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The Digital Urban Experience of a Lost City
Using Mixed Methods to Depict the Historical Street Life of Edo/Tokyo

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Abstract This paper digitally reconstructs street life in Edo (present-day Tokyo), the largest lost city of the pre-modern world. The ephemeral character of the Edo makes the historic urban experience extremely difficult to capture. We argue that the hypothetical digital reconstructions should incorporate evidence on human agency and spatial properties for a holistic simulation of historic street life. We develop a 3D hypothetical reconstruction based on multi-layered historical evidence to unlock the lost character of the Edo streets. It reveals the streets of Edo, including the rhythms of everyday life and the impact of the material culture.

Keywords Urban history. Everyday life. Space-use. Pre-modern Japan. Streetscape. Digital past. Virtual reconstruction. 3D modelling.

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1 Introduction

The character of urban spaces has often been labelled via sets of terms such as public/private, open/semi-open/closed and indoor/transition/outdoor space. These distinctions have long been blurred when defining pre-modern streets as urban spaces due to the pluralistic dynamics of street life. As the governance of streets and squares are shaped by a combination of everyday use and physicality, the space of the street can only be investigated via a joint exploration of practices and materiality.

The use of digital visualisations is not new for historical research involving analysis of large quantities of unstructured historical data in two-dimensional (2D) space, and the extensive use of digital tools and strategies have long contributed to an enhanced understanding of the dynamics of urban space in pre-modern cities. The Geographical Information Systems (GIS), known also in the field as historical GIS, has allowed greater insights into the patterns of street use and has furthered understanding of the physical culture of the city in all aspects deemed imperative in shaping the way agents behave in physical space. A broad range of applications in the form of digital three-dimensional (3D) reconstructions has also begun to give way to an authentic, immersive urban experience of the past. Nevertheless, studies focusing on 3D reconstructions have disproportionately concentrated on the material culture of historic streets and have based their hypotheses on photographic or material evidence in particular. In fact, 3D reconstructions can also play an important role in providing insights into the spatial dynamics of long-lost streets despite the lack of material evidence. They can support historians' explorations of the relationship between the built environment and individuals, although current digital applications have scarcely begun to bring this connection forward.

The streets of pre-modern Edo, before the city's transition into Tokyo as we have come to know it today, provide an excellent yet challenging case to pursue the possibilities of such a blended digital approach: the ephemerality of its built environment and the scarcity of extant historical testimonies – whether in the form of textual, physical, or visual evidence – inevitably requires the sort of cross-disci-

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plinary study we propose. This paper thus attempts to digitally hypothesise facets of material and immaterial culture alike so as to uncover the richness of the long-lost street life of Nihonbashi in the city of Edo. It offers a 3D reconstruction of a street space that provides a revealing snapshot of everyday life in Edo, and it showcases a dramatically different kind of urban scenery than we see today. This area was witnessing rapid urbanisation; it reveals the drawbacks of a Golden Age and indicates a rise in culture.

2 A Global Perspective on the Role of the 'Digital' for the Discovery of Historical Street Life

When investigating historical street life, a key problem concerns adding the perspective of space and human agency together in order to uncover everyday urban space-use, social activity patterns, and mobility. In historical research, the relationship of human agency and the built environment plays a crucial role, but it rarely takes centre stage in digital methods. Only a limited body of studies address this essential issue, and current research is dominated by a 2D mapping approach, typically in the form of historic datasets projected onto maps of urban space. Such an approach has confirmed its considerable capacity when research is focused on the densities of agents' use of urban space or on changes in street and block densities (Noizet 2020), or has engaged in reconstructing vanished streetscape patterns in 2D space (Page, Ross 2015), to cite a few of many examples. Certain other scholars tend to address the spatial analysis of historical urban street networks using space syntax and investigate the relationship between urban space and urban life. This method has been followed by the integration of the space-syntax approach with GIS, enabling a wider analysis of street use to decipher accessibility, visibility and networks in the service of advancing historians' interpretation of urban life itself (Griffiths, Vaughan 2020). The drawback of these studies is in their representation capability: bounded in 2D space, they lack the vertical dimension that is required to fully decipher historical street use.

Stepping beyond the horizontal representation in 2D space is especially important when unlocking the relationship between buildings and the street, and its effects on the form assumed by street life. A relevant major advance is the Time Machine Project, which coined the concept of a four-dimensional (4D) world for historical urban space. Here the 3D model has been complemented by a conception of time, placing the formation of a digital information system on the horizon and underlining the value of recreating cities as they were in the past. "The Advent of the 4D Mirror World" (Kaplan, Di Lenardo 2020) ambitiously aims to provide a search engine for access to information about historical places and human agency, and has begun to

show its capacities with regard to certain historical European cityscapes such as in Dresden (Münster et al. 2020). From the urban perspective, the 3D/4D modelling approach of a historical urban section requires 3D documentation from reality (Devaux et al. 2018), 3D modelling based on historical sources (Chevrier 2016) or the combination of both (Rodríguez-Gonzálvez et al. 2019). Amongst these approaches, 3D modelling from reality has received significant attention and yielded highly accurate, even photo-realistic representations of historical urban environments. Nonetheless, such an approach is only possible when evidence of historical stratification exists as physical traces. In fact, the material culture of a particular locale might be utterly vanished due to changes (planned and unplanned) attributable to natural or human-made causes that have brought forth physical surroundings that differ from what historical agents experienced in the past. This calls into question the applicability of reality-based or mixed 3D reconstruction methodologies when hypothesizing ephemeral urban sections such as the long-lost streets of Edo, where extant material culture is utterly lacking. Such instances draw attention to the importance of source-based methodologies.

The topic of historical streets has also begun to draw attention from researchers working with machine learning algorithms. Google Artificial Intelligence Research attempts to provide a Google Street View experience of historical urban space through the use of deep learning and crowdsourcing in its work on the recreation of historical Manhattan streetscapes in 3D (Kiveris 2020). Its developers acknowledge the difficulty of finding historical images for each building, making the 3D reconstruction an extremely challenging problem. Taking up the source-based methodology, the research by Tamborrino and Rinaudo (2015) is useful when considering a demolished streetscape and making use of various historical drawings to compile a reliable historical 3D world, and the Pudding Lane project's (Dempsey et al. 2014) creation of a textured seventeenth-century London streetscape in 3D provides an authentic virtual urban experience. Last, the research project focusing on Early Baltimore streets (Rubin 2020) innovatively attempts to interrelate groups of agents with the street space surrounding them; nevertheless, their work-in-progress remains at the phase of attributing human agency very implicitly in 3D.

As a consequence, the recent concepts highlighted involving the historical GIS approach when studying historical street life at large are critically important. Moving towards 3D space digitally, however, the research remains limited and is mostly bounded to the building envelope in efforts to represent the street space in 3D space. Digital reconstructions guided by the interpretive process possess tremendous potential as an analytical research tool, allowing scholars to test their hypotheses in a blended way and to answer historical questions about lived space, mobility, and the urban landscape.

