

Blockchain and Image Processing to Reinforce Provenance in the Narrative of a Handwoven Carpet

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Abstract—The sharing economy, which is empowered by digital technologies, drives platform business models and creates new forms of growth and value, which disrupts many businesses. The essential challenge for the formation of business interactions between individuals in the context of platforms is mutual trust. Blockchain, with broad applications in different domains, is an emerging technology to build trust and improve transparency and traceability within the sharing economy and platform business models. The purpose of this paper is to explore the role of blockchain in disrupting the luxury industry and leveraging storytelling to create an immutable digital identity. The paper will review the business model of Chamrosh Technology, which transforms a handwoven carpet into the smart carpet. Within the model, blockchain is reinforcing provenance in the narrative of a handwoven carpet, and image processing is generating a digital fingerprint to deal with counterfeits.

Keywords—Smart Carpet; Startup; Storytelling; Handwoven carpet; Blockchain; IoT; Identity management; Image processing; Carpet fingerprinting

I. INTRODUCTION

This paper is an extension of the work initially presented in the Eighth International Conference on Ambient Computing, Applications, Services and Technologies [1] which discussed the role of digital technologies in transforming handwoven carpet to the smart carpet and co-creating value with carpet fans to influence their behavior.

The rise of the sharing economy, which is empowered by innovation and growth in digital technologies, drives online peer-to-peer platforms where individuals can leverage their existing and under-utilized assets to create value together [1]. The essential challenge for the formation of interactions between individuals is mutual trust [2]-[5]. Many businesses and industries are being transformed by these digitized, open, and participative platforms, which act as a Trusted Third Party (TTP) and commercially connect suppliers and consumers. Through these platforms, companies such as Alibaba, Uber, and Airbnb are disrupting retail, transportation, and accommodation industries, respectively. Disruption is associated in part with “Disruptive Innovation Theory” coined by Clayton Christensen [6] and refers to the fact that even successful companies are at high risk that their product, system, or technology become obsolete. Disruption usually happens when a newcomer displaces the value proposition of the incumbent by offering a cheaper and more accessible

solution and later poses a barrier that would prevent the incumbent from quickly imitating a similar model [7].

The luxury goods industry has also experienced disruption by innovation in the sharing economy, which is driven by digital technologies. On the one hand, the sharing economy has displaced the value proposition of luxury brands by providing access to goods and services through online platforms [1]. On the other hand, the entire value chain of luxury goods from procuring raw materials, design, and production up to in-store experience, and even consumption is personalized and transformed by digital technologies [1].

Blockchain with broad applications in different industries can improve transparency and traceability within the supply chain of luxury goods and verify authenticity. A blockchain is a data structure which combines multiple technologies including cryptography and peer-to-peer networks to create a digital and decentralized ledger of data and share it among a network of independent parties [2][3][8]. Decentralized system and cryptography enable each participant to manage the ledger securely without the need for a central authority to enforce the rules [2][8]. Blockchain can, therefore, generate trust for the entities who do not know each by building a secured medium in which data are protected from unauthorized access. That is why blockchain is proliferating in different sectors especially where identity management and verification are required

This study explores the emerging role of blockchain to disrupt the luxury Industry and further discusses how to reinforce the provenance of a handwoven carpet and deal with counterfeiting. The rest of this paper is organized as follows. A brief overview of the smart carpet and background of blockchain is presented in Section II. The four elements of storytelling are presented in Section III where it is also discussed how they can be reinforced by digital technologies. In Section IV, the smart carpet business model is reviewed to show how blockchain can reinforce the provenance and leverage the power of storytelling to prove the origin and verify the authenticity of a handwoven carpet. The collaboration of two startups is discussed in Section V. The challenges of the smart carpet model are identified in Section VI where image processing is reviewed as an innovative solution to generate a digital fingerprint to deal with counterfeit carpets. Discussion is presented in Section VII which is followed by the conclusion and future works in Section VIII. Contribution is summarized in Section IX.

II. BACKGROUND

The concept of smart carpet was first introduced in a research project which aimed at developing a sensor system to detect falls and summon assistance for older adults who cannot use wearable devices due to cognitive deficits [9]. Later, other applications of a smart carpet such as physical therapy emerged where the walking pattern of the owner is detected and analyzed. With the help of the therapist, it is argued that these patterns can predict mobility problems and correct them [10]. Also, it is shown that the smart carpet can identify the presence of an intruder by acting as a kind of alarm system which detects environmental threats, like fires [10].

Roshanzamir et al. [1], for the first time, discuss how the Internet of Things (IoT), blockchain, and platform business can offer a game-changing solution and disrupt handwoven carpet business by bringing transparency and trust to the supply chain, dealing with counterfeiting and increasing customer engagement. They suggested an extension built upon the EIC model [11] in which it is argued that digital technologies can improve operations and contribute to the marketing campaign and create strong brands by generating an immutable digital certificate [1].

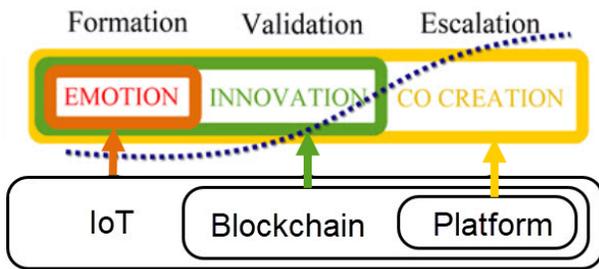


Figure 1. The practical extension of the EIC model [1]

The framework breaks down the narrative of a carpet from the time procuring of knots and weaving starts in a simple connection of cause and effect. The blockchain globally stores, and collaboratively writes a list of all transactions that have ever taken place within a given system [12] and offers the possibility to keep the whole story of a carpet in a decentralized system.

Blockchain technology can, therefore, reinforce trust between individuals because it is a decentralized database, without a central repository and usually without a central authority. Blockchain functions as an immutable digital ledger and generates the list of records that are bundled together in so-called blocks. The ledger is distributed across many participants in a peer-to-peer network as a block that is duplicated thousands of times across a network of computers. Each block has three major components that are: data including facts or transactions plus timestamps, a hash of the previous block, and a hash of the existing block to be added in the next block [13][14].

A hash is created by using a mathematical function or algorithm to convert the input of letters and numbers into an encrypted output of a fixed length. Processing the hash functions to encrypt new blocks or decrypt previous blocks

requires substantial computer processing power, which is very costly.

