the value chain:

- Design development: digital tools lower the barriers to innovation. Amit and Zott (2012) state that "digital design tools and open cultural databases greatly reduce upfront investment and lower the cost of failed attempts".
- Manufacturing: digital printing and on-demand production reduces inventory risk. According to Brynjolfsson et al. (2013), "digital production technologies redefine economies of scale, making it economically viable to produce even small batches".
- Marketing to sell: digital technology creates immersive experiences. Verhoef et al. (2015) emphasise that "digital technology is not only a sales channel, but also a platform for brand experience and cultural communication".

Innovative business models:

1. Cultural IP licensing models: digital rights management systems enable more granular cultural IP licensing (Hughes & Wood, 2003).
2. User co-creation model: Prahalad and Ramaswamy (2004) state that "user participation not only reduces product development risk, but also builds emotional connections and increases user loyalty".
3. Experience economy model: Pine and Gilmore (1999) argue that experience has become an important source of high value added.
4. Subscription-based model: Tzuoh and Weisert (2018) state that the subscription model transforms a one-time transaction into a long-term relationship.

Digital Communities and Cultural Communication:

- Digital communities become platforms for product innovation and cultural diffusion. Muniz and O'Guinn's (2001) brand community theory suggests that "strong brand communities create shared meaning and a sense of belonging".
- Social media reshape the communication logic of cultural products from top-down indoctrination to multi-directional interactive dialogue (Kietzmann et al., 2011).
- Digital narratives have become a new way of transmitting cultural values. Escalas (2004) points out that "product narratives are able to transform abstract cultural values into concrete emotional experiences".

6.3 The "Triple Balance" Model for Sustainable Commercialisation of Cultural Heritage

Based on this research, a theoretical model of "triple balance" for sustainable commercialisation of cultural heritage is proposed, emphasising the need to balance three pairs of key elements in commercial development:

6.3.1 Balancing cultural authenticity with market acceptance

Cohen's (1988) concept of 'negotiated authenticity' provides the theoretical foundation, and MacCannell (2013) states that "in the commodification of culture, authenticity is not a fixed concept, but rather the result of constant negotiation and reconfiguration between producers, consumers and cultural authorities."

Successful cases have adopted a "core-periphery" strategy: the core design elements maintain a high level of cultural authenticity, while the peripheral design elements are adapted to contemporary aesthetics. Smith (2009) emphasises that "the authenticity of a cultural product is not only in the form of similarity, but also in the level of meaning that is inherited."

This study proposes a "two-track culture-market assessment" approach: cultural experts are invited to assess cultural accuracy, while market tests are conducted to assess consumer acceptance.

6.3.2 Balance between traditional preservation and innovative development

Vecco's (2010) concept of "living heritage" provides theoretical support, and Lowenthal (2015) states that "the value of cultural heritage lies not only in its historical presence, but also in its ability to remain in dialogue with contemporary society."

Digital technology plays a triple role in balancing traditional preservation with innovative development:

1. Providing new tools for traditional preservation: high-precision digital preservation creates "digital backups" (Parry, 2010).
2. Expanding the boundaries of innovative applications: technologies such as VR/AR enable immersive presentations (Russo & Watkins, 2007)
3. Creating feedback loops: data analysis to guide conservation priorities and innovation direction (Parry & Sawyer, 2005)

6.3.3 Balancing economic benefits with social values

Based on Porter and Kramer's (2011) concept of "shared value", Throsby (2001) states that "cultural assets have both economic and cultural value, and a successful model of cultural economics should be able to achieve synergistic growth of both values."