3 The Digital Attempts to Reconstruct the Pre-Modern Urban Space of Edo

The long-lost urban space of pre-modern Edo has attracted substantial historical research, especially during the seventies and eighties. This scholarship has been grounded in various disciplines: architectural history, Japanese history, urban planning, archaeology. The insights of leading scholars such as Tetsuo Tamai, Jun Hatano, and Nobuyuki Yoshida, to name only a few, into issues concerning the commoners' district in Edo have addressed its diverse aspects, ranging from its physical built environment to its administrative system and social structure and to people's everyday life and their changes over time. These research efforts resonated with a strong aspiration to reconstruct the lost cityscape (Takahashi 2018, 10-19, 39-61). Many attempts have been made to reconstruct the visual appearance of the city and its streets, first via physical scale models, more recently via digital technology.

Museums in Tokyo began featuring multiple scale models as historic reconstructions, created by many architects and in varying scales, to showcase the city's urban development from the Tokugawa period up through modern Tokyo. Among the highlights are the scale model showcasing the northern half of the Nihonbashi commoners' district, exhibited at the Tokyo Metropolitan Edo-Tokyo Museum, and the model on the urban space around Edobashi Bridge together with its adjacent *hirokōji* (wide street), which was on view at the National Museum of Japanese History. Realised by Hatano, both scale models stimulated the intellectual curiosity of museum visitors with their 'realistic' visual representations of now-lost urban spaces. Although Hatano based these scale models on multiple layers of knowledge and had implemented a thoroughly interdisciplinary investigation based upon historical documents (Hatano 1987; 1998), it is inevitable that in most cases one fails to trace the information presented back to its provenance (instances of the black-box effect). Furthermore, the separation of the scholarship from the 3D visualisation becomes critical since such physical models cannot be changed or revised when new historical evidence comes to the fore.

The arrival of 3D techniques that can be used in digital visualisations also fostered many digital attempts to restore the lost appearance of Edo within two main sorts of initiatives. On the one hand, some scholars based their studies on seminal findings on the 'past' and used 3D reconstructions not as an aesthetic model but rather as an analytical tool to support the scholarly investigation process. One such work was created by Tachikawa, Takeuchi, and Yoshihara (2003) who published the digital drawings of the reconstructed streetscape in Edo's city centre. Based on archaeological findings from the foundations of a *dozō* (storehouse) excavated beneath the early modern

strata within the Nihonbashi commoners' district, Takaya and Yokota (2003) digitally reconstructed the view of the site by comparatively integrating knowledge about *dozō* buildings' design specifications at nearby sites. In a more recent study, Hashimoto and Masuta (2018) examined the Great Meireki fire in 1657 and the fire prevention system in Edo together with the NHK Japan Broadcasting Corporation via a digital simulation of the fire and put forth hypotheses about vacant urban sites.

On the other hand, however, there are potential problems caused by the ability we possess today to create a 'real' image of the 'past'. Certain works, especially when solely designed for public engagement, are dominated by the polished visual appearance characteristic of the digital model. For instance, through virtual reconstructions the ongoing *Edo Persistent* project is currently taking ambitious steps through its integration of recent research progress with regard to the capital city's urban history in order to demonstrate the drastic change of the Ginza's streetscape in the Edo, Meiji, and Shōwa periods (Ito 2020). However, the immense historical knowledge employed for the design is generated via a generic evaluation of the historical spatial properties and space-use patterns, whereas the decision-making process that has been integrated is based to a greater extent on rule-generated volumes to the enhanced 3D models.

A significant concern, from the perspective of historical research, is the observation that the capacity of cutting-edge digital technologies to present a 'realistic' optical image can give an apparent impression that such images are absolutely true to the historical reality, as has been discussed by Peter Burke: the 'reality effect' of well-preserved historical architecture can give the visitor "a sense of direct contact with life in the past", even though such "immediacy is an illusion" (Burke 2019, 106-8). This may raise a particularly crucial problem with regard to the studies of lost cityscapes such as those in Edo, whose extant relics are extremely limited and the availability (or scarcity) of historical evidence and its granularity largely vary from one place to another.

4 The Case of Edo: Urban Form, Dwellers, and Street Life

Developed as the Shogun's residence and the seat of its political power, the castle town of Edo was characterised by a segmented sociospatial structure whose parts were nonetheless interrelated. The city, accommodating a large population of diverse social standing, was marked by urban space segregated according to social status and spatially divided into separate areas: warriors', commoners', religious districts, and Eta and Hinin villages, respectively. Nevertheless, the different communities were not completely isolated. They

interacted with one another through, for instance, economic activity, the warriors' class serving as consumers and the commoners as suppliers (Iwabuchi 2018).

The streets that crisscrossed the city of Edo demarcated socio-spatial segmentation but nonetheless functioned as intermediary spaces that bridged the separated areas. Furthermore, inside the commoners' district, the streets performed as a bonding space that united the community. The oldest part of the district, built during the initial stage of urban construction at the north side of the Nihonbashi bridge (first built in 1603), divided the space by streets into urban blocks of 60 ken (about 109 meters) squares each. The two sections that faced each other along the opposite sides of a street constituted a *chō* (town/quarters/neighbourhood), which formed the basic unit of communal society and administrative governance (Tamai 1986a, 16-47, 106-22).

From the material aspects, a *chō* consisted of (i) residential sites; (ii) essential infrastructure, including streets, waterworks, wells, garbage dumps, and shared toilets; and (iii) communal facilities for the (self-) governance and maintenance of the neighbourhood's safety with regard to fire and crime prevention, such as town gates, guardhouses, fire watchtowers (Ito 2018). On the practical side of maintenance and preservation works, the street space shared by the community functioned as the 'axis' that "tied the social relationship and spatial unity of the chō as a community" (Takahashi 2018, 109, translation by Author Yasunaga). In other words, the street, unlike those in the modern city in which blocks are separated from others as boundaries, was considered the space that was subsumed by the neighbourhood (Takayama 2018, 203).

The fair versatility of street space, as demonstrated by its physical and functional plasticity, is conspicuous for instance in the shopfront space covered under eaves overhanging the street. The shop tenants along the street opened the space to use it as an extended shopfront. When it was closed at night, the space would be restored to the street, being regarded as part of it (Tamai 1986b). The demarcation between the open street space and the buildings was not predetermined or fixed but rather was adjustable and flexible. Such an interface of space between the street and its buildings, and the versatility of such spaces, are essential characteristics of the urban space of Edo.

The digital reconstruction in this paper demonstrates such transformative, versatile, ephemeral characteristics of the street space in Edo by incorporating the shift in the time of day and thus arriving at a better understanding of the relationship and interaction between human agency and the built environment. We focus on the intersection of two arteries in the commoners' district of Nihonbashi, located roughly 500 meters to the north of the Nihonbashi bridge fol-

lowing the famous fish market, at the crossroads of the prestigious 'high street' offering strong economic advantages for merchants, Nihonbashi Street within the north-south axis, and the street along the Kanda moat connecting the castle to the Kodenmachō prison and the execution ground, Honshirogane-chō Street within east-west axis. Known in pre-modern Edo as the neighbourhood of Honshirogane-chō 2 chōme, today the location corresponds to the Nihonbashi Muromachi 4 chōme, Chūō ku, Tokyo **[fig. 1]**. The area was chosen not only because it demonstrates the general idea of *chō* in the urban planning of Edo commoners' district, representing Edo's material qualities through the use of the particular wooden workmanship which substantially differentiates it from the European culture of bricks, stone and mortar, but also because it demonstrates the different spatial qualities and modes of interaction between people and physical settings on the street.

