Mapping and Analysing Historical Transport Data in China – Usage of GIS and Database Queries in Historical Context

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Abstract

This paper presents a method combining the use of GIS applications, database queries and statistics to analyse historical transport data. The aim of the study is to find spatiotemporal explanations for certain incidents that occurred along historical mint-metal transportation routes in China during the Qing dynasty (1736-1850). For this purpose historical documents were extracted from a database and underwent spatial and statistical processing to form risk maps and diagrams. Historical accounts of the incidents and the climate along with topographic maps and historical GIS data were used to examine and explain the results.

1 Introduction

1.1 Research Framework and topic

This study is part of the project group 'Natural Resources in the Mining Areas of Yunnan during the Qing Period – Landscape Development, Environmental Change, Cartography, and GIS-based Web mapping' within the research framework 'Monies, Markets and Finance in China and East Asia, 1600-1900: Local, Regional, National and International Dimensions' (German Science Foundation DFG – Research Group FOR 596). The research framework aims at contributing a new, empirically founded perspective on East Asian monetary history. The project groups investigate the production and shipment of monetary metals, the impact of mining on society and environment, the casting of coins, developments in monetary policy, the importance of cash coins for markets and the monetary economy, as well as selected aspects of financial history (HIRZEL et al. 2008, KIM et al. 2012).

To reach this aim, primary sources from the eighteenth and nineteenth centuries were analysed, such as Qing government reports, documents from local archives and local gazetteers, coins, illustrations and maps, travel reports, newspaper articles and other kinds of literature. The data obtained was gathered into four databases: place names, mining places, exchange rates and transport routes (ROSNER et al. 2009). The last of these databases, the Mint Metal Transportation Database, contains detailed information on the routes of mint metal transports within the whole of China. The present study presents the analysis of the information included in this data. The main goal is to find spatiotemporal reasons for certain incidents, such as delays and shipwrecks that occur along the transport

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routes. This will be achieved through the implementation of database queries – the results of which will then be cartographically visualised and analysed.

1.2 The Mint Metal Transport Database

Relevant for the research within this study is the Mint Metal Transportation Database (Transport-DB) about transport from southwestern China via the Yangtze River and the Grand Canal to the capital mints in Beijing (VOGEL et al. 2012). The database contains detailed information on the mint metal transports which took place in the Qing dynasty from 1736 to 1850. In this period there was no coherent system to record transport information – it was therefore often recorded as a document and mostly written in prose. These 'palace memorials', were stored in the archives of the Qing emperor and are currently available e.g. in Taipei. They contain detailed information on transit traffic within a certain province and its prefectures. Apart from containing information on the title and function of the officer in charge they also contain precise information on the type and volume of cargo, the places passed within each province as well as unexpected incidents that occurred during transport. Within the research framework these documents were processed and integrated into a relational SQL database (LUTSCH, 2007). Currently the integration of data is still in progress; therefore new documents and information are continuously being added to the database.

Fig. 1: Historical record (ACA-(DEMICA SINICA 2011)

2 Collection and Preparation of Historical Transport Data

2.1 Collection of historical transport data

With regard to the main goal of the study information on the spatiotemporal course of particular transports and the occurrence of delays or shipwrecks was queried in the form of CSV-Datasets. Since the requested data was stored in separate tables in the database, these tables had to be connected. For this purpose tables with information on historical documents had to be joined with tables that contained information on a certain transport. The resulting aggregation represents the relationship between a historical document and its corresponding transport. All subsequent tables in the database are based on this aggregation. In this manner 17.054 transport, 10.626 delay and 1.989 shipwreck recordings were queried simultaneously from the database.

2.2 Preparation of historical transport data

A key point for the subsequent analysis was to locate intermediate stops on the transport routes, stated in the Transport-DB. Therefore locations gathered from the SQL-Queries were synchronised with China Historical GIS datasets. Matching locations from both datasets were connected with unique key IDs in order to visualize those using GIS. The resulting dataset contains every location stored in the database which can be found on at least one of the reported transport routes. This dataset provides the basis for additional queries, such as the number of transports that took place at a certain location, their loading information and duration of transport as well as the number of delays and shipwrecks. Furthermore datasets were generated to trace all transport routes from their starting to their ending point containing detailed statements on intermediate stops, delays, shipwrecks and their duration.