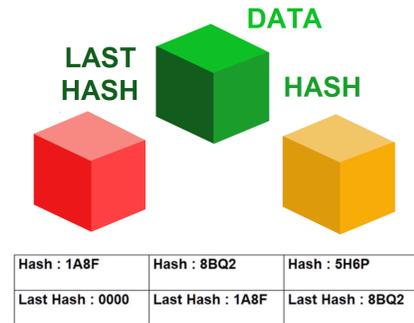


Figure 2. Connecting blocks and checking the hash function

Types of transactions and rules, which can be carried out, must be agreed between participants in advance and stored in the blockchain as a smart contract which was introduced in 1997 by Nick Szabo [15] to ensure that everyone is fulfilling the rules. The main components of the smart contract are a set of executable functions and state variables. Each transaction has some input parameters which are required by a function in the contract. During the execution of a function, the status of the state variables is changed depending on the logic implementation. The new blocks are constantly added and updated to the chain, and data in any given block can only be altered by modifying all previous blocks, which would require the control over a majority of computing power in the network. The benefits and innovation of blockchain, described in below key characteristics from a combination of four technologies: a distributed data storage; peer-to-peer networks; cryptographic algorithms; and decentralized consensus mechanism [16]-[18]:

- Distributed ledger: Blocks are recorded, duplicated, shared and synchronized on independent computers (referred to as nodes) with no centralized data storage. The indistinguishable copies available on different nodes allow participants to validate information without a central authority and make it failure resistant, even if few nodes fail.
- Immutable: Blocks are time-stamped, and each block is connected to the one before and after it within the same transaction in a growing chain structure. This creates an irreversible, immutable chain in which the trail and history of blocks and transactions cannot be modified.
- Secure: Blocks are permanently recorded and encrypted in a growing chain, which makes them impossible to delete, edit, or even copy already created block and add them in the network. This ensures a high level of robustness and trust.
- Consensus mechanism: A transaction on the blockchain can be executed once the parties on the network unanimously approve it. This stop illegal and bad transactions and blocks.

Blockchain can, therefore, generate trust for the entities who do not know each other by making data and the relevant digital identity tough to change due to decentralized

features and very hard to read due to cryptography (hash function). That is why blockchain has been successfully expanding its application across different domains including investment, logistics, global organizations, and even governments where identity management and verification are required. More importantly, blockchain can provide emerging opportunities in the platform business model since it facilitates real-time granular visibility, ensures trust, and enforces security using a chronological order of smart contracts. These contracts can automatically implement a binding agreement between two or more parties, where every entity must fulfill their obligations according to the agreement. In the next section, we will explore the role of storytelling with an implication in the luxury industry and how these stories can be verified through the blockchain.

III. AUTHENTICATED STORYTELLING IN THE LUXURY INDUSTRY

Storytelling is defined as “sharing of knowledge and experiences through narrative and anecdotes to communicate lessons, complex ideas, concepts, and causal connections” [19]. It is one of the oldest and most powerful modes of communication and has been an integral part of cultures throughout history, both as entertainment and as a means of passing on knowledge, values, and desired behaviors from generation to generation [20]. The fact that people naturally organize their experiences through the construction of stories has an essential implication in marketing and branding. In fact, stories are the pillars of Word of mouth (WOM) communication, and a significant dimension of brands and advertising needs to support them [21]. McKee [22] argues that stories are effective at persuasion because they emotionally involve audiences as many people are interested to know more than just the product or service by observing behind the scenes stories of organizations according to market research [23]. That is why the appropriate way to convince someone to purchase something is by telling a compelling brand-oriented story rather than providing rational arguments, statistics or facts. For example, Woodside et al. [19] consider storytelling through blogs as a more effective way of driving purchase intentions than traditional websites. These stories can provide a strong point of differentiation that cannot be copied [23] [24], and that fulfills the purpose of a brand to differentiate goods or services of one seller from a competitor, according to the American Marketing Association’s definition. In fact, a brand is what people feel about us and our products and services. Therefore, it is partly rational but mostly emotional. Nonetheless, our brand and story, however visionary and brilliant, carry no weight, unless we can win the hearts and minds of customers and deeply motivate them on a personal level to act not because they need to, but because they want to. We must be mindful that at the heart of a strong brand are great products and services, but every brand contact matters [24] and storytelling is the most important one [25]. Therefore, organizations need to build a strong brand story to communicate with their potential and existing customers and regularly reveal the compelling benefits of using our ideas, products, or services.

Therefore, we can argue that stories are considered to be powerful tools to structure reality, facts, conclusions, and recommendations about a brand in a persuasive manner that play to the emotions and rely upon empathy. Literature review and different studies have identified four elements of good brand stories [26], and we will discuss here how two elements including authenticity and humor, can be verified and reinforced by integrating technologies including the Internet of Things (IoT), blockchain, and platform business. The goal should be to cultivate an authentic, trustworthy, and compelling narrative to inform, engage, persuade, and build trust with customers.

A. Authenticity

Authenticity is a sense which readers or audiences obtain that makes them believe and associate the story with reality. In fact, the authenticity of narratives, which should tell real and incredible stories, is a critical issue since how they reflect the truth within an organization can be questioned [27]. The corporate reputation is defined as a stakeholder’s perception of the organization. Brown et al. [28], and Dowling [29] suggest that if the story causes stakeholders to perceive the organization as more authentic, distinctive, expert, sincere, powerful, and likable, then it is likely that the overall corporate reputation will be enhanced. Recent studies show that digital technologies, including blockchain, can provide promising possibilities for authentication and verification of corporate stories. For example, Maxwell et al. [12] argue that digital technology has transformed the ways we create and consume narratives, from moving images and immersive story worlds to digital long-form and multi-branched story experiences.

B. Conciseness

A story should deliver complete thoughts in a few words, while still covering essential points. This is sometimes referred to as plot, which is a sequence of events starting from anticipation and then progresses towards crisis, getting help, and finally achieving a goal [24]. The story must also be presented as something inherently valuable where the value comes from the story itself and from the role it is playing for a broader significance that is promoting a brand. In this manner, we try to give the events a meaning that our potential and existing customers may not otherwise grasp.

C. Reversal

A climax is a turning point when the emotion takes a surprising twist. Corporate stories bring an emotional dimension to an organization and enable people to make a personal connection to learn, understand, and share information and ideas [23]-[25]. Here participating in our customer’s transformation can give new life and meaning to our business suggested by Miller [30]. He argues that we need to think about who we want our customers to become and how we can improve the way they see themselves [30].

D. Humour

A statement, picture or other things which call for action or give rise to a kind of emotions. Peter McGraw [31]

posited the “Benign Violation Theory,” which states that humor occurs when a situation is both benign and a violation of moral or social norms, or some other expectation. That is how humor can challenge expectations, make connections between conflicting ideas or emotions to surprise the audiences.