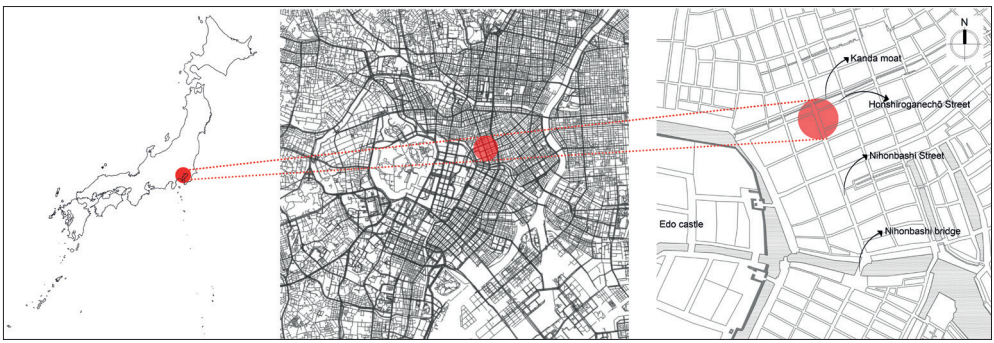

Figure 1 The case location on maps in (from left to right): Japan, Edo/Tokyo, Nihonbashi commoners' district

5 A Digital Reconstruction of the Lost Streets of Edo at the Turn of the Nineteenth Century

Since the pre-modern stratigraphy of the case location has spatially vanished, leaving no physical trace *in situ*, there is neither the possibility of conducting any reality-based 3D documentation nor any sort of definitive publication about the archaeological excavations to draw upon. To research such a challenging case, we implemented a source-based approach by extensively investigating primary sources and the secondary literature and by comparing them.

Source-based digital reconstructions, being a synthesis of historical research or archaeological findings in 3D space, represent a key expressive medium of choice for complex information discovery (Demetrescu 2018). The London Charter (Denard 2012) highlights the great potential of such digital works, which can enhance our understanding of history by providing virtual access of spaces and phenomena that, being lost to the present, are otherwise inaccessible. Its robust and authoritative guidelines draw attention to the importance of ensuring the intellectual integrity of visualisation methods and outcomes through the use of relevant research sources and the explicit engagement in interdisciplinary projects. The report of the European Commission's Expert Group on Digital Cultural Heritage (2020) recently underlined the tight bond between the quality of 3D and key aspects such as historical accuracy, range of data and metadata as opposed to measurement through captured accuracy, photo-realism or resolution. Yet there is no standard 3D reconstruction method: the reconstruction process involves an extensive reasoning process and is highly interpretative, as would be required in creating validated visual content corresponding to a now-nonexistent object (Demetrescu 2018), and is a matter of the trustworthiness (reliability, certainty) of the conception.

In fact, the generation of a historical hypothesis as a digital reconstruction in 3D space is not a linear progression. Each virtual segment reconstructed in 3D derives not from a single source but is a result of multiple sources, corresponding to different spatial particularities, being blended together (Demetrescu 2018). An extensive 3D digital reconstruction such as the lost street space in Edo involves a dramatically different process than what one finds in reality-based reconstructions. Furthermore, the accuracy does not only entail geometric precision in the final output but also corresponds to the cognitive process, as every digital entity stems from an interpretive process blending multiple sources. Yet the process is not a simple decomposing of features: each feature is spatially tied to other features at different levels of spatial granularity. In turn, it requires drone-like navigation of the resources for deciding on each component that makes the street space an urban land-

scape in order to understand each feature's role in the structural making of the spaces.

Furthermore, it is very critical to assess how reality is captured in the available sources, since each piece of material is an interpretation of the past through someone's eyes. To avoid incorrect, inconsistent or missing information within the sources, we follow two major principles: (i) contextual assessment of the source itself and decipherment of how reality was represented in the segments of the source itself; and (ii) evaluation of the consistency within different sources containing the same historical and spatial information. The former requires an evaluation of the (visual) language, the creator's setting, the timeframe, and the context. The latter indicates a cross-comparison of multiple primary sources of one scene or multiple reproductions of the same depiction.

5.1 Primary Sources and Information Coverage

The records coming from the Mitsui Bunko Archives in Tokyo have been fundamental to this research **[tab. 1]**. For instance, Tamai (1977) argues that the cadastral register of 1807 must have been documented for the purpose of rebuilding after the Great Bunka Fire of 1806, which destroyed a large part of the Nihonbashi commoners' district. These documents carry the utmost historical value for unveiling spatial features and people's living conditions at this precise location. They provide a detailed view of the land use within the urban block located at the southern side of the intersection of Nihonbashi and Honshirogane-chō streets, as well plot dimensions within the land, the dimensions of the land and the plots, information on legal ownership, the land price, the rental amount of each plot, and the name and function of certain agents **[fig. 2]**.

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Table 1 An overview of the records from the Mitsui Bunko Archives

Date	Inventory as exemplified in fig. 2	Inventory number in the archives	Simplified inventory title
1808	(e)	No. 1733 (inv. no. 追 696)	*Edo Kakaeyashiki Meisaisho* (Account book on Mitsui's land in Edo with inscriptions)
1807 with editions in 1836	(c)	No. 1734 (inv. no. 追 697)	*Edo Kakaeyashiki Ezu* (Drawing of Mitsui's land in Edo with inscriptions)
Unknown [c. 1727-1729]*	(b)	No. 12234 (inv. no. 続 1546)	*Kakaeyashiki Ezu* (Drawings of Mitsui's land in Edo)
1754, 1802, and 1871, with editions in 1876	(a)	No. 12047 (inv. no. 本 2087-1)	*Edo Kakaeyashiki Onamae Kensū Koken Tsuki* (Mitsui's land in Edo, names, frontage width and land price)
Unknown [1726?]	(d)	No. 12236 (続 1547-2)	*Ieyashiki Tsubotsuki Shukuchintsuki* (Mitsui's land [in Edo], measurement and rent price)

* The date is based on the interpretation by Tamai 1977, 117.

Figure 2 Partial views of certain document pages available at the Mitsui Bunko Archives: (a) the land price, the year of acquisition and in pawn history, 1754; (b) the land use and vacancies, ca. 1727-29; (c) the ownership, measurement and disposition of each site inside the premise, as of 1807; (d) the rent price per *tsubo*, ca. 1726?; and (e) the ownership, total measurement, land price, and name of *yamori* as of 1808.

The second indispensable primary source for this study has been the *Kidai Shōran* (1805) (Excellent View of this Prosperous Age), a well-preserved, coloured picture painting scroll 1,232.2 cm long and 43.7 cm wide, discovered only two decades ago and kept at the Museum of East Asian Art in Berlin **[fig. 3]**. It illustrates the west-side view of Nihonbashi Street, starting at Imagawabashi Bridge by the Kanda moat, and ending with Nihonbashi Bridge; it covers about 760 meters of street length in a bird's-eye view perspective that spans five urban blocks and illustrating more than 1,600 people. It is acclaimed as a critical medium for visual memory in its portrayal of street life in Edo before the Great Bunka Fire, and since its discovery the accuracy of the entities in its visual depictions has been a great subject of criticism among scholars. Up to now, historians have investigated the scroll by focusing on different aspects of historical urban space and street life. They have looked at the texts-in-pictures to analyse each symbol and character depicted in the painting (Ehmcke 2007), have examined the degree of precision in the architectural typology of the *machiya* (townhouse) (Ito 2003), have identified the shop-names lined up along the street and have compared the indications on the scroll with other primary resources (Asano 2003; Kobayashi 2018). They have also specified the illustrated people's occupations and labours (Ozawa, Kobayashi 2020), have interpreted society's urban structure and the layered connections among people and within different groups (Yoshida 2003), and have investigated the illustrator, author and literati involved in the making of the scroll (Eriguchi 2017; 2018).