2.3 Difficulties of data preparation

A challenge of data preparation was that most of the datasets from the Transport-DB were written in Chinese characters. Due to the fact that most GIS software applications do not support Chinese characters, the respective data had to be transformed into the phonetic notation pinyin. Furthermore the database contains different specifications for the same place. This is either due to the fact that the data input was mistaken, that the historical documents contained different specifications or that place names had changed over the course of time. Date specifications in the Transport-DB showed similar difficulties – they were stated according to the dynastic Chinese calendar. According to this calendar, date specifications began with the inauguration of a new emperor. For example the 27th year of the government of Qianlong emperor is equivalent to the year 1762 of the Gregorian calendar. The date specifications as well as the place specifications had to be subsequently converted. Another difficulty was the lack of completeness of the datasets. As long as not all historical documents were gathered in the Transport-DB, only datasets for the period from 1749 to 1794 could be compared to each other. All datasets that consists of incomplete place or date specifications were rejected from the analysis.

3 Analysis and interpretation of historical transport data

3.1 Localization and spatial analysis

An important goal of the present study was to identify incidents, such as delays or shipwrecks at a given location. This can be to be achieved through the analysis of the historical transport data. For this purpose every located intermediate stop was allocated with its particular number of transports, delays and shipwrecks. In order to determine at which location or on which river a transport had taken place, a buffer zone of 15 km was created around every located stop. The buffer distance was set to a range of 15 km due to the fact that place specifications in the Transport-DB often correspond to the capitals of the prefectures and not to the exact locations. In the next step, overlapping buffers were merged in order to create so called risk areas, where the number of shipwrecks and delays reached a local maximum. The risk areas were then classified into 4 categories according to their frequency. Areas and river sections with a high number of incidences during a transport are presented on the resulting maps of risk areas (Figure 2 and 4). In order to explain the spatial distribution of delays and shipwrecks, areas with a maximum number of incidents were the subject of closer examination using topographic maps and a digital elevation model (DEM).

Risk areas for shipwrecks

Considering the map of risk areas for shipwrecks (Fig. 2), four areas with an elevated risk for shipwrecks can be identified. More than three quarters of all shipwrecks occur within these four areas.

- Area I: At the upper reaches of the Yangtze River between Luzhou and Yichang with 943 recorded shipwrecks.
- Area II: At the middle reaches of the Yangtze River between Yichang and Poyang Lake with 495 recorded shipwrecks.
- Area III: At the lower reaches of the Yangtze River between Poyang Lake and Nanjing with 118 records.
- Area IV: Along the Grand Canal at the border of Shandong and Hebei province with 27 recorded shipwrecks.

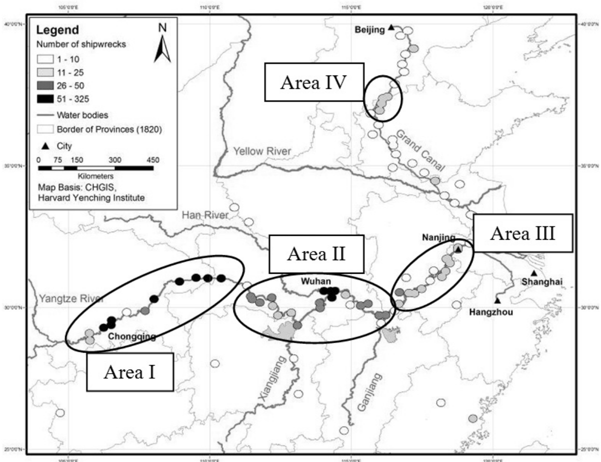

Fig. 2: Map of risk areas for shipwrecks

Due to the fact that almost every transport route from the southern provinces to the northern parts of China is located either at the Yangtze River or at the Grand Canal, the majority of risk areas are located there. From this point of view it is not surprising that the majority of shipwrecks are located on the upper and middle reaches of the Yangtze River in the risk areas I and II. The first one covers almost the entire upper reaches of the Yangtze River. Within this area most of the shipwrecks occurred at the Yangtze Gorges (Fig. 3), which is known for its dangerous rapids and shoals (PLANT 1920). Therefore the 18th century transport convoys tried to avoid this section during times of high water levels (SUN 1971). Risk area II includes confluences of several major river systems: the confluence of the Yangtze and Xiangjiang rivers, the confluence of Yangtze and Han rivers and the confluence of Yangtze an Ganjiang rivers. The confluence of greater river systems, especially at times of high water levels, can cause turbulence which restricts shipping in these sections. However, closer examination of the oldest available western maps of the region – the US-Military topographic maps from the 1930s – reveals that the riverbed of the