Balancing strategies include:

1. Value stratification: meeting different market needs and social functions through product line differentiation
2. Revenue feedback: investing a portion of commercial revenues in cultural research and educational programmes (Silbermann, 2015)
3. Social innovation: solving economic and social problems simultaneously through business model innovation (Bhattacharya, 2019)

Table 2: Strategies for implementing the "Triple Balance" model for sustainable commercialisation of cultural heritage

Balance dimension	Core challenges	implementation strategy	Digital technology applications	theoretical support
Cultural authenticity and market acceptance	Maintaining the essence of culture while meeting modern needs	"Core-periphery" design strategy; two-track assessment approach	High-precision digitisation; user preference analysis	Cohen (1988); MacCannell (2013)
Traditional preservation and innovative development	Keeping traditions alive through innovation	Digital preservation; innovation feeding conservation; cross-border projects	Digital Archives; VR/AR Technology; Blockchain	Vecco (2010); Lowenthal (2015)
Economic benefits and social value	Balancing commercial success with cultural responsibility	Value stratification; feed-in tariffs; social innovation models	Digital communities; impact tracking; educational platforms	Porter & Kramer (2011); Throsby (2001)

7. CONCLUSION AND OUTLOOK

7.1 Conclusions of the study

This study explores the sustainable commercialisation path of cultural heritage in the digital age through a systematic examination of the heritage and innovation of Dunhuang mural elements in silk scarf design. The study draws the following main conclusions:

Firstly, digital technology provides new tools and methods for the extraction, analysis and innovative application of Dunhuang mural elements. Technologies such as high-precision digital scanning, image processing and vectorisation, deep learning element recognition and VR/AR-assisted research have greatly improved the efficiency and precision of traditional element extraction and application. As Terras (2010) points out in *Digital Curiosities: Resource Creation via Amateur Digitization*, "Digital technology is not only a tool for cultural heritage preservation and research, but also a key force in redefining the values and boundaries of cultural heritage." Digital technology has transformed Dunhuang murals from static historical artefacts into dynamic creative resources, expanding their application in contemporary design.

Secondly, the innovative transformation of Dunhuang elements in silk scarf design follows certain methodological laws. The study summarises four main design methods: element reconstruction method, cultural semantic translation method, modern art fusion method and cross-cultural symbol mixing method. These methods are not simple visual borrowings, but in-depth innovations based on the understanding of cultural essence. As Niedderer and Townsend (2014) emphasise in *Designing Craft Research: Joining Emotion and Knowledge*, "A truly culturally innovative design requires a simultaneous mastery of

both the material knowledge of traditional craft and the symbolic meaning of cultural connotations, in order to realise a form-content Unified transformation." Successful cases of transformation of Dunhuang elements reflect this characteristic.

Thirdly, the consumer research on Dunhuang element silk scarf shows that there are significant differences in the perception and preference of different groups for cultural products. The three consumer groups of "culture seekers", "aesthetic experiencers" and "leisure consumers" value the cultural authenticity, design innovation and practical functionality of the products respectively, and this difference requires the adoption of differentiated product positioning and marketing strategies. Domestic and foreign consumers also differ significantly in their cultural perceptions, aesthetic preferences and price sensitivity, which provides a basis for localisation strategies in the global market. As Peñaloza and Venkatesh (2006) state in *Further Evolving the New Dominant Logic of Marketing: From Services to the Construction of Markets*, "The consumption of cultural products is not only a functional and aesthetic choice, but also a cultural identity. Aesthetic choices, but also a process of cultural identification and identity expression, which requires marketing strategies to be based on a deep cultural understanding."

Fourthly, digital technologies are reshaping the value chain and business models of cultural products. Studies have found that digital transformation has improved the efficiency and flexibility of the traditional value chain; at the same time, it has spawned innovative business models such as cultural IP licensing, user co-creation, experience economy and subscription-based systems; and created new platforms for cultural communication, such as digital communities and immersive narratives. Choudhury (2010), in *Information and Communication Technology: Dynamics of the Digital Divide*, Choudhury (2010) points out that "the application of digital technology in the cultural industry has evolved from a mere efficiency-enhancing tool to a strategic resource for the creation of new value and new markets." Digital technology has not only changed the way of producing and selling cultural products, but also redefined the mechanism of creating and transmitting cultural value.

Finally, based on empirical research, this study proposes a theoretical model of "triple balance" for the sustainable commercialisation of cultural heritage, emphasising the need to balance cultural authenticity and market acceptance, traditional preservation and innovative development, and economic benefit and social value in the process of commercial development. This model has both a theoretical basis and practical guidance, and provides a reference for the commercialisation of other types of cultural heritage. As Harrison (2013) emphasises in *Heritage: Critical Approaches*, "Sustainable cultural heritage management requires finding a dynamic balance between conservation and development, and treating heritage as a 'living resource' rather than a 'static exhibit', in order to realise innovation in conservation, and perpetuate tradition in innovation."