Also, it should be noted that we have moved from mere consumers of content in web 1.0 towards increasing our participation and documenting our activities in social media, which is referred to Web 2.0 as proposed by Tim O’Reilly [32][33]. Unlike Web 2.0, which refers to the participation of users, Web 3.0 is based on users’ cooperation [34]-[36], which integrates the generated data to create new meaning. In fact, the concept of Web 3.0 is often associated with the idea of the Semantic Web which was first coined in 1999 by Tim Berners-Lee, the creator of the World Wide Web, who foresaw the possibility of enabling machines to ‘talk to one another’ and to understand and create meaning from semantic data [37] [38]. The blockchain is a technology that can reinforce semantic data by building up trust between the parties and ensuring data integrity. That is why blockchain empowers Web 3.0 to have a user-centric transparent and secured internet, which is based on a decentralized network. Maxwell et al. [12] conduct three experiments that draw on some of the fundamental principles of blockchain including the ledger, the blocks and the mining process and argue that blockchain opens up new possibilities to explore how storytelling might adapt as distributed ledger technologies become part of how we read, write and share stories. They further argue that blockchain could significantly transform the distribution, promotion, and propagation of stories, especially with regards to data archival, originated from time-stamping principles. Managing collaboration, contribution, and attribution, as well as ethical and moral issues, are other implications of generating narrative through blockchain as they discuss.

In Section IV, we are going to review the case study of a new venture who integrates blockchain technology to offer

a solution in one of the most traditional businesses i.e., handwoven carpet.

IV. SMART CARPET BUSINESS MODEL

Founded in early 2018, Chamrosh Technology [39] is a startup in the Middle East, who aims to transform a handwoven carpet to the smart carpets through digital technologies. It is an Intelligent System of identifying, recording, and verifying the provenance of a handwoven carpet by generating the fingerprint and issuing and storing a digital certificate on the blockchain with data-backed evidence. Chamrosh integrates digital technologies including the Internet of Things (IoT), image processing, steganography, blockchain, asymmetric encryption and mobile technology to issue an irrevocable and immutable digital certificate for a handwoven carpet and store it on the blockchain.

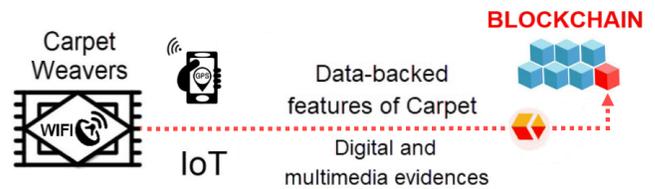


Figure 3. The narrative of carpet is stored on the blockchain [1]

The narrative of a handwoven carpet begins by collecting data-backed features as well as multimedia evidence from the weaving process. Also, a smart chip is embedded inside the carpet from the beginning with a low energy wireless IP network via the Internet of Things (IoT) or Bluetooth to integrate with Global Positioning System (GPS). This is achieved through a mobile app that pings out to the GPS every month to fetch the location of the carpet weaving and communicate it through the smartphone of the weaver(s) with the system as illustrated in Figure 3. Data-backed features of carpet including original map, designer’s

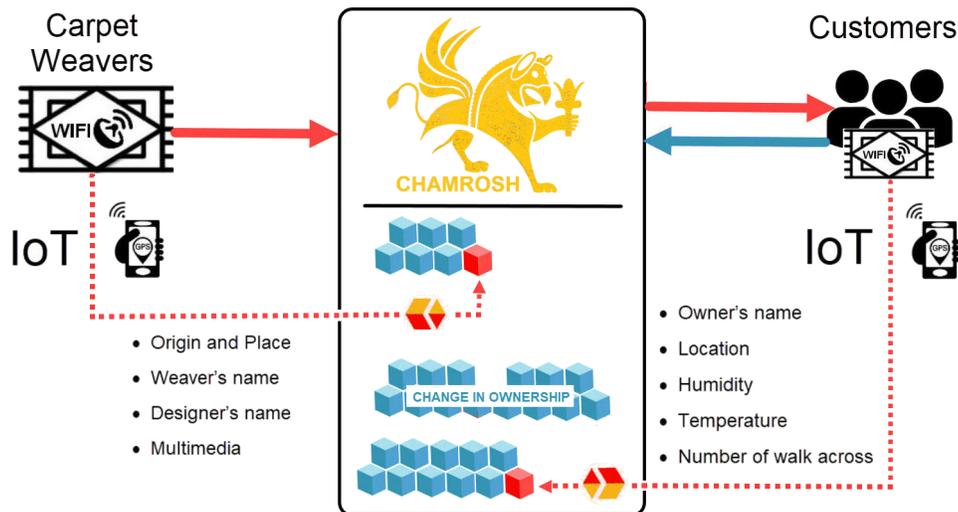


Figure 4. Chamrosh business model can reinforce the provenance by immutable digital certificate [1]

name, size, number of knots and colors, etc. together with audio, video, and pictures from the weaving process are stored in story blocks as successive stages. Therefore, the potential customers feel what the weaver feels and see what the weaver sees [1]. Most importantly, the ownership history and other environmental data, including temperature, moisture, location of use, and even the number of times carpet was walked over, can be recorded as new blocks and be verified later, as shown in Figure 4. Here, we see a paradigm shift in story-giving where the customers can actively contribute to composing the story of the brand before selling the carpet [1] which makes the product part of a bigger story and more meaningful to the customers' lives [40]. Customers can both buy and sell their smart carpets within the platform. This is highlighted by blue and red arrows within Figure 4. Also, the owners of a smart carpet can use the Chamrosh platform to sell his or her carpet, and the new customer can verify the ownership, and that is how the legal norms and ownership rights are enforced without the need for a third-party authority. This resonates with recent arguments that the hybrid institution of property is a distributed ledger that can hold information about the intellectual property of right holders instead of a centralized government database [41].

Kapferer [42] argues that a luxury strategy places a high priority on localized production to support the brand story and increase intrinsic value. That is why the country of origin symbolizes expertise and cache. For example, Swiss watches and German cars are endowed with unique local know-how and the magic spirit of place of production. The same argument holds true for Persian handwoven carpets or Persian rugs which were first referenced around 400 BC, by the Greek author Xenophon in his book "Anabasis". He described them as precious, and worthy of being used as diplomatic gifts which put them into a context of luxury and prestige[1]. "Carpet" and "Rug" are terms that are used interchangeably. In the US, a carpet is a floor covering that is laid wall to wall, and rugs cover a small specific area. But in business "carpet" and "rug" are used to denote a covering over the floor.

In fact, Persian rugs are the singular and invaluable symbol from one of the most ancient civilizations in the world. Persian rugs carries more than 2500 years of heritage, culture, and art that covers stories of failures, victories, peace, passion, prosperity, and love and that is how two pieces of rug can be made of the same material within the same size, and even have a similar design, yet, Persian origin can reel the price by 5 to 10 times [1]. That is why the Persian rugs have always been subjected to counterfeiting due to their supremacy in all aspects over handwoven carpets from other countries.