The works by Morisada Kitagawa (also known as Morisada Mankō, 1837), titled *Kinsei Fūzokushi*, which form an encyclopedic account of manners and customs in the Edo period, has also been an essential primary source for this research. His account is characterised by his comparative approach, which enabled him to differentiate the subjects in Osaka and Edo based on his own experience and observations, which were enhanced with excerpts and citations from literature and images. His descriptions, particularly those on architecture, were greatly detailed and were accompanied by illustrations with annotations for further clarification, making the books one of the most valuable overall sources for the study of daily life in the late Tokugawa period and a resource that has long proved reliable among scholars. His sketches, acclaimed for their high precision, include careful representations of some common architectural typologies of the era, such as *machiya*, *dozō*, and town gates and wells **[fig. 4]**.

Figure 3 Kidai Shōran. Detail, showing Nihonbashi Street at the intersection of Honshirogane-chō Street. Hand scroll, ink and colours on paper, 43.7 × 1232.2 cm. Japan, Edo/Tokugawa period, ca. 1805. © Staatliche Museen zu Berlin, Museum für Asiatische Kunst, Former collection of Hans-Joachim and Inge Küster, gift of Manfred Bohms. Photo: Jürgen Liepe

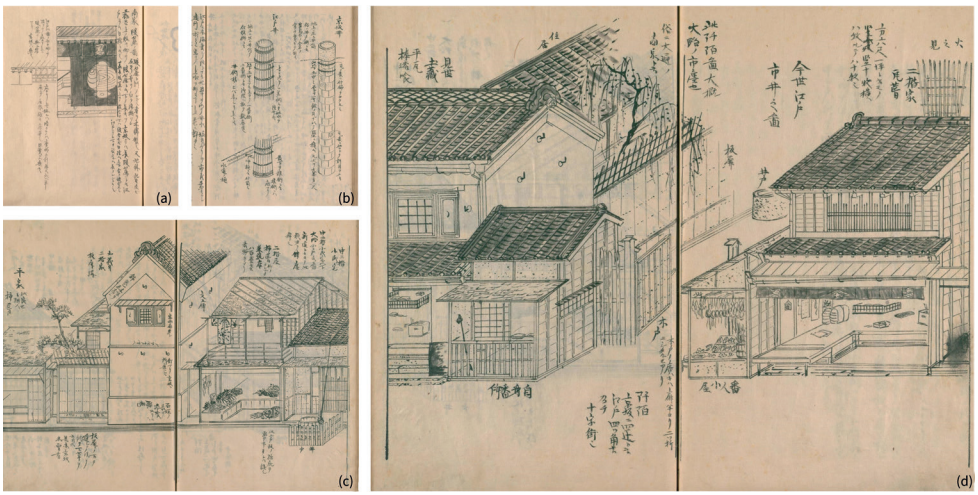

Figure 4 Example of street features in the work of Kitagawa 1837; (a) a detail from shop curtains; (b) the structure of the wells; (c) a typical line-up along a street including *machiya* and *dozō*; and (d) a street intersection, including town gates

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Another primary source has been the regulations found in the *Edo Machibure Shūsei* (Collection of the Ordinances issued by the Edo City Magistrate's Office): for instance, those pertaining to the building construction restrictions, since street space belonged, in essence, to the public authorities (Kinsei shiryō kenkyūkai 1994). In addition, the magistrate of construction also supervised matters such as the construction of a new street (Matsumoto 2015; Takahashi 2018, 109-31).

The last primary source was the map *Edo Kiriezu* published by the publishing house Ōmiya Kingo-dō, completed as a set in 1856. These maps can be roughly translated as 'cut-in-pieces map of Edo', and a total of 37 maps cover the entire city (Takashiba, Murakami 1849). Although the representation of geographical accuracy was not prioritised in the eighteenth- and nineteenth-century maps of Japan, the *Edo Kiriezu* map represents the perception of urban space as it was lived in and moved through, demonstrating agents' intra-city mobility; it was published for the political purposes of urban planning as well as for practical use in everyday life. In particular, the section map of *Nihonbashi-kita* dating to 1854 has been insightful when assessing the streetscape within the urban context **[tab. 2]**.

Table 2 Available primary sources about the case location and their information coverage

		Primary sources				
		Kidai Shōran scroll	**The works by Kitagawa**	**Edo Machibure Shūsei**	**The Mitsui Bunko Archives**	**The map of Edo Kireuzu**
Localisation (Exact/Proximate - in Edo)		E	P	P	E	E
Open street space morphology	dimensions					x
	material					
	alleyway	x			x	
	land-use	x				x
Building footprints	existence	x			x	
	dimensions				x	
Extended shopfronts	dimensions			x	x	
	shape	x	x			
	material		x	x		
	style	x	x			
	existence	x	x	x	x	
Architectural features	dimensions					
	shape		x			
	material			x		
	style	x	x			
	existence	x	x		x	
Human agency	spatial attribution				x	
	outlook	x	x			
	density	x				
	space-use	x			x	
	mobility	x				

5.2 Spatializing the Historical Evidence in 3D

The buildings standing next to each other and occupying the juxtaposing plots facing Nihonbashi Street created the most dominant spatial unit at the streetscape in 3D space. The typical *machiya*, although there are some variations, followed a repetition pattern with a similar design format and created an abutted image along the main street. Closer historical investigation allowed us to obtain more detailed information about the space-use in the area, in particular the function of each shop and/or workshop occupying the ground floor of each *machiya*. At the intersection of Honshirogane-chō Street, we find the communal facilities of the town gate and guardhouse, and following that, going from North to South, we encounter a shop named Heizaemon Yamadaya's Raincoats, Zengoro Suharaya's *dozō*, the bookshop, and Hanbei Yorozuya's Buddhist figures shop. The lined-up *machiya* pattern altered with the purportedly unique one-story building with wooden shingles along Nihonbashi Street: Fujiya Mochi Restaurant, serving period specialities such as sweet bean porridge with *mochi* (rice cakes). Beside it ran an alleyway giving access to the rear-house tenements in the inner part of the urban block. Next to this alleyway, the last *machiya* within Mitsui's land had a carpenter workshop on the ground floor **[fig. 5]**. Further in the essay, we reflect on the spatial use by hypothesizing in 3D virtual space and blend the material culture with evidence on human agency.