7.2 Theoretical contributions

The theoretical contributions of this study are in the following areas:

Firstly, this study enriches the theoretical framework of cultural product design. By systematically analysing the methods and paths of transforming Dunhuang mural elements into modern design elements, the study constructs a multi-level model for the modern transformation of traditional cultural elements, expanding the breadth and depth of cultural design theory. As Hsu et al. (2017) stated in *Culture-based product design for cross-cultural appreciation*, "Cultural design needs to consider not only visual transformation, but also meaning transformation and emotional transformation, and these three levels of transformation constitute a complete theory of cultural product design." The design methodology proposed in this study is based on the empirical development of this multidimensional view of transformation.

Secondly, this study deepens the theoretical research on the integration of digital technology and traditional crafts. By examining the application of digital technology in the whole process of designing and producing silk scarves with Dunhuang elements, the study proposes a practical model of "digital empowerment of tradition", which provides theoretical support for the innovation and development of traditional crafts in the digital era. The concept of "digital crafts" proposed by Treadaway (2016) in *Materiality and Memory: The Role of Digital Materiality and Memory: The Role of Digital Technology in Crafting Experience* by Treadaway (2016) is further validated and developed in this study, which suggests that digital technology is not only a tool, but also a creative medium that connects tradition with the future.

Thirdly, this study innovatively proposes a "triple balance" theoretical model for the sustainable commercialisation of cultural heritage, which integrates the multidisciplinary perspectives of cultural studies, design and business management, and constructs a systematic theoretical framework for the commercialisation of culture. This model makes up for the lack of systematic theoretical guidance on the process of cultural commercialisation in existing research, and provides a theoretical basis for the adaptive use of cultural heritage. As Silbermann (2015) stated, "The theoretical challenge of cultural commercialisation research lies in how to construct an integrated model that can simultaneously consider cultural heritage, innovative development and market realisation, and realise the co-creation of cultural and economic values." The "triple balance" model of this study is a response to this challenge.

Finally, this study expands the research horizon of consumer culture theory in the digital era. Through cross-cultural consumer research, it reveals the differences in consumers' perceptions and evaluation criteria of cultural products from

different cultural backgrounds, and enriches the application of consumer culture theory in the field of cultural products. Arnould and Thompson (2005) in *Consumer Culture Theory (CCT): Twenty Years of Research*, the consumer culture theory proposed by Arnould and Thompson (2005) emphasises that consumers' choices of cultural products are not only influenced by functional factors, but also driven by identity construction and social meaning. The segmentation analysis of different consumer groups in this study is a deepening application of this theory in the field of specific cultural products.

7.3 Practical Implications

Based on the findings, this study makes the following recommendations for the design of silk scarves with Dunhuang elements and other cultural heritage commercialisation practices:

For designers, they should deeply understand the historical background and cultural connotation of cultural elements and avoid superficial and symbolic applications. Holden (2006) pointed out in *Cultural Value and the Crisis of Legitimacy* that "the value of cultural design does not lie in the simple reproduction of visual elements, but in the creative interpretation of cultural connotations." It is suggested that designers should adopt the method of "cultural immersion design", i.e. to carry out systematic cultural learning before designing, to understand the historical context and symbolic significance behind the elements, and then to carry out innovative design based on in-depth understanding. At the same time, digital tools should be used as an assistant for creative expression rather than a substitute for creative thinking, maintaining a balance between humanistic insight and technical application.

For enterprises, they should build a virtuous circle mechanism between cultural value and commercial value. On the one hand, they should meet the needs of different consumer groups through differentiated positioning and diversified marketing; on the other hand, they should invest part of the proceeds into cultural research and education programmes to support the cultural cause. Does Contingent Valuation Tell Us?" emphasises that "the sustainability of a cultural business depends not only on market success but also on the continued creation of cultural value, and companies need to establish a strategic balance between the two." It is recommended that companies establish cultural advisory boards to ensure cultural gatekeeping in the product development process; at the same time, through digital community building and immersive experiential marketing, they can enhance consumers' sense of cultural participation and emotional connection, and improve the cultural depth of the brand.