Adored for their intricate designs, elegant colors, and perfect craftsmanship as well as intrinsic value, Persian rugs have found their way into households, catwalks, and concert stages, as well as in scores of artworks [43]. Persian rugs also become important ingredients of the luxury ambiance in many premium locations such as China Room on the Ground Floor of the White House. Despite advancements in technology used to produce machine-made carpets, the

handwoven carpets or rugs have retained their value as an attractive and masterful product.

Persian handwoven carpets are exported to about 80 countries, and the exported value is estimated to be \$500B per year, according to the Persian Carpet Research Center [44]-[46]. The tallies, however, do not cover the potential value of the millions of carpets woven and remaining in Iran as well as sold before throughout the world, since, it is nearly impossible to track or quantify them [44]. Most of the designs are named after the village or area that is expert at a unique pattern or style of weaving such as Tabriz, Kashan, Naeen, Isfahan, Qom, and Kerman. In addition to data-backed evidence of carpet including origin, place, pattern, map, designer name and other physical features like size, the number of colors, weaving style. Every handwoven carpet can carry provenance and much trustworthy information about the owner and environmental parameters that form the ingredients of a successive story and potentially increase the intrinsic value of a carpet. For example, those carpets which are placed at the holy sites of Islam, Christianity, and other religions are traded at premium prices because the potential buyers assumed them to be blessed and cherished by the location of use [1]. The smart chip which pings out to the GPS offers an innovative solution to trade these used carpets by verifying the location. This positively influences the purchase intentions and willingness of customers to pay a premium [1].

V. CHAMROSH AND BLOCKTAC

BlockTac [47] is a Spanish startup who offers solutions in the Identity Management and Authentication field for various industries through in house technology, which is built on the integration of blockchain, cloud, and mobile app. Founded in 2018, BlockTac has developed a cost-effective technology in the educational sector which empowers Universities, Business Schools and other educational institutes to register the certificate of their students on the blockchain. BlockTac further provides a mobile platform to enable the third party to verify the issued certificate. The technology is implemented in five simple steps as illustrated in Figure 5.

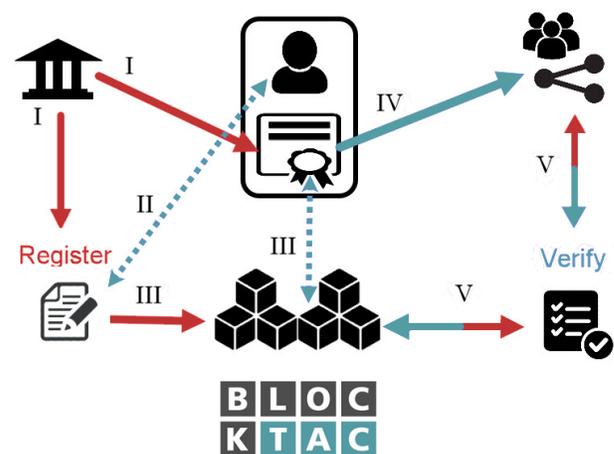


Figure 5. BlockTac methodology to verify certificates

First, the University or Educational Institute who has the record of registered students will issue the certificate for those who fulfilled the requirements and then communicates the details to BlockTac through a private and secure channel. Second, BlockTac notifies the student and facilitates an Android or iOS application to view the certificate and get the student's confirmation on personal and other details. Third, BlockTac registers the certificate on the Blockchain through in-house technology and sends the blockchain certificate with a relevant link to the student. Forth, the student can share the certificate with whomever he or she wishes. Fifth, any person or third party can verify the authenticity of the certificate without having to contact the University or Institute.

Relying on Blockchain technology to provide the properties of inviolability, immutability and open verification for all digital certificates, BlockTac is now diversifying the technology and integrating it with the value chain of industries such as luxury, healthcare, pharmaceutical, insurance, supply chain, food, and logistics as well as government administration and financial sectors. For example, BlockTac has developed a digital seal for food products, including oil, wine, and saffron as well as medicines and perfumes, to battle counterfeiters. In the food supply case, for instance, all information is digitally connected to a particular food including farm-origination, processing protocol, factory information, storage, and transportation details, most importantly expiration dates are collected, agreed and stored in a digital certificate which becomes a permanent record that cannot be changed. The records are approved by consensus among participants and then verified through the mobile app by consumers.

The solution works as follows: in the first step, the seal of a bottle or package will be opened, and the mobile scans the Quick Response (QR) trackable code. The digital certificate in the blockchain is just valid for one-time verification. Upon scanning, the system verifies the credentials and confirms that the package is original and the seal has never been opened. In the second step, if we rescan the code or try to use it on another product or package, the system disproves the credentials and indicates that the package was opened before.



Figure 6. Digital seal for food products by BlockTac [47]

In most industries and sectors, including investment, logistics, and even governments, the issue of identity management, traceability and authentication are critical.

BlockTac technology would contribute to reinforcing identity via blockchain and enabling verification through a mobile application without Trusted Third Party (TTP).

BlockTac and Chamrosh are now collaborating on a well thought strategic partnership to forge a technology to transform handwoven carpets to smart carpets. Synergizing each other's core competencies, both startups are expecting to seize evolving opportunities by leveraging mutual resources and expanding their geographical reach in the digital era where most companies become increasingly interdependent. The technology is developed by using a smart chip and seal containing QR code, embedded in a handwoven carpet, to store the data-backed features of carpet on the blockchain system as successive story blocks. The process is shown in Figure 7 when data to be collected through a protocol every month and recorded in an individual block basis where the last block will contain the whole story. The immutable history of ownership will also be recorded, and once the real owner verifies a purchase, as an update, the system automatically forms a new block of ownership with all other features for the next owner.

The sharing economy can also provide an emerging opportunity to rent or lease luxury handwoven carpet on a daily or weekly basis for special occasions including weddings, and anniversaries. Blockchain and IoT can help to trace this luxury item during the rental period.

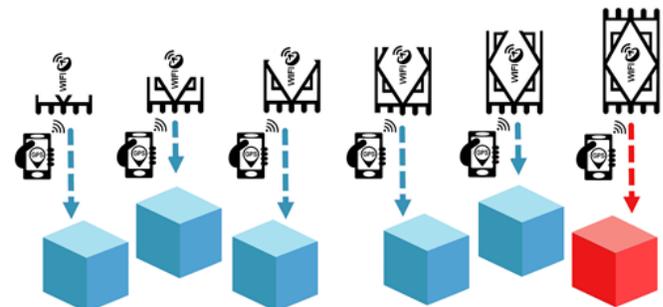


Figure 7. A narrative of weaving to be stored in story blocks

Powered by blockchain, the smart carpet business model can offer significant benefits for carpet weavers, dealers and customers, by improving efficiency, transparency, and traceability of supply-chain. The platform gathers, shares and verifies key information and evidences about a woven carpet by integrating secure, trustworthy and accessible technologies. We can enumerate the benefits as indicated in Figure 8.