Yangtze River appears to be very wide and branched at this section. Furthermore sand banks are highlighted. In addition, 19th century travel logs (BIRD 1899, RICHTHOFEN 1868-72) mention shipping constraints caused by rapids, shoals, changes in the channel, running on gravel and contact with the river's banks. Additionally the analysis of the DEM (SRTM) shows that the gradient of the Yangtze River at this section is very low. Rivers with a wide and branched riverbed and a low gradient have higher rates of sedimentation. In years with low precipitation, shipwrecks occur with higher frequency along these sandbanks. We assume that these conditions have historically led to a higher risk for ship transport in this area.

Other possible causes are collisions with other transport ships or logs, due to the high number of transports at these sections. At risk area IV on the Grand Canal there are two main hazards for the transport convoys. Firstly, the low water levels in winter terms can be a threat for the convoys and secondly the frozen canal could block the convoys in the Grand Canal (NEY 1869-1870). Furthermore the convoys had to cross the Yellow River on their passage on the Grand Canal, which requires according to LEONARD (1988) risky maneuver. There is no evidence in the data of armed attacks or robbery causing shipwrecks.

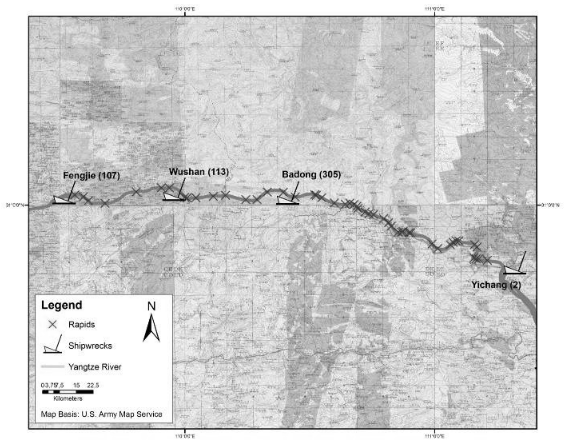

Fig. 3: Shipwrecks and rapids at the Yangtze Gorges on a 1930s topographic map (U.S. ARMY MAP SERVICE, PLANT 1920, KIM 2012)

Risk areas for delays

A number of different reasons for delays are mentioned in the documents: waiting for wind, low or high water levels, ice, transshipment or tax payments. The map of risk areas for delays (Figure 4) identifies four areas with an elevated risk for delays. Two of them (area I and II) intersect with the shipwreck risk areas and their spatial location shows a high correlation to the location of shipwrecks. At these two areas between Dongting Lake and Wuhan (risk area I) and between Poyang Lake and Nanjing (risk area II) the majority of delays occurred. Furthermore, the whole transport section on the Grand Canal shows a high number of delays. At the southern part of the Grand Canal and its junction with the Yellow River most of the delays could be caused by crossing the Yellow River, when the convoys had to wait for the right circumstances (LEONARD 1988). Close to Beijing, at the northern part of the Grand Canal also a high number of delays occurred. Due to the fact that the cargo had to be transported to Beijing by carts, the delays at this section were mostly caused by transshipment (SUN 1971).