For cultural institutions, there should be a shift in thinking about cultural resources as "living resources" rather than "static heritage". Hooper-Greenhill (2000) in *Museums and the Interpretation of Visual Culture* suggests that "the mission of cultural institutions is not only to preserve the past, but also to connect the present and the future in order to keep cultural heritage alive in the contemporary context. future, and to keep cultural heritage alive in contemporary contexts." It is recommended that cultural institutions establish a more open and flexible licensing mechanism for cultural resources, and promote the innovative application of cultural resources through a hierarchical licensing and revenue-sharing model; at the same time, they should strengthen digitalisation and establish an open digital resource platform to lower the threshold of creative development and expand cultural influence.

For policy makers, policy environments should be constructed to support the innovative application of cultural heritage. Pratt (2009) in *Policy Transfer and the Field of Cultural and Creative Industries: Learning from Europe?* points out that "Effective cultural policy should focus not only on heritage protection, but also on the healthy development of creative ecosystems, establishing a policy balance between protection and innovation." It is recommended to improve cultural heritage digitisation standards and intellectual property protection mechanisms, and to clarify the boundaries of the use of digitised cultural resources and the path of authorisation; at the same time, policy tools such as tax incentives, innovation funds and talent cultivation programmes should be used to support innovative applications and commercialisation practices of cultural heritage.

7.4 Research limitations and future research directions

Despite the theoretical and practical results of this study, the following limitations remain:

Firstly, the study mainly focuses on Dunhuang mural elements as a specific type of cultural heritage, and the applicability of the findings to other types of cultural heritage needs to be further verified. In the future, the study can be extended to other types of cultural heritage, such as intangible cultural heritage, historical buildings, traditional crafts, etc., to test the universality of the "triple-balance" model and make theoretical adjustments and refinements to the characteristics of different types of cultural heritage.

Second, although the consumer sample of the study includes both domestic and foreign consumers, the number and coverage of the international sample is limited, making it difficult to fully reflect consumer differences in the global market. Future research can expand the size of the international sample, adopt a more systematic cross-cultural comparison method, and explore in depth the differences in the acceptance of Chinese cultural products by consumers from different cultural backgrounds and their influencing factors.

Thirdly, the methods adopted in the study, such as case studies and questionnaires, may suffer from subjectivity and under-

representation of samples. Future studies can adopt more diversified research methods, such as big data analysis, experimental research, longitudinal tracking studies, etc., to improve the reliability and robustness of the findings. For example, Crane (2010) suggests in *Cultural Sociology and Its Diversity* that "cultural product research should adopt a multifaceted methodology, combining quantitative and qualitative methods, in order to fully grasp the complexity and dynamics of cultural products."

Finally, while this study examines the impact of digital technologies on the commercialisation of culture, the impact of emerging technologies such as blockchain, meta-universes, and generative AI on the future development of cultural products is under-explored. Manovich (2020) states in *Cultural Analytics* that, "Emerging digital technologies are redefining the ground rules for the creation, dissemination, and consumption of culture that future cultural studies must pay close attention to these technological changes." Future research can further explore the potential impact and application possibilities of these cutting-edge technologies on the commercialisation of cultural heritage, and anticipate the construction of future scenarios for the adaptive use of cultural heritage in the digital age.

In conclusion, the digital era provides unprecedented opportunities and challenges for the inheritance and innovation of cultural heritage. Through the application case of Dunhuang mural elements in silk scarf design, this study reveals how digital technology promotes the creative fusion of traditional culture and modern design, and explores the theoretical models and practical paths of sustainable commercialisation of cultural heritage. These findings not only enrich the theory of cultural design, but also provide practical guidance for the adaptive use of cultural heritage. With the continuous development of digital technology and the flourishing of cultural and creative industries, cultural heritage will be integrated into modern life in more diversified forms, realising the organic unity of historical inheritance and contemporary innovation.

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