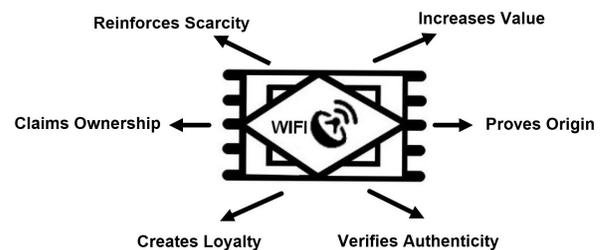


Figure 8. Smart carpet can offer six significant benefits [39]

First, through smart chip, which identifies the place of production, the system determines genuine carpets woven within Persian territory and essentially differentiates them from fake carpets that copy the design and are produced in other places. This proves the origin and craftsmanship quality. Second, the system creates an immutable and live digital identity with a mobile application to verify authenticity. This deals with counterfeiting and fake items and gives peace of mind to the customers. Third, the system generates a platform to directly interact with consumers and make them part of a weaving story. This wins the hearts and minds of Handwoven carpet's fans in a new and innovative way and creates loyalty. Forth, the system records and tracks the ownership, and this makes the carpet transferable and updatable once the status changes. Fifth, the system reinforces scarcity and exclusivity by making the item unique and irreplaceable. Sixth the system increases the value of a smart carpet since its aesthetic, historical, and sole significance and all former benefits contribute to the value.

The aforementioned business model aims to bring back confidence to handwoven carpet fans and empowers them to interact with their luxury items in the most direct, secure, and transparent way that cutting-edge technologies allow. The possibility to track ownership and update the changes once the real owner of carpet requests, provides a unique opportunity to earn money for transferring ownership to the next owner. This can justify the commercialization of technology and business model.

The prototype of the solution is shown in Figure 9 in which the credentials of a carpet is framed into a digital certificate and then stored on blockchain with Quick Response (QR) trackable code. A QR code, which is a two-dimensional code in square shape image, mostly represented by black and white pixels in a binary format and is used in consumer advertising such as web pages and posters.



Figure 9. Digital certificate of carpet stored on the blockchain [48]

QR code has fast readability, and larger storage capacity compared to barcodes and used to hold and record the credentials of carpet on the blockchain by distributing a full copy of the database to multiple computers or nodes. All participants must approve the changes, so it is incredibly

challenging for individuals to tamper with the carpet's digital certificate or commit fraud.

The QR tag is attached at the back of the carpet and once an app scans it, the relevant certificate paired with the carpet credentials will appear on the mobile. The user can scroll down to verify the certificate as shown in Figure 10 by clicking on the verification button, and within a few seconds, the features of the carpet will be authenticated through blockchain.



Figure 10. Mobile App verifies the credential of carpet [48]

VI. CHALLENGES AND IMPLICATIONS

One of the emerging challenges in the smart carpet business model is the fact that smart tag can be removed and then attached to a replica carpet. In these circumstances, the owner has an option to push another carpet of similar kind and lower value into the system. Obviously the owner cannot own two carpets with the same smart tag, yet, he or she can still sell the first carpet in the market and leverage the value of the second replica because of smart tag. In this section, we offer a solution to address this challenge by digital image processing and steganography.

With the advancement of Artificial Intelligence abbreviated as AI technology and the power of computers, digital image processing is now among growing technologies with various applications in business, science, and everyday life. Traditional image processing technologies mainly focus on image acquisition, transformation, enhancement, restoration, compression coding, segmentation, and edge extraction [49]. Yet, image feature analysis, image registration, image fusion, image classification, image recognition, content-based image retrieval, and image digital watermarking have made significant progress in different fields [49][50], which reflect on human intelligence activities [49] and are empowered by Artificial Intelligence. The recent and major applications of image processing include but not limited to aerospace, land mapping, urban planning, medical research and treatment, product anti-counterfeiting, surface damage identification, real-time monitoring, iris recognition, and military, cultural, artistic and communications aspects of human life and work [50].

Image processing includes two key steps or two-dimensional functions, namely sampling and quantization

[49][50], which enable a computer to recognize images. Sampling and quantization are sometimes referred to as acquisition/scanning and preprocessing in image processing literature, respectively. Ponti et al. [51] argue that the image-based visual recognition pipeline includes a step that converts colored images into images with a single channel, obtaining a color-quantized image that can be processed by feature extraction methods.

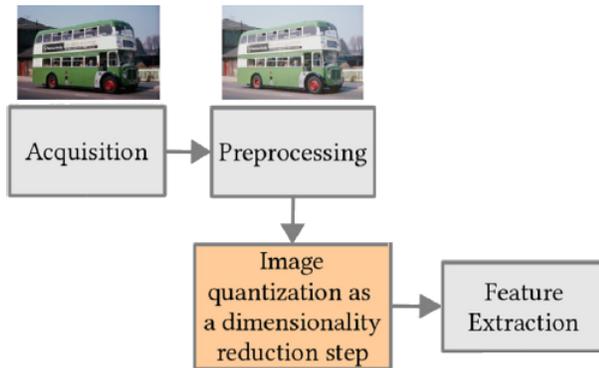


Figure 11. The pipeline of image processing [51]

Digital images are generally obtained by optical scanners or cameras. The allocation of pixels to locations in the original image is called sampling, which means each pixel represents a sample of the image from a particular place [50]. Quantization assigns numbers from 0 to 255 in color images for each pixel from 3 channels (Red, Green, Blue). Each channel has 8 bits, which contains 256 grades starting from 0 which is the darkest color to lightest that is 255. Therefore, $(2^8) \times (2^8) \times (2^8) = 16,777,216$ choices of color are available for each pixel. The next step in image processing would improve the quality of the image, which can be done via Contrast & Brightness, Filters, Threshold, Edge Detection and Contour, Sharpening and Blurring, and Noise Reduction.