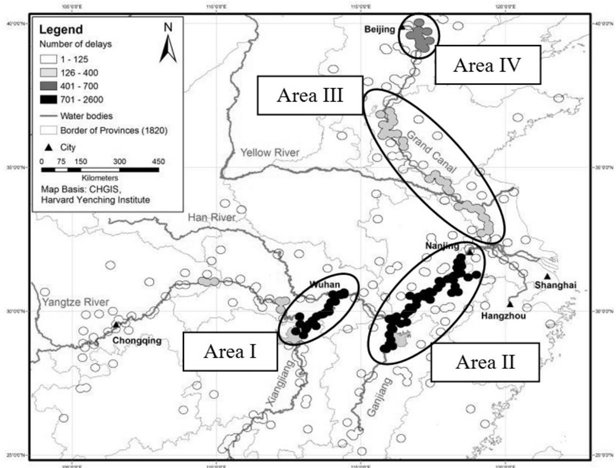

Fig. 4: Map of risk areas for delays

3.2 Historical analysis

Besides the spatial analysis of the data, the historical analysis is of greater interest. For this purpose the results of the database query were examined with regard to the number of transports, delays and shipwrecks that occur during each year (Fig. 5). To ensure comparability of the information, only data of the period 1749-1794 was taken for this analysis. Previous and subsequent records are incomplete and could not be incorporated into any further analysis. If we consider the number of transports, an almost continuous increase can be recognized up to the year 1777. After that period, sharp declines occur for the years 1778, 1782, 1784/85 and 1791. Each decline, except that from 1791, was followed by a short increase. Overall, an increasing decline in the number of transports can be seen from the year 1778 on. Since data after the year 1794 was not examined, it should be mentioned that for these years the number of transports principally remains at a low level. In this context, the question arises why these annual variations in transport numbers and incidents occurred.

Variation of the number of transports

A possible explanation for the strong decline after the year 1794 is the lack of data over this period. For these years the manual data input might have been fragmentary. Another approach to explain the number of transports or delays in a specific year is to determine whether or not any major incidents took place during the year. For example climatic events such as floods and droughts or political and warlike conflicts could have an effect on the number of transports and delays. In this case the end of the Qianlong emperors' government

(1736 to 1796) should be mentioned. The last years of his rule were dominated by corruption (WOODSIDE 2002) and uprising rebellions: From 1790 to 1792 against the Gurkhas of Nepal, 1795 the Miao minority of the provinces Hunan and Guizhou (ibid) followed by the White-Lotus-Rebellion 1796 to 1805 (ROWE 2009). Alongside the political conflicts, climatic events also occurred in the 1790s. According to GE (et al. 2003), mean winter half-year temperatures declined by up to -1K around the year 1790. This decline marked the end of a period of continuously rising winter half-year temperatures from 1700 to 1790. DOMRÖS (et al. 1988) describes how Dongting Lake, which is close to the Yangtze River, was frozen over in the year 1790. The decline in temperatures could have caused an increased number of frozen sections along the waterways. Furthermore GE (et al. 2005), who derived high resolution precipitation data from Qing dynasty archives, reported a severe drought in Hebei in the year 1792. This drought could have affected the shipping because of low water levels. Considered as a whole, these events could be a cause for the decline of mint metal transports after the year 1790.

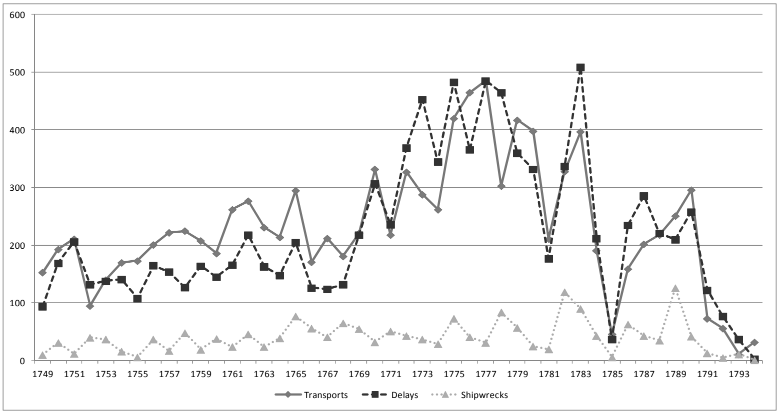

Fig. 5: Number of transports, delays and shipwrecks during the period from 1749 to 1794

The whole period from 1778 to 1794 appears as a period of high fluctuation in the number of transports. At figure 5 three strong declines, 1778, 1781 and 1784/85, can be seen in this period, immediately followed by an increase. Simultaneously this time is described as a timeframe of years with very high and low precipitation. According to historical documents, different droughts are mentioned in the years 1778 (HAO et al. 2008), 1780 (ZHENG et al. 2006), 1782/85 (GE et al. 2007, DOMRÖS et al. 1988) and 1792 (GE et al. 2005). This period of low precipitation is accompanied by years of higher precipitation from 1760 to 1775 and from 1788 to 1800 in the Jiangnan region (ZHENG et al. 2006), as well as from 1761 to 1780 and from 1791 to 1820 in the Yellow River region (ZHENG et al. 2005). Based on these results we can assume that the fluctuation of transports from 1778 to 1794 could be caused by a shift of precipitation patterns.