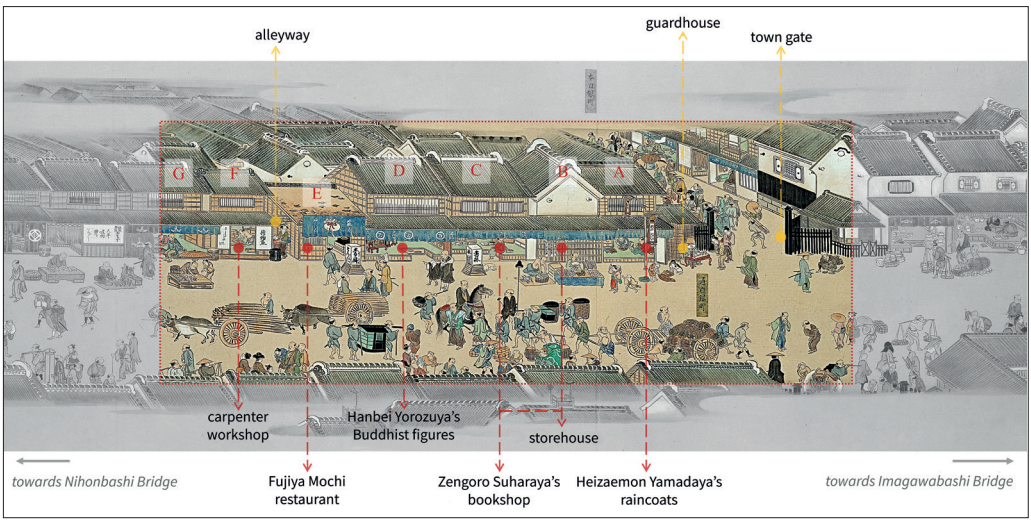

Figure 5 Kidai Shōran. Detail, with annotations showing function of the shops/workshops on the ground floor. Hand scroll, ink and colours on paper, 43.7 × 1232.2 cm. Japan, Edo/Tokugawa period, ca. 1805. © Staatliche Museen zu Berlin, Museum für Asiatische Kunst, Former collection of Hans-Joachim and Inge Küster, gift of Manfred Bohms. Photo: Jürgen Liepe. Annotations by Author Saygi

5.2.1 Digital Reconstruction Pipeline

The cadastral register showing plot divisions within Mitsui's land and annotated with dimensions has been fundamental for the spatial modelling performed here. We applied single image rectification to the photograph of this original document as a simple initial procedure to avoid camera distortions and the effect of the paper's curves. Although written measurements were indicated on the document, such rectification allowed an accurate comparison of the indicated distance to what had been drawn. Furthermore, it allowed us to hypothesise with reasonable precision the width of the alleyway after the alignment of the boundaries of the land at the north and south. The cadastral register demonstrated the alleyways within the land and its connection to the main street, and it marked the coverage of the shop eaves; however, it did not indicate any spatial properties concerning the surrounding two arteries (Nihonbashi and Honshirogane-chō Streets) and provided no further correspondence within the urban layout such as with gatehouses or urban infrastructure **[tab. 3]**.

In order to extract more features at a greater scale, we worked with Edo Kiriezu maps. A priori, we georeferenced the section map of Nihonbashi-kita (1854) using an open-source GIS platform via the implementation of an automatic transformation method. Afterwards, we superimposed the interpreted drawing of the building footprints lined up at Nihonbashi Street on the georeferenced map section. Although the map provided no clues about the plot divisions and/or building footprints within the urban block, the urban blocks within the corresponding *chō* and the open street space layout were explicit. Alignment of these horizontal traces of the street network with building footprints showed only 4 degrees of angular difference along the north-south axis. We concluded that the drafting technique of the cadastral register in 1807 might not have reflected each building's façade rhythm nor the slight angular orientation of the land.

The superimposition also revealed a striking contradiction in the sense of scale if we compare the alleyway's width to the widths of Nihonbashi and Honshirogane-chō Streets, which follow the urban planning regulations in Edo. In the pre-modern era, the main street width, delineating regular urban blocks of 60 *ken*, were set to six *jō* (about 18.2 m), with smaller perpendicular streets measuring four *jō* (about 12.1 m), three *jō* (about 9.1 m), or two *jō* (about 6.1 m) (Sorensen 2002). Furthermore, the alleyways giving access to the interior of the blocks were designated only to be wide enough for one person to walk through and thus did not result in any greater width than 2 meters, which creating a dramatic contrast in width compared to the open street spaces surrounding urban blocks **[fig. 6]**.

Table 3 The information coming from the cadastral register and their digital interpretation

		Records in the Mitsui Bunko Archives		**Digital interpretation of the cadastral register**			
		Measurement in *Kyoma*	Metric conversion	Drawn footprint in length	Roof eaves included (Y/N)	Corner of an open space (Y/N)	Shop eave (Y/N)
Total given length facing Nihonbashi Street		15 *ken* 2 *shaku* 5 *sun*	28.05 m				
From the corner of Honshirogane-chō street (North to South)	Building A	3 *ken* 1 *shaku*	576 cm	576 cm	N	Y	Y
	Building B	5 *ken*[*]	910 cm	490 cm	Y	N	Y
	Building C			434 cm	Y	N	Y
	Building D	2 *ken*	364 cm	364 cm	Y	N	Y
	Building E	3.5 *ken* 5 *sun*	667 cm	546 cm[**]	not applicable	Y	Y
	---- alleyway ----						
	Building F	2 *ken*	364 cm	364 cm	N	Y	Y
Sum of the given lengths			28.81 m				
Difference between the indicated length and sum			76 cm (%2)				

[*] The land rented by Zengoro Suharaya, consisting of both the bookshop and the storehouse, were demonstrated together.
[**] It corresponds to the drawn footprint on the cadastral register and a dimension of 3 *ken*.

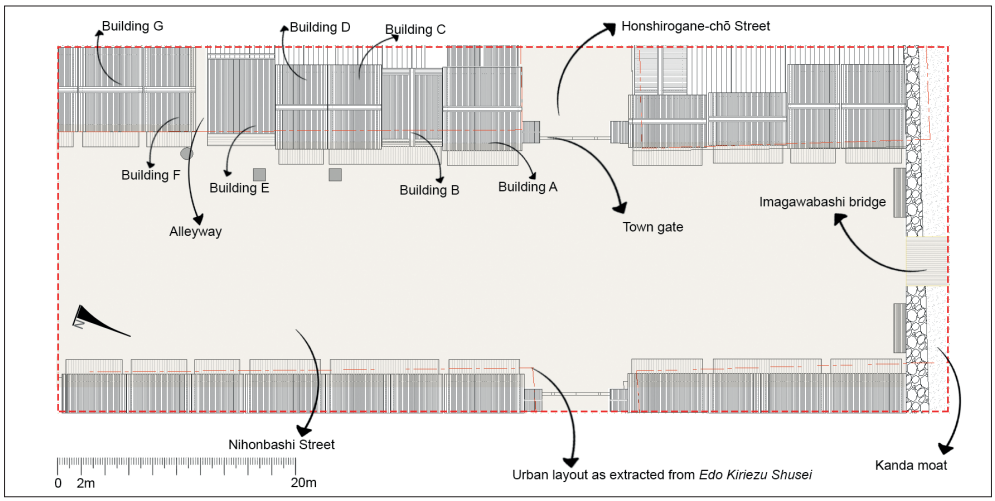

Figure 6 Site plan showing the case location

Another remarkable component contributing to the street space schematically shown by the cadastral register were the shop eaves facing Nihonbashi Street, something also demonstrated in the Kidai Shōran. The expansion of private space by means of the eaves was peculiar to Edo, as described by Kitagawa (1837), who compared the front eaves' structure in Edo with those in Kyoto and Osaka, which for their part were hung from the upper roof and were supported not by pillars but only by roof trusses. Moreover, the testimonies in Edo Machibure Shūsei include even greater detail about the exceptional regulations for two of the most significant main streets in Edo, each having the width of 1 *ken* (about 1.8 m), twice as wide as those along the side streets. Besides, another clause informs us that support of the wider eaves by pillars was permitted in those streets (Tamai 1986b, 90-8).