A. Carpet fingerprinting by detecting human errors

It is often said that all carpets are perfectly imperfect which means that slight inconsistencies and imperfections prove that a carpet was woven by hand [48]. The fact is reflected in David Benioff and DB Weiss interview with Japan's Star Channel addressing Game of Thrones' controversial eighth season in which a coffee cup left in a scene in front of Daenerys Targaryen. David Benioff called it their "Persian rug" to justify the issue by saying, "In Persian rugs, it's a tradition that you make a little mistake when making the rug because only God can do anything perfectly." [52]

A carpet is usually woven by a reader who speaks out the color of each knot pixel by pixel from the original carpet map. The weavers, who listen to the reader, select the colors and weave them in the same sequence, which they hear. Yet, they are likely to commit a few random mistakes by weaving a wrong color specially when they are tired or lose their concentration. Other errors such as knot loss, and

carpet ragging i.e., changing the width of the carpet due to the aggregation of the pulling force of the carpet weft are all exclusive and distinct features of any handwoven carpet. Therefore, we can argue that every carpet has unique and distinct features that cannot be replicated whatsoever, and that is how every carpet is perfectly imperfect. This is exactly like human fingerprints, which are detailed and unique i.e., no two people, not even identical twins, have the same fingerprint. That is why we use fingerprint term for handwoven carpets since no two handwoven carpets can have exactly the same errors.

For example, it is very much possible that in a handwoven luxury carpet of 5 Million knots, 5,000 knots are woven with the wrong color which indicates 0.1% errors. These errors are the unique characteristic of a carpet that randomly took place and are unlikely to happen in the same knot or pixel in another carpet, even if the original map, reader, and weavers are the same. These errors are considered to be the fingerprint of a carpet and are stored on the blockchain as a part of the immutable digital certificate. We can then use this innovative idea to identify a handwoven carpet by using image processing technology. The first step is to utilize a high-resolution scanner for scanning the back of the first carpet to record the woven layout in the computer. The scanned layout then must be compared to the original map through image processing algorithms to reduce noise and contrast and sharpen the brightness. For example, in Figure 12, we can observe that in pixel 6, 13, and 15, there are slight brightness errors, and the real colors are not properly sampled and quantized. That is why our image processing algorithms should enable us to correct the color according to the color of the original map.

Moreover, the weavers of the first carpet have committed few mistakes on the color of pixels 4, 18, and 30. These are originally red, green, and yellow respectively in the carpet's original map. Yet, we can see that they are wrongly woven as blue instead of red (pixel 4), yellow instead of green (pixel 18), blue instead of yellow (pixel 30).

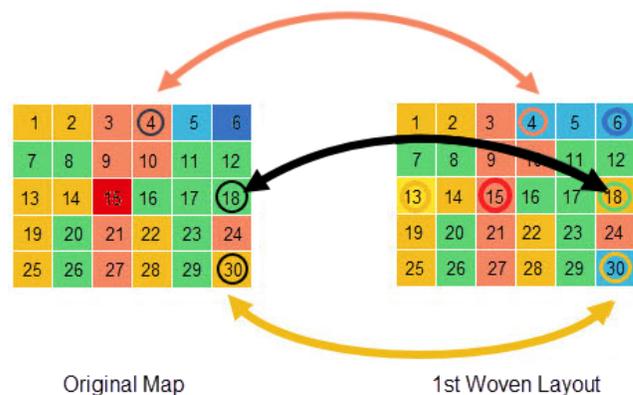


Figure 12. Comparison between original and 1st woven layout

Therefore, we identify pixels 4, 18, 30, which are mistakenly woven in different colors, as the unique feature

of the first carpet and add them to the next block in the blockchain as an element of carpet’s digital certificate.

TABLE I. THE ERRORS IN WEAVING PROCESS

Pixel	Original layout	1 st Woven Pattern
4	Red	Blue
18	Green	Yellow
30	Yellow	Blue

Now, let us say that in a very optimistic scenario, there is a new weaving team who have access to the original map and try to weave a replica. They cannot succeed to copy exactly the same carpet simply because the errors will randomly take place in different pixels during the weaving process of the second carpet. Therefore, it is absolutely unlikely that the errors on the second carpet happen in the same pixel as the first carpet.

For example, we assume that the random errors of the second carpet happen in pixel 6, 21, 26 as indicated in Figure 13. These are originally dark blue, red and green respectively in the carpet hardcopy layout. Yet, we can see that they are wrongly woven as red instead of dark blue (pixel 6), blue instead of red (pixel 21), red instead of green (pixel 26).

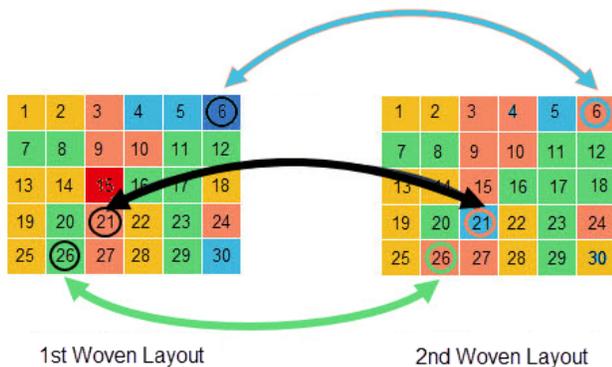


Figure 13. Comparison between 1st and 2nd woven patterns

Therefore, we can identify more dissimilarities (here six) by comparing the layout of the 1st and the 2nd carpet, which are highlighted in Table II.

TABLE II. COMPARISON OF ORIGINAL AND WOVEN PATTERNS

Pixel	Original	1 st Woven	2 nd Woven
4	Red	Blue	Red
18	Green	Yellow	Green
30	Yellow	Blue	Yellow
6	Dark Blue	Dark Blue	Red
21	Red	Red	Blue
26	Green	Green	Red

The theoretical assumptions discussed with examples are based on human errors during the weaving process. These errors provide an excellent identifiable characteristic

for any handwoven carpet to be integrated within the digital certificate and then stored on the blockchain. These errors are as unique as human fingerprints which are detailed, very difficult to alter, and durable over the life of an individual

In addition to colors, there is a good possibility to identify symmetric and asymmetric issues within the woven layout. The original map of a handwoven carpet is based on either symmetric or asymmetric pattern. Yet, due to human errors, the woven layout does not fully match with the original map in terms of the size and dimensions of features. Therefore, we can reutilize image processing to identify the errors which took place in the pattern of the woven carpet. These errors are always unique for each and every handwoven carpet because they happen randomly.

B. Carpet fingerprinting by a hidden message

In addition to random errors of a handwoven carpet, the possibility of storing and communicating secret and/or private information can provide an invaluable solution to identify and verify the original carpet and act as the second fingerprint. This can be achieved by committing a few intended errors during the weaving process.

Information security systems are separated into two major categories i.e., encryption and information hiding [53]. Whereas cryptography keeps the data secret by converting it into an unreadable form, information hiding which is divided into watermarking and steganography does not change the format of data or message and keeps the presence of its actual data [54]. Watermarking is a process in which the information or message which verifies the owner is embedded into carriers such as images, audios, or videos.