Variation of the number of delays and shipwrecks

A remarkable decline in the number of transports combined with an increase in the number of delays can be determined for the years 1751, 1773, 1778, 1786/87 and in the early 1790s

(Fig. 6). In the 1790s this was probably caused by the strong decline in the number of transports, especially in the year 1793, when the number of transports reached its minimum. Also, the peaks during the years from 1778 to 1787 are possibly caused by the above mentioned changing patterns of precipitation over this period. These delays occur within the surveyed risk areas as well as within nearly all other places mentioned in the database presented by the authors. In 1751 an earthquake with an estimated magnitude of 6.8 struck the region of northern Yunnan and southern Sichuan and could have constrained shipping at this time (NGDC/WDC 2012). Even the strong increase of shipwrecks in the years 1751 and 1752 could be associated with this earthquake, when the waterways might be full of flotsam and other earthquake caused obstacles. The number of shipwrecks presents considerable fluctuations from 1749 to 1794. However, two several peaks from 1778 to 1789 can be seen in Fig. 6. These could be connected with the low precipitation in this period (GE et al. 2007). According to these assumptions we conclude, that low precipitation and following shallow waters could be a possible cause for shipwrecks.

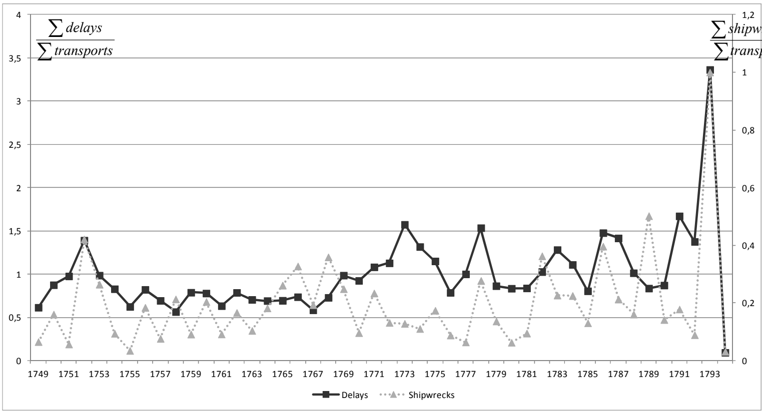

Fig. 6: Delays and shipwrecks normalized to the number of transports

In the risk area III for delays at the junction of Yangtze River and the Grand Canal many delays as well as some shipwrecks occurred mainly during the years 1785 and 1791. The high precipitation in most parts of China during 1785 and a starting period with high and long enduring precipitation at the lower and middle reaches of the Yellow River from the year 1791 on could explain the number of shipwrecks at these two years (ZHENG 2005). Increased traffic could have interfered the metal transportation on southern Chinese waterways as well; e.g. the military campaign against Burma in the years from 1765 to 1769 (WOODSIDE 2002). For the year 1773 neither reasonable political conflicts nor climatic events were found to explain the number of incidents.

4 Conclusion

The combined use of database queries, historical topographic maps, a digital elevation model, national geospatial data (CHGIS) and the analysis of historical documents allows the reconstruction of different incidents along historical transport routes in Qing China. The usage of GIS benefits the localization, visualization and spatial analysis of the information stored in the Transport-DB. The aim of this study is to detect risk areas for shipwrecks and delays along the main transportation routes using historical documents and spatial datasets. GIS serves as a platform where all information is connected. Serving as an interface between space and time, GIS profits the contextual analysis of historic documents. Without a GIS it would have been difficult to connect locations over space and time. The linkage of information gained by GIS and historical analysis allows intensifying the search for explanations to smaller regions, e.g. large-scale analysis.

The results show that many of the identified events can be explained by linking spatial and historical information. Climatic and political reasons are determined as causes for annual variations of the number of observed incidents. By means of the creation of risk areas, an additional visual component could be embedded to the research. Due to this, regional features of the affected river sections such as rapids, shallow waters or the historic regional climate, which may have changed over time hydrological and geomorphological, as well as political incidents could be incorporated in the interpretation.

Acknowledgment

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