In Nihonbashi, the buildings were typically two stories in height and were obligated to have tiled roofs for the sake of fire prevention. Ito's (2003) assessment of the architectural typologies of *machiya* along Nihonbashi Street as depicted in the Kidai Shōran, as represented by the artist and relating the proportions of the facades to the urban blocks' widths, concluded that the artist was precise in depicting the subtle differences in the building facades, whose average frontage was 6.43 m. To take this comparison to a fine-grain spatial layer, we first digitised his depictions as reproductions based on the scroll, and then aligned them to the length of the Mitsui's land, including within it each building's footprint. The comparison showed some proportional distortions at height and width, attributable to Ito's implementation being at a greater scale, taking the length of the urban blocks rather than basing them on the dimensions of an individual building's footprint (information rather scarcely available for pre-modern Edo). Still, having a strong proportional correlation and possessing a typological assessment, we reflected the typological clues such as window or roof types in our reconstruction **[tab. 4]**. Nonetheless, we did not rely on those reproductions as a unique point of departure. We employed a more accurate method, combining typological counters with plot dimensions per building, and cross-comparing those with information drawn from architectural rules and building standards in Edo **[fig. 7]**.

Table 4 The architectural styles in/next to the Mitsui's land at Nihonbashi (adapted from Ito's 2003, 85)

Building number	Land of Mitsui (Y/N)	Building Type	Number of stories	Material style	Ridge/ entrance	Tiled roof (Y/N)	Spatial organisation of ground floor	Opening type of first floor	Shop curtains
Building A	Y	*machiya*	2	wooden	Hirairi[i]	Y	open	Tateyoko goushi[iii]	Half-length
Building B	Y	*dozō*	2	white plastered	Tsumairi[ii]	Y	closed		Half-length
Building C	Y	*machiya*	2	wooden	Hirairi	Y	open	Tateyoko goushi	Half-length
Building D	Y	*machiya*	2	wooden	Hirairi	Y	open	Fukiyose goushi[iv]	Half-length
Building E	Y		2	wooden		N	semi-open		
Building F	Y	*machiya*	1	wooden	Hirairi	Y	semi-open	Tateyoko goushi	
Building G	N	*machiya*	2	wooden	Hirairi	Y	semi-open	Fukiyose goushi	Half-length and long

i It signifies that the building has a gable roof and the entrance to the building was constructed parallel to the ridge.
ii The opposite of *hirari*.
iii Latticework made of wood, composed of vertical and horizontal strips.
iv Lattice strips with different widths are arranged in groups with equal intervals among the groups.

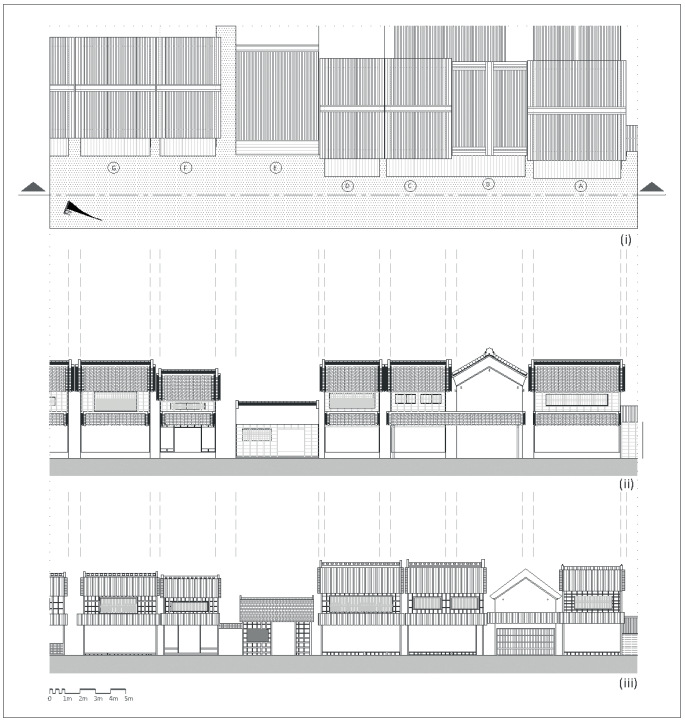

Figure 7 Comparison of the building footprints with street elevation: (i) site plan showing building footprints; (ii) proposed facade composition based on the digital interpretation; and (iii) digital reproduction of the facades by Ito 2003

Demonstrating the different modes of interaction between people and the physical/material settings on the street, it is remarkable to see how the ground floors' spatial organisation is designed to be mostly open and semi-open, contributing to the open street space during daytime in Edo. Prioritising the in-flux boundaries of the streets and elements of the transitional space, we digitally modelled each principal structure lined up along the street individually, using a bottom-up approach covering lateral-, top-, and base- envelopes.

The remarkable plasticity of Edo's built environment was based on three main constraints: the size of building frontage, proportions, and production standards. This, in turn, contributed to the creation of strong commonality in the urban space, especially along Nihonbashi Street. Because standardisation produced the unified look of the main streets and the secondary literature depicted structural components, dimensions and other characteristics, it was possible to complete the reconstruction in detail. For instance, the frontage length of a building was the major parameter defining architectural appearance, defining features ranging from the slope of the roof to the number of sliding screen doors. With size defined by the frontage, the second dominant structure are the roofs, which, in comparison to those of European architecture, are remarkably large because of the roof's symbolic status as a representation of the social status of its owner. Functionally, it created an extended space under the eaves that provided protection from environmental conditions such as rain or the high summer sun (Itoh 1972, 55-66). However, the repetitive pattern of the gabled roofs shaping the top envelopes were altered in Building F, which was single-storied and had a thatched roof.

In support of the dimensional aspects related to the architectural elements, we also made use of many works of secondary literature, applying information comparatively with that of the primary sources. Basing his work on the modular order of the traditional Japanese house and its features, Engel's work (1985) was highly useful with regard to the dimensions of the structural elements, partitioning elements, and the window details of the *machiya*. Hatano's works (1981; 1993) on other *machiya* and *dozō* within the Nihonbashi area were used as a basis for creating the scaled models in support of the reconstruction process when cross-comparing the proportion of the height/widths and extracting details of the elevated *tatami* floors and the roof. Fluidity and modularity were the most noteworthy aspects of reliance on wood as the primary material, together with the post-and-lintel system; standard dimensions of the materials, such as straw for the *tatami* mats and paper for the screens, increased the particularity.

Another vertical element contributing to the street space along the shop eaves were the *noren* (shop curtains). The curtain, typically a dark blue cloth, could assume various sizes and was hung at shop en-

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trances, offering the functional benefit of protection from the sun and dust as well as providing shade and privacy. It was also used for advertising since it displayed a trademark or owner's crest. Structurally, it was hung from the top by knotted cords and suspended from a rod of bamboo. We could hypothesise about the communal facilities of town gates and guardhouses, along with the essential infrastructure of the wells located on the streets, by cross-comparing the work of Kitagawa with the Kidai Shōran. We did not, however, delve into infrastructure details such as the streets' water-drainage system.