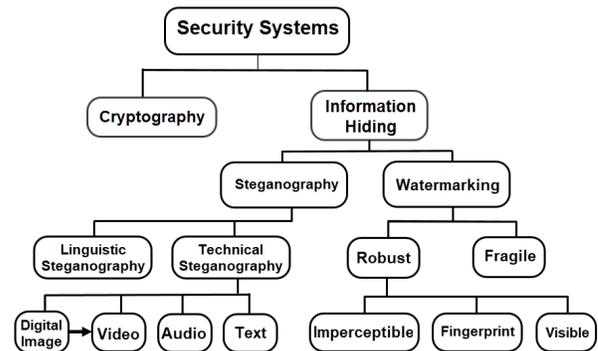


Figure 14. Classification tree of information hiding [53]

In 1993, Tirkel et al. [55] first introduced the digital watermarking system, which embeds hidden copyright marks or other verification messages into digital multimedia. When a dispute of copyright occurs, the owner can prove his ownership by revealing the copyright mark from the embedded watermark. Watermarking is of two types; visible and invisible. The embedded watermark must be robust to accidental processes, such as JPEG compression, or malicious attacks like cropping, noise adding, and rotation. Otherwise, the embedded watermark may be distorted or totally lost.

The goal of watermarking is one to many communication in which the intruder cannot remove or replace the message. Figure 15 shows a watermark in EURO banknote which is a recognizable image that appears when viewed by reflected light. Here, it is challenging to extract the watermark because the image will be distorted under some capturing process, such as scanning.



Figure 15. Watermark in Euro banknote

Steganography is another technique using digital images for secret communication where a hidden message is embedded in the image that only the sender and intended recipient can reveal. The goal of steganography is one to one communication in which the intruder cannot detect a message. Therefore, steganography can be used to reinforce the identity of a woven carpet by embedding a message such as the designer's name and time and date of design during the weaving process. Carpet's layout offers an excellent platform to embed messages because of two major reasons. First, layout can be altered to a certain extent without losing their beauty and quality. Second, humans are unable to distinguish minor changes in image color and a carpet pattern once the layout is woven. For example, we can turn 1000th to 1020th pixels or knots in the layout to colors that correspond with a letter of the alphabet or a number. While the carpet appearance would not appear exceedingly distorted or perhaps slightly corrupted at worst, we can decrypt colors and find the message.



Figure 16. Steganography embeds a secret message inside the pattern

Steganography, as discussed, can embed few intended errors during the weaving process that corresponds to a secret message like date or place which is hidden in the pattern. This method ultimately produces another unique feature like a fingerprint that can be stored on the

blockchain. As such, we can spot a counterfeit carpet that does not carry the embedded message within the pattern.

To sum up, we can integrate both solutions, i.e., human errors and a hidden message to generate an integrated digital fingerprint for every handwoven carpet and store it on the blockchain.

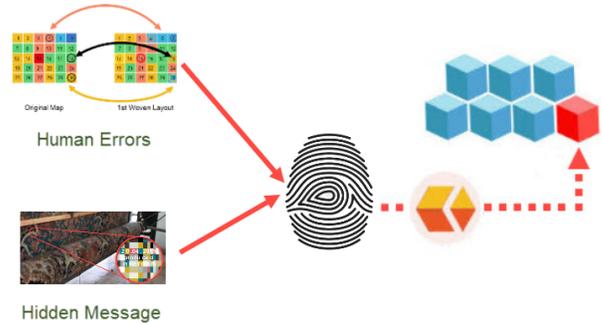


Figure 17. Carpet fingerprinting by integrating errors and hidden message

This digital fingerprint builds a robust and immutable connection between physical carpet and digital carpet. Even if the QR code is lost from the back of carpet, the digital fingerprint (random human errors and secret message) will maintain this connection and we just need to take a few photos from the back of carpet and utilize the fingerprint stored on the blockchain to compare and contrast the so-called layout with the original map.

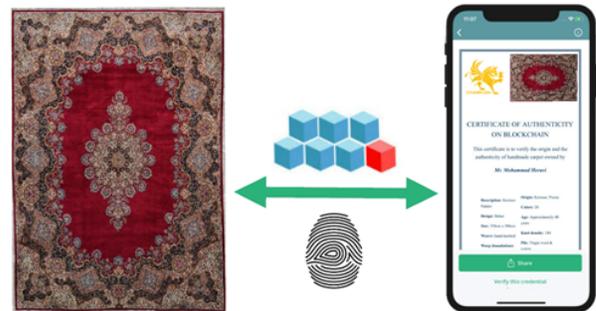


Figure 18. Digital fingerprint connects physical carpet to digital certificate

The fingerprint verifies the authenticity of the original carpet by matching the errors with the original map. If errors do not match, the system crackdowns and reports counterfeit.

VII. DISCUSSION

The platform, as discussed by Parker et al. [56], is an emerging business model that leverages digital technology to connect people, organizations, and resources in an interactive ecosystem in which tremendous amounts of value can be created and exchanged. The most valuable companies in the world Microsoft, Apple, Amazon, and Google — have harnessed platform power to achieve rapid growth and market dominance as their products and services permeate our daily life [57]. These platforms usually consist

of common technological building blocks that the owner and ecosystem partners can share to create new complementary products and services, such as smartphone apps or digital content from Apple iTunes or Netflix [58]. Uber and Airbnb are two other famous companies whose business model is to create transaction platforms which connect suppliers to the consumers. These platforms are largely intermediaries or online marketplaces that make it possible for people and organizations to share information or to buy, sell, or access a variety of goods and services [58]. Platforms generate network effects and positive feedback loops where the value each user experiences, increases as more users adopt the platform [56].

The idea of generating a fingerprint and issuing and storing digital certificate of handwoven carpet on the blockchain through the platform is novel and still under thorough research in order to study the feasibility and value proposition for stakeholders who are brought together to produce network effects. Yet, Chamrosh Technology is already demonstrating the “start-up soul” argued by Gulati [59] in which he observed that startups have an essential and intangible notion such as energy and soul which inspire people to contribute their talent, money, and enthusiasm and fosters a sense of deep connection and mutual purpose. Chamrosh is intended to leverage digital technologies to co-create the legacy of luxury handwoven carpet to globally protect and promote Persian carpet, which struggles to keep the centuries-old industry alive. This is an ambition to fill needs that handwoven customers had not realized before, and it is as if Chamrosh is articulating new problems that cannot be solved by existing solutions. The concept of an utterly new category was highlighted in “How Unicorns Grow” [60] as a successful strategy formulated by Facebook, LinkedIn, and Tableau who were carving out entirely new niches. Ramadan et al. [61] believe that the most successful start-ups become Category Kings and bury the competition and therefore, they argue that a common phrase in technology ‘There’s room in this market for several players’ seems to be utterly false. The data shows that there’s room in any well-defined category for one super successful player and a bunch of companies that wind up as category serfs and those that just die [60].

The business intent of Chamrosh is, therefore, the first element in Gulati’s [59] dimension of the soul which can run deeper and spark a different, more intense kind of commitment and performance as argued in his framework. Moreover, the research-oriented approach resonates with improvisation concept suggested by Gulati and DeSantola [62] in which they argue that young ventures need to try new things and react to dynamic markets, but with an eye toward larger objectives and sustaining the business. The brand is created with this strategy in mind since Chamrosh is a bird in Persian mythology with the body of a lion and head and wings of an eagle. It is said to live on the summit of Mount Alborz and is sent by an angel to snatch invaders and drop them from mountaintops in order to protect the Persian Land.

Chamrosh vision is to be the global platform to cherish the odyssey of Persian art and culture.



Chamrosh is a bird in Persian mythology with the body of a lion and head and wings of an eagle who is sent by an angel to protect the Persian Land.

Figure 19. Chamrosh Brand [39]

The second dimension is customer connection where Chamrosh business model tries to inspire carpet fans to contribute and be part of the narrative of a handwoven carpet and co-create a brand for example through the style and location of the carpet which are all collected and stored while observing the confidentiality and privacy issues.

The third dimension is to allow people and employees to have a voice and choices. Here, Chamrosh must work very hard to give employees ‘freedom within a framework’—the liberty, i.e., to operate within well-delineated boundaries—as well as opportunities to influence key decisions, such as which strategies or products to pursue as suggested by Gulati [59]. This dimension is critically highlighted in other studies. For example, Henrich [63] argues the internal startups, filled with a small number of passionate believers dedicated to one project at a time, can experiment rapidly and scale their impact. Gulati and DeSantola [62] consider culture a big part of what draws people to join start-ups—and what keeps them going. As employees battle the odds to turn a fledging business into a viable company, working late nights and weekends to make it happen, they’re motivated by camaraderie and a sense of belonging to something important. Also, the founders must develop and practice some crucial skills and traits including building a great team, leadership, team management, selling, marketing, product design, strategy formulation recommended on a survey of 141 founders of enterprises by Eisenmann et al. [64].

VIII. CONCLUSION AND FUTURE WORKS

Chamrosh like other successful startups can possibly preserve and revive its soul and remain innovative and grow as long as it keeps those three elements suggested by Gulati [59] at the forefront of its strategy and daily operations. This will take time, effort, and iteration to improve the business model and enhance technology. But the critical question is whether the handwoven carpet market can be cultivated into an active ecosystem that appreciates Chamrosh solution. This question resonates with the “scalable startup” definition [65] which argues that startup must aim not only to prove its business model but to do so quickly, in a way

that will have a significant impact on the current market. There are three key ingredients in this definition :

- First, the goal is to seek, explore, examine, and validate an unmet need within the handwoven carpet market by providing a vision of a smart carpet with a set of features.
- Second, assumptions and hypotheses about carpet platform model are made to iterate until they are proved.
- Third, Chamrosh must quickly validate the model and check if customers behave as the model predicts. The feedback and input of stakeholders, including weavers, dealers, and carpet fans, are instrumental in answering this.

The above three ingredients are in line with three innovation challenges raised by Eppinger [66]. Here Chamrosh suggests digital certificate solution to build trust with handwoven carpet fans (People). Then it leverages blockchain and image processing to develop the solution (Technical). Finally, it formulates a platform model to encourage stakeholders to contribute.



Figure 20. Three innovation challenges [66]

Building on platform model, Chamrosh enjoys two significant benefits of platforms highlighted by Parker et al [56]. First, it leverages marginal economics of production and distribution, since Chamrosh can expand with minimum marginal cost just by integrating digital technologies on selected new carpets when the listing fee of carpets is very small. Second, the possibility to scale quickly is enhanced by network effects of carpet fans.

The other important question after successfully passing former stages is that how quickly Chamrosh can become a Category King, dominate the entire technology industry, bury the competition and reach a pinnacle that even founders could not have dreamed. This demands high levels of trust, cooperation and innovation which can be achieved by infinite mind set in business as suggested by Sinek [67]. He argues that the game of business fits the very definition of an infinite game and infinite mind ensures that an organization's employees, customers and shareholders remain inspired to continue contributing with their effort, their wallets and their investments [67]. Chamrosh can embrace surprises and adapt with and even transform by changes if it is structured to last forever and this is the nature of a company built for resilience i.e., as highlighted by Sinek [67]. Time will reveal if Chamrosh can do this as "most overnight successes took a long time" Steve Jobs.

Future research is suggested on evaluating the feedback and comments of stakeholders, including handwoven carpet fans and the owners of luxury carpets. Also, the image

processing solution must be put into practice to assess the feasibility and technical implications

Chamrosh has developed Minimum Viable Product (MVP) and is planning to introduce the first Blockchain-Empowered "Carpet" or "Rug" focused on verifying the origin and authenticity in the first quarter of 2020. The steering committee of the startup has identified a masterpiece that crystalizes the craftsmanship quality of Persian rug.



Figure 21. The first Blockchain-Empowered rug in the world [68]

The creator of this unique 1.5m x 2.46m item, Ali Lahiji, spent 8.5 years designing the original map and weaving the layout. The rug was completed in early 2019 and has 1000 different artistic elements, including flowers, birds, and animals in 110 compound colors of pure silk. These elements have a significant meaning which reflects their close affinity with nature. The rug is woven with 6 million knots and will be the first in the world that has equipped with electronic fingerprint and certificate of authenticity stored on the blockchain. The aim is to create a unique user experience through a mobile application where potential customers can authenticate and verify the history of this masterpiece.

IX. CONTRIBUTION

The sharing economy, platforms, and digital technologies are disrupting the luxury sector by offering a new catalyst for growth and enabling individuals to share goods and services and even contribute to their design, production, and consumption.

The first and significant contribution of this study is to bring insights into the emerging and disrupting role of blockchain in the sharing economy and luxury industry for reinforcing provenance, building trust, and verifying the credentials and ownership.

The real application of blockchain technology in one of the most traditional businesses, and enumerating the benefits is the second contribution. Here, it is highlighted how a handwoven carpet can be transformed into the smart carpet as a blockchain-empowered product which enables carpet fans to verify the authenticity, claim ownership, and enjoy scarcity and exclusivity.

Third, the study points to the vital role of a strategic partnership between new ventures to explore and seize evolving opportunities for maximizing value for both parties especially in the digital era where most companies become increasingly interdependent.

Forth, the study suggests an innovative revenue model for strategic partners to earn money from second-hand trade onwards on the blockchain.

Last but certainly not least, this study offers state-of-the-art solutions by utilizing image processing to generate an identifiable feature for any handwoven carpet. This feature can be as unique as human fingerprint.

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