The transformative feature of the street space can also be recognised through its changes aligned with the time of day. During the day, the street served to accommodate individuals' mobility and provided the space where businesses would take place. The street was an 'intermediary space' that acted as "the agency that connected one neighborhood to its external surroundings" (Takahashi 2018, 109). On the contrary, at night the town gates at both ends of the street physically separated one *chō* from the next, explicitly marking each as a closed, resident-only community space. After the gate was closed in the evening, a passerby needed to be attended by the gatekeeper stationed at the guardhouse in order to pass the neighbourhood the few exceptions to this intra-city mobility regulation being doctors and midwives (Ito 1987, 148-63).

5.2.2 Human Agency Within the 3D Space

We discovered that Takatoshi Mitsui acquired the first portion of land at the corner of Honshirogane-chō Street and Nihonbashi Street with a frontage width of roughly 28 m in 1687, a footprint expanded through the additional purchase of the juxtaposing area at the western side in 1691 (Edo Kakaeyashiki Onamae Kensū Koken Tsuki 1754). Nonetheless, Mitsui's family resided neither on that site nor in Edo like many other well-to-do landowners. The day-to-day practical management of the residential sites were entrusted to *yamori* 'landlord's agent/tenement superintendent', responsible for conveying the directives passed down from the *nanushi* 'neighbourhood chief' as well as collecting rent from the tenants (Sorensen 2002). From another record dating back to 1808, we learn that the neighbourhood of Honshirogane-chō 2 chōme, together with three other neighbourhoods, was under the supervision of a neighbourhood chief named Aketa Sōjiro, and the Mitsui's two sites were taken care of by three yamori, Denbei Takatsu, Sadakichi Yorozuya, and Yohei Yorozuya (Edo Kakaeyashiki Meisaisho 1808).

Even though a person had to own a residential site to be considered an official townsfolk dweller, such owners were rather small in number, and many did not live in their properties but rented them

out to tenants. It was these commoners in its widest sense who vitalised the streetscape: mostly tenants who earned their livelihood by working in a diverse range of occupations, from small to large business owners, artisans and craftsmen, market sellers and street vendors, to day labourers (Yoshida 1992).

In the Kidai Shōran, one discovers a vibrant mingled crowd that precisely reflected the mobility in Nihonbashi visible in the daytime. In the case location, we can spot people from various social classes, such as two commoners greeting each other, a woman going out of the back alley with her child, another woman listening to her fortune, a monk with his novice, a trader with his apprentice, a *sōji shiyo* (let's clean!) beggar sweeping the street, some street hawkers and samurai. Although it gives a lively picture of mobility as represented in various forms such as a samurai on horseback, a palanquin for samurai, and some ox carts transporting goods, it is quite cumbersome to fully decipher the everyday life patterns of agents, e.g. clerks, officials, and residents going to and from home and work.

In order to make a rough quantitative assumption regarding the number of people, *ninbetsuchō* (population registry) records for pre-modern Edo, might serve as valuable resources. Nevertheless, such records are scarce, as they were not spared destruction from frequent fires. Hayakawa (2014) states that there are only 26 *ninbetsuchō* records for only 12 *chō* in the city of Edo, dating from the end of the Edo era to the early Meiji period. In basing the estimate of the number of people we related our assessment only to the Kidai Shōran, as there is a certain threat to reliability when one includes human agency in certain numbers while thinking of the uneven distribution of the agents, whose patterns accord with different functions and restrictions in the street through the town gates. In addition, it would have been impossible to investigate each and every figure depicted on the street.

To illustrate people's appearances, we based our visualisations on real-life model photographs in the Edo Period collection of the Costume Museum in Kyoto, whose holdings include many items that show the changes in clothes and accessories throughout Japanese history (The Costume Museum n.d.). Since it is too early to conclude a matrix of possibilities that would cover the detailed apparel worn by the agents, we abstracted the figures into silhouettes, paying attention to the clothing and hairstyle outlines and distinguishing the appearance of commoners and other social classes. In addition, to give a proper sense of scale, we based the stature of the agents on research by Hiramoto (1972). The mean value is 155 cm for male and 145 cm for female silhouettes **[fig. 8]**.

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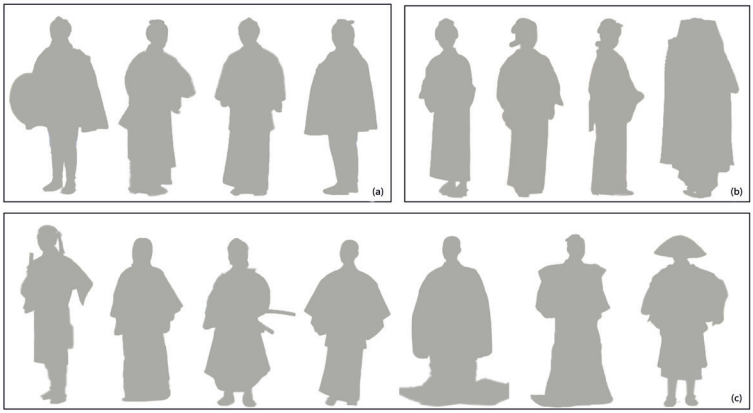

Figure 8 Examples of the silhouettes: (a) commoner/male; (b) commoner/female; (c) other agents from different social classes (warrior, Buddhist monk, samurai fighter), based on the collection of the Costume Museum, Kyoto

6 Results and discussion

The resulting 3D reconstruction digitally represents street life on Edo's Nihonbashi Street at the southwest corner of Honshiroganechō Street during the Bunka Era at the beginning of the nineteenth century – specifically, in 1805 – as accurately as the historical evidence allows. The 3D digital reconstruction as a hypothesis does not only consider the built environment to be a static physical feature; rather, it attempts to present this particular instance of street life in a visual way that spatializes historical knowledge and presents a legitimate hypothesis. Furthermore, the reconstruction demonstrates the basic/general idea of *chō* in the urban planning of Edo commoners' district and is an example of a typical urban landscape **[fig. 9]**.

Our particular attention directed towards the street's 'shifting boundaries', the digital reconstruction demonstrates the extension of the shops by the shop eaves and the expansion of the street via the spatial inclusion of 'indoor' space and acknowledges its importance in facilitating the livelihood offered on the main streets. At the same time, it emphasises the uniformity of the eaves, showing how every neighbourhood provided covered passage for passersby as informed by the Edo Machibure Shūsei. On the street, the division between public and communal ownership and private ownership was not always explicit but rather overlapped to accommodate certain flexibility, especially when the actual use of the space mattered **[fig. 10]**.

Stylistically, the reconstruction shows the distinct qualities of surfaces as well as of shadow, light, and depth resulting from the atmospheric conditions and architectural culture. The modelling idea is far from the textured renderings. The reconstruction does not try to create a photorealistic result; doing so risks creating a perception of authenticity that would be false, given the lack of explicit sources. The realistic effect achieved via the rendering of materials and colours does not contribute to the trustworthiness of such an analytical 3D reconstruction in line with the available historical evidence. Speculative information is avoided.

Figure 9 3D street-views of the reconstruction at eye-level

Figure 10 The visual perception of the 3D space created by the extensions of the shops

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During the day, the shops' sliding doors were held aside, so that 'indoors' and 'outdoors' as well as 'public' and 'private' were blended. But we hypothesise that when night fell, a different sort of street space emerged. The shops, by closing their sliding doors, created a 'wall', as Bharne (2014) suggests, and the regulation of the closing of the gates dramatically differentiated the boundaries of the night from those of daytime, which were more in flux. As a result, digital reconstructions of day and night illustrate the distinctive contrast in terms of street use and the urban experience between day and night. Daytime – where we find a 'high street' defined as a shopping destination characterised by a lively atmosphere of economic activity, with people from different social strata, from samurai to small street vendors, mingled together – is opposed to nighttime, with its closed gates and the limited mobility of people, evidence of a closed community **[fig. 11]**.

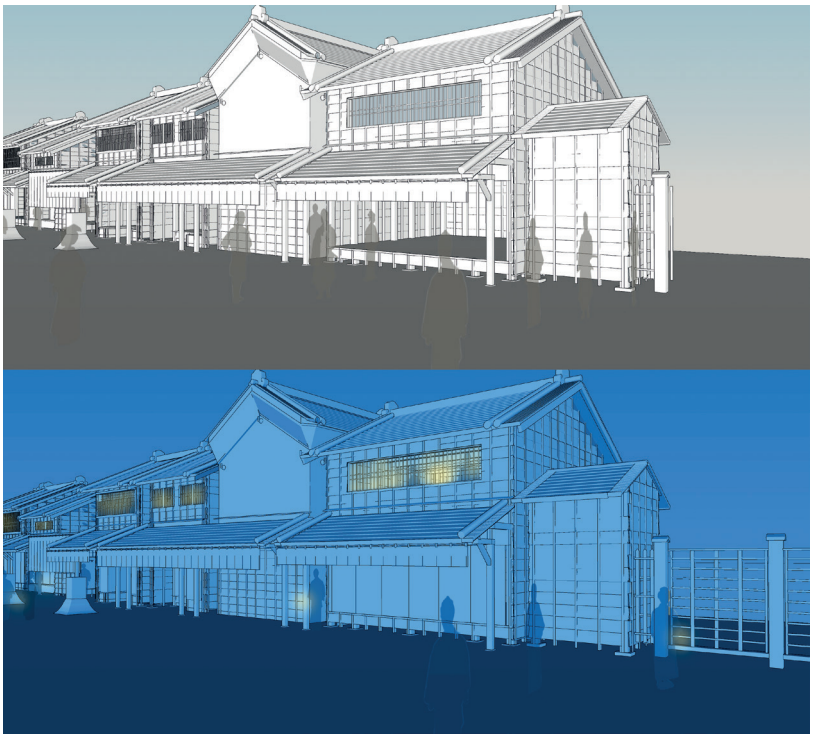

Figure 11 The daytime scene on top represents the street's boundaries, which are in flux; in the nighttime scene shown at the bottom, the buildings create a wall effect

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Such a reconstruction creates a digital medium that is open to further revisions. Potentially other layers of historical knowledge about the culture or social life in this time and place could be represented. The level of complexity relies on a critical assessment of each digital entity's truthfulness. In such an extensive reconstruction, not all entities can be reconstructed based on the same degree of evidence. Neither it is possible to fully replicate the lost past as some sort of 'digital twin' or 'mirror world'. We defined the level of historical evidence for the digital reconstruction: one can see the areas reflecting higher levels of evidence in colour shades from pink to purple, whereas the areas relying on lower level of evidence are depicted in tones from yellow to pink **[fig. 12]**.

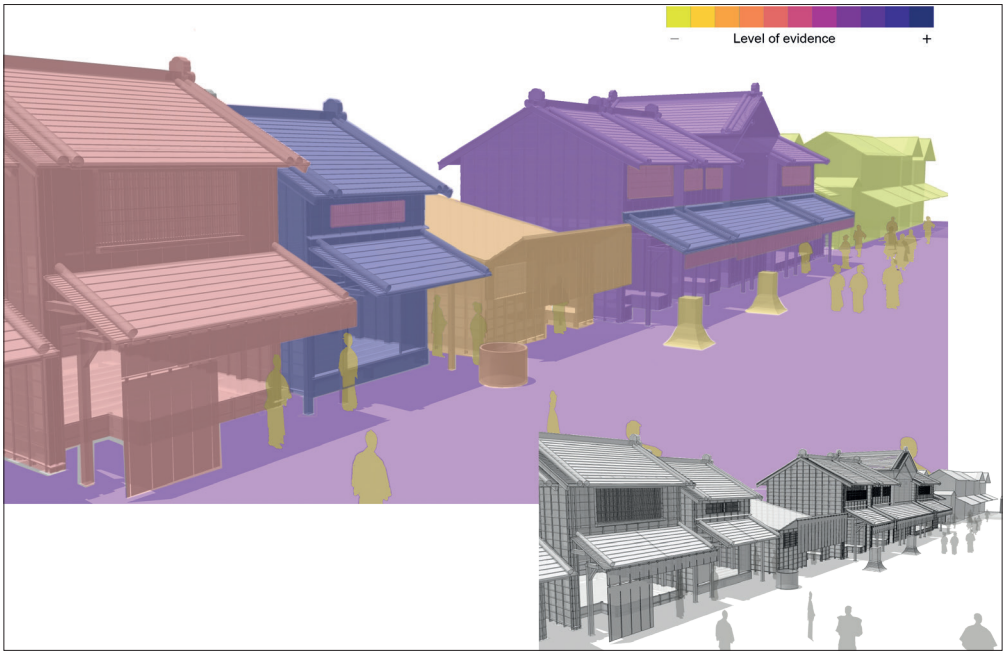

Figure 12 Scale of evidence in the 3D reconstruction

7 Conclusion and Future Work

This cross-disciplinary work has shown the interdisciplinary possibilities of exploring street life in the pre-modern city of Edo. The vibrant discoveries and insights have generated prompt advanced historical questions on materiality, spatial use, mobility of agents and the notion of community. Focused on a long-lost urban space, the work was always mindful of the importance of the assessment and interpretation process when overlaying evidence in a 3D space and has employed a source-based approach in its digital reconstruction of urban spaces. We hypothesised about street life within a digital environment as accurately as the sources would allow, and our hypotheses, using digital methods allied with primary sources and aligning with arguments in the secondary literature, avoided any speculative visualisation based on very limited evidence. Indeed, the interpretation process is where most of the time was spent, compared to the time devoted to the selection of the digital method, the modelling itself and the extraction of the outputs.

This research has digitally explored the streetscape as social space beyond its materiality and has expanded the de facto vision of the contours of buildings when working with virtual reconstructions, providing a vision accounting for the embodiment of the spaces depicted and the human agency evident there. We demonstrated the reliability of the model components through colour codes applied according to the scale of available evidence; nonetheless, it does not, by itself, present a rigorous transparency in the 3D visualisation. It generated an effective understanding of the 'past' but is not conclusive. A work towards that end would have to provide the ability to integrate source material for each component and enable a multifaceted process of discovery. Another step that awaits is the inclusion of deeper parts of the urban block, covering alleyways, back alleys, rear houses and comparing the street life between the front and the back areas in 3D space